

Earth building construction processes in Benin City, Nigeria and engineering classification of earth materials used

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Villages in Oka, Use and Uselu were visited and interviews of earth constructors in these locations were conducted to determine their mud house construction techniques. Earth building materials were also taken from these villages and laboratory tests were conducted on the soil samples in order to classify them. Natural moisture content, sieve and hydrometer analyses, and Atterberg limits tests were performed in the laboratory. The interaction between the culture, tradition and earth construction technique of the Benin people was revealed from the interview sessions. The soil samples at the three locations were suitable for mud house construction, based on the results of laboratory tests. It was revealed from the interview sessions that the construction technique widely used in these locations is similar in procedure to that of cob construction, except that straws are not added. The soil samples from the three villages were classified as silty, clayey sand (SC-SM), according to Unified Soil Classification System. According to American Association of State Highway and Transportation Officials, soil samples from Use, Uselu and Oka were classified as A-4, A-6 and A-7, respectively. The soil samples taken from Use and Uselu were found to be more suitable for mud house construction than that from Oka, based on the results of laboratory tests.

Keywords: Earth construction, Low-income housing, Mud, Soil classification, Sustainable housing

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The housing crisis being experienced worldwide has resulted in a renewed interest in earth building construction. More than one billion people live in inadequate housing, especially in Africa and Asia¹. It is estimated that around 2 billion people and about half of the people living in developing countries live in earth buildings². Earth based materials are the most commonly used building materials in the world. They are widely available locally, economically attractive and environment-friendly. Some of the techniques used for earth building construction around the world include the use of sundried clay bricks (adobe or earth bricks), moist soil placed between removable form board (rammed earth), moist clayey soil mixed with straw placed by hand to form walls (cob), or mud reinforced with woven or laid timber (wattle and daub).

Recent concerns for sustainable development have aroused the interest of civil engineers³⁻⁹ to seek innovative and standardized ways of selecting, testing, stabilizing, characterizing and using earth materials for earth building construction. There seems

to be a practical prospect of addressing today's worldwide housing crisis by increased use of earth materials for building construction¹⁰.

This paper aims to explore earth building construction in Benin City, Nigeria, as part of ongoing research to encourage indigenous building culture and to improve the materials used. Specifically, the building construction procedure in Benin City is examined. The author classified the earth materials, according to standard soil classification systems.

Study area and methods

Study area

Benin City is located between latitudes 06°17' and 06°26' North and longitudes 05°35' and 05°41' East. It is the capital of Edo state in Southern Nigeria and also the headquarters of Oredo Local Government Area. It is an ancient city, having a rich tradition of mud house construction and noted for its bronze works and crafts. It is also the main hub of Nigeria's rubber industry.

The villages in Benin, where this study was carried out, are Oka ($06^{\circ}17'46''\text{N}$ and $05^{\circ}39'29''\text{E}$), Use ($06^{\circ}21'44''\text{N}$ and $05^{\circ}34'58''\text{E}$) and Uselu ($06^{\circ}23'04''\text{N}$ and $05^{\circ}36'40''\text{E}$). A map showing these three locations is presented in Fig. 1.

Interviews and experimental works

Thirty two earth building constructors and twenty one elders of Oka, Use or Uselu were interviewed to determine their typical mud house construction procedure. Seven elders and at least ten constructors per village were interviewed. They were randomly selected based on their availability and some of the constructors were, at the time of the interviews, involved in earth building constructions.

Oka, Use and Uselu were selected as locations for sample collection because they have appreciable number of mud houses than Owah, Ogogugbo and Avbiama. Disturbed soil samples were collected because they were only needed for soil classification purpose. In these locations, samples were collected from mud house construction sites with the aid of digger, shovel and watertight bags.

To classify the soil, *in-situ* moisture content, sieve analysis, hydrometer analysis and Atterberg limits were conducted on the samples in the Laboratory. These tests were conducted in accordance with the requirements of BS1². Atterberg limits tests carried out comprised liquid and plastic limits. For analysis, samples taken from Uselu, Oka and Use have been denoted as samples A, B and C, respectively.

Results and discussion

Typical earth building construction procedure in Benin city

From the interviews conducted, it was gathered that once an individual conceives the idea of a proposed earth building construction and is about to commence the construction, he is first expected to inform the committee of elders of the village or community. After getting their approval, they offer prayers for the success of the construction.

The commencement of construction begins with site preparation, involving clearing and removal of trees, shrubs, grass, dirt and debris from the site. The developer then prepares a feast for the community, inviting the leader of the committee of elders to set the first benchmark or peg on the site. This serves as a declaration of the beginning of the construction and communicates its approval by the

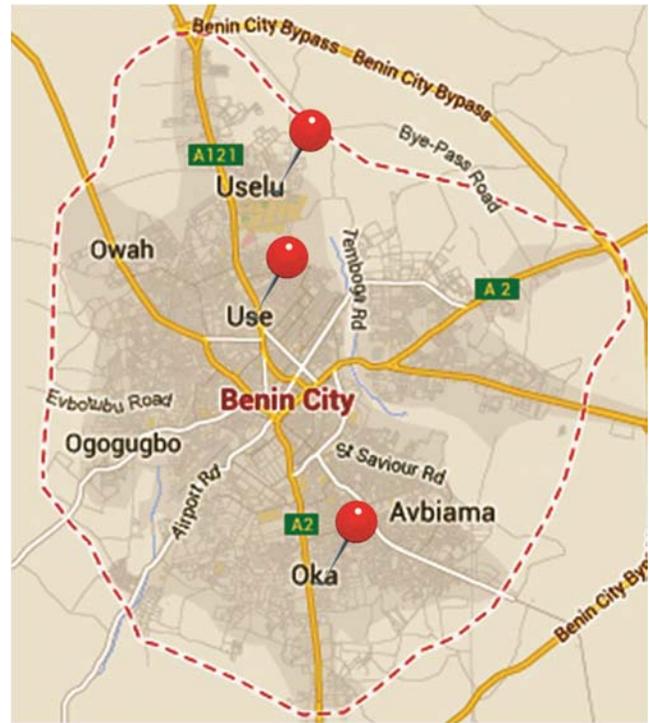


Fig. 1—Oka, Use and Uselu in Benin City

elders. Consequently, allowing other villagers to assist the developer during the earth building (mud house) construction. During this construction period, the developer has the obligation to feed other villagers who he has permitted to assist him with the construction.

The construction commences with the setting-out of the foundation. Excavation of about 1m depth is carried out and the excavated materials are taken to an off-site location. Soil materials identified to be suitable for mud house construction and usually obtained near the construction site are placed in the excavation in layers. A little amount of water is added to each layer and stamped on by the constructors with their feet until the soil becomes sticky or stretchy. The foundation material is then left for 2-3 days to dry.

The next phase involves the construction of the earth building superstructure. Suitable soil material is stamped on until it forms a sticky paste. It is then cut into small blocks with shovel and the first set of blocks are placed on the foundation. Subsequent blocks are stacked on each other, until a layer of 2 ft has been achieved. Afterwards, this first layer is left for 3-5 days to dry. This process is repeated for the second, third and fourth layers of 2ft each.

Holes are created within the top of the fourth layer to receive the rafter or roof support system. Palm vines are usually woven around palm fronds and tied

to the rafters to form the roof. Recently, the use of roofing sheets is becoming popular. Also, finishing the surface of the walls with Portland cement mortar is becoming common.

Laboratory test results

The three samples have reddish-brown coloration. Their natural moisture contents are shown in Fig. 2. Samples C and B had the highest and least natural moisture contents, respectively. The results of the tests for the determination of liquid and plastic limits; and the plasticity index, for each of the three mud samples are presented in Fig. 3. Fig. 3 shows that the liquid and plastic limits; and plasticity index of the samples ranged from 24-41%, 14-22% and 10-19%,

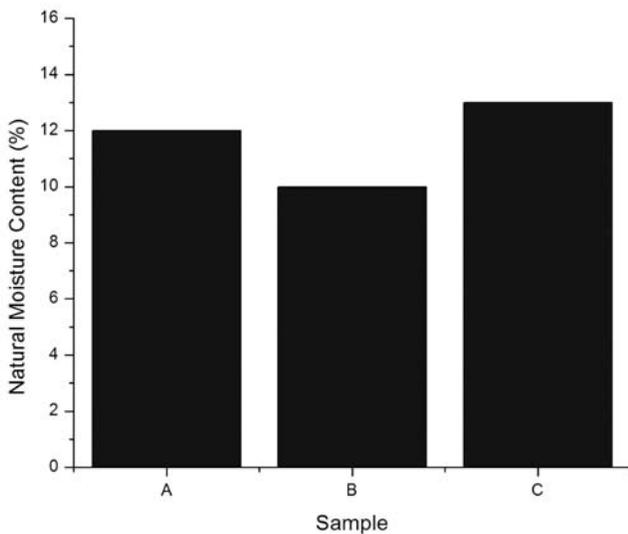


Fig. 2—Natural moisture content of samples

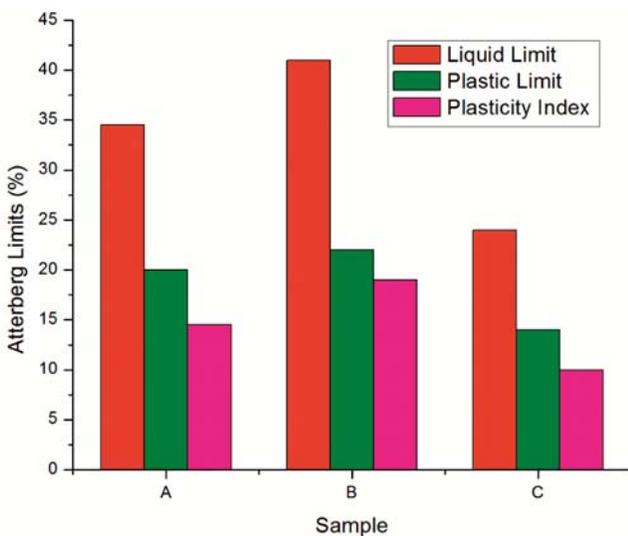


Fig. 3—Results of Atterberg limits tests

respectively. Their liquid limits are less than 50% showing that the three samples are of low plasticity. Consequently, they are workable. The liquidity index for samples A, B and C was determined to be -0.55, -0.63 and -0.10, respectively. This indicates that the samples were in their semisolid state when they were taken from the locations.

The results of the sieve and hydrometer analyses of the three samples are shown in Fig. 4.

From Fig. 4, the fractions of soil samples A, B and C, passing the sieve with 0.075 mm opening, were determined to be 39.7%, 40.5% and 44.8%, respectively. This shows that the soil samples are coarse-grained. Fig. 3 and the ternary plot (Fig. 5) of the percent of clay, silt and sand show the predominance of sand in all the samples. The internal triangle in Fig. 5 shows where the ideal soil-types mix for earth building materials should fall; as proposed by North and Kanuka-Fuchs¹³. Fig. 5 shows that sample B fell out of this triangle while samples A and C are on the boundary of the triangle. Consequently, samples A and C are more suitable for use for earth building construction.

Samples A, B and C were classified as silty, clayey sand (SC-SM), according to the Unified Soil Classification System (USCS). According to the American Association of State Highway and Transportation Officials (AASHTO) system, samples A, B and C were classified as A-6, A-7 and A-4, respectively.

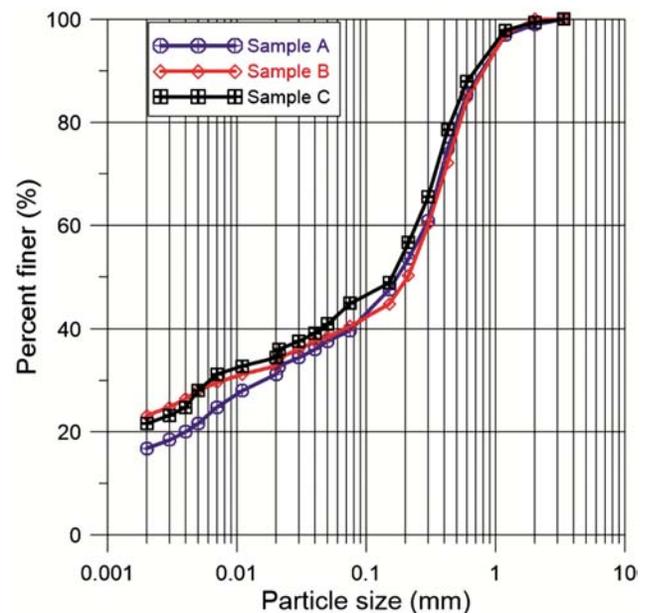


Fig. 4—Particle size distribution for each of the samples

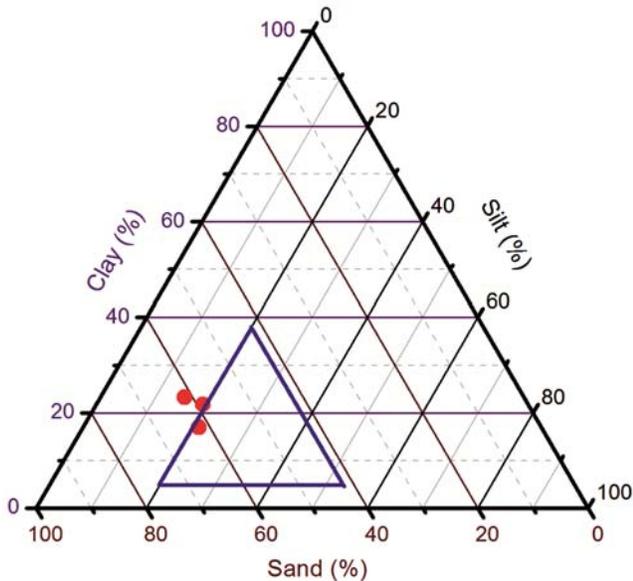


Fig. 5—Tri-plot of particle size distribution for samples

Conclusion

Based on the research results presented, the following conclusions were drawn:

- i. The construction procedure for earth building construction in Benin City is similar to that for cob construction, except that straws are not used.
- ii. There is interplay between the tradition of the Benin people and their earth building construction procedure. It represents the cultural building heritage of the Benin people.
- iii. Suitable soil for earth building construction is readily available in the study areas.
- iv. Soil samples at Uselu, Oka and Use were classified as silty, clayey sand (SC-SM), according to the Unified Soil Classification System (USCS). According to the American Association of State Highway and Transportation Officials (AASHTO) system, these were classified as A-6, A-7 and A-4, respectively.
- v. This research further confirms the assertion by many researchers,^{6,14-16} on earth building construction technique, who have reported that there are numerous local variations in the procedures and methods of materials selection in different localities. Very few research works have been carried out to detail the engineering classification of earth building materials. This is very significant towards elucidating the selection of earth building materials and consequently
- vi. This research work is also significant in that there is no official documentation of earth-building construction processes used in Benin City, Nigeria.

The engineering properties of the soil samples in these study area can be improved by manipulating their proportions of sand clay and silt. For instance, addition of 10% silt soil particles to these samples shifts their points on the tri-plot in Fig. 5 to the right. Thereby, making these soil samples better suited for use for earth-building construction.

Earth construction technologies should be included in the curriculum of engineering, architecture and building technology programs of higher educational institutions in order to promote the development of these sustainable technologies.

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