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Engineering Properties of Cob as a Building Material

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Abstract: The present study looks into some properties of Cob as a building material. Cob is an ancient technique of building, which is a combination of sand and clay, mixed with straw and water. The study determined some of the engineering properties of cob for its suitability as building material. The soil sample used was obtained from a site in front of the Federal polytechnic Ado-Ekiti, in Nigeria. The plastic index and the plastic limit results for the soil are 23.8 and 40.5%, respectively. Also straw content of about 1-1.5% gave the highest compressive strength at optimum moisture content of 2-4%.

Key words: Building materials, cob, engineering properties

INTRODUCTION

The term building material refers to any material used in the process of any civil engineering construction work. Different kinds of materials have been used in building from age to age depending on the locality and the technological advancement therein. Due to its vasality and widespread availability, earth has been used as building material on every continent from age to age. It is one of the oldest building materials on the planet (Steve, 1997).

Earth construction takes many forms, including adobe, cob, rammed earth, straw-clay and wattle-and-daub. Cob is a very old method of building with earth and straw or other fibers. It is one of many methods for building with raw earth. It surpasses related techniques such as adobe, rammed earth and compressed earth bricks both in ease of construction and freedom of design. It can add-on, cut-out, or reshape anytime, even after the cob is dry. Cob-building is a traditional technique that has been used for thousands of years and in all kind of climates (Greer and Short, 1995). Cob is highly resistant to weathering, because of its porous nature; it can withstand long periods of rain without weakening (Keefe *et al*., 2001).

The basic ingredients of cob are soil, sand and straw. Under normal conditions, the topsoil removed from the footprint of the building is enough to supply all construction needs. Clay soils require the addition of more sand than do silty soils, but the overall quantities of sand and straw needed for a modest cob building are surprisingly small.

Economically, Cob is one of the cheapest building materials imaginable. The owner-builder can take great satisfaction in supplying the labor, building little by little in leisure time, or inviting friends to share the excitement of hand-sculpting a whole house. With inventiveness and forethought, the costs of other components (doors, windows, roof, floors, etc) can also be extensively reduced (Ianto *et al*., 2002).

Cob homes are one of the most durable types of earth architecture. Because the mud mixture is porous, cob can withstand long periods of rain without weakening. A plaster made of lime and sand may be used to windproof the exterior walls from wind damage (Michael, 2000).

Earth constructions are found in all parts of the world, though to a lesser extent in areas of extreme rainfall, generally, Cob houses are suitable for the desert or for very cold climates. Building can consist entirely or partially of soil, depending on the location, climate, available skills, cost and use of the building. In areas where there is large temperature variation (arid zones or highlands) the walls and roof are probably thicker than in more uniform climates (humid zones), where the need for material of high thermal capacity is less (Houben and Hurbert, 1984; Trott, 1994).

A typical soil of cob is likely to contain about 30% gravel, 35% sand and 35% silt and clay. However each of

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these could vary by +/-10% and still acceptable. For materials finer than 0.425 mm, which includes all the silt and clay, an easy guideline for suitability is the plasticity index (PI). This is the moisture content range from liquid limit (LL) to the plastic limit (PL). I f the PI value is less than about 10%, the soil may not be sufficiently clayey to give adequate strength (Agarwal, 1981; Saxton, 1995). Generally when the proportion of the fine particles present exceeds about 15% it is sufficient to act as a binder between the coarse particles and the strength will then depend more on the moisture content.

MATERIALS AND METHODS

Soil: The subsoil, from which the matrix of Cob is made, is the erosion of rock material producing the aggregate fraction. Chemical erosion of rock material produces the "binder fraction. In the present study, the aggregate fraction is that fraction of the matrix material with an effective diameter greater than 0.002 mm; the binder fraction has an effective diameter less than 0.002 mm. The binder fraction of the material used in this work consisted substantially of clay minerals. The binder fraction of the material used during the tests consisted substantially of clay minerals therefore binder fraction will be used to refer to these clay minerals. Soil sample was obtained from a site in front of the Federal polytechnic Ado-Ekiti, in Nigeria.

Rice straw: Straw gives Cob its tensile strength-the ability to move and bend without breaking and to withstand ground movement and shear forces (Michael, 2000). Straw is an annually renewable crop, available wherever grain crops are grown. Most of straw is derived from crops like rice, barley and wheat while much smaller amount are derived from oaths, maize, oilseed, rape and field beans (Jenkins *et al*., 1998). Straw is in most countries a waste product, much of which is burned in the field. In the construction of Cob, the straw of a grain producing plant is used. Due to the locality in which the study was conducted and the comparatively availability of rice in most areas, it was most reasonable to use rice straw for this testing programme. The rice straw is usually the golden brown color and it is the part of the plant actually carrying the rice grain. The rice straw used was obtained from a hilltop in a farm in Aare-Ekiti, Ekiti State in Nigeria where the threshing of the rice from the straw has taken place.

Test analysis: The top soil containing the vegetable matter and living organism were removed. The soil samples were taken from a depth of up to about 1.5 m by manual extraction. The tests were carried out in conformation with the procedures on ASTM and British Standard specification. Laboratory test to determine the properties of the soil were carried out between April and July 2003 at structural laboratory of The Federal Polytechnic, Ado-Ekiti, Nigeria.

Production of Cob: The production of cob involved three stages

- Preparation of the soil mix
- Compression of the soil mix
- Curing of the Cob

The tests on Cob were divided into three parts. The main variables for the sets of specimen were the initial moisture content at which the specimens were prepared and the straw content. All the moisture and straw contents relate to the dry soil weights. For part 1, 36 specimens were prepared, 12 of which were axially unconfined compression tested immediately after preparation to determine their initial wet strengths, the other 24 were allowed to air dry in the laboratory 12 of which were unconfined compression tested (and loaded in excess of that of failure to help clarify the failure mode). For the part 2, 14 similar specimens were prepared with a straw content of 1.5%. Several of these specimens were trimmed and then centrally loaded at one end via a 38 mm diameter steel disc.

Part 3 consists of 4 pairs of specimens with straw content 0, 0.6, 2 and 3%, respectively. They were air dried for 28 days and frequent weight and size measurements were taken.

RESULTS

Sieve analysis: The sieve analysis results is presented in Table 1, the results shows that the mixture contains good percentage of coarse aggregates, more than 50%, while percentage silt and clay is also more than 15%, this is still acceptable, however the plastic index will also be used to further determine its suitability.

Table 1: Sieve analysis results

Sieve sizes	Weight retained	Retained (%)	Passing (%)
12.500	42	8.4	91.6
9.500	26	5.2	86.4
4.750	133	26.6	59.8
2.360	133	22.6	37.2
1.180	60	12.0	25.2
0.600	37	7.2	18.0
0.425	129	1.8	16.2
0.300	12	2.4	14.8
0.150	3	0.6	14.2
0.075	22	4.4	13.8

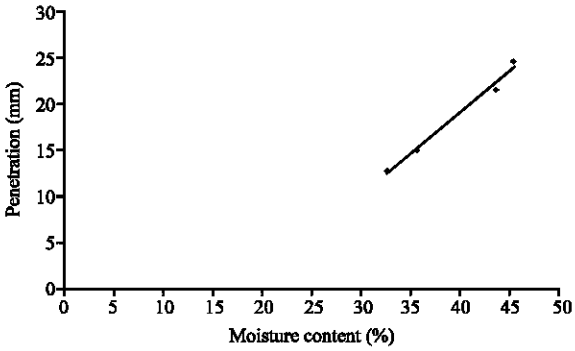

Fig. 1: Atterberg limit for soil sample

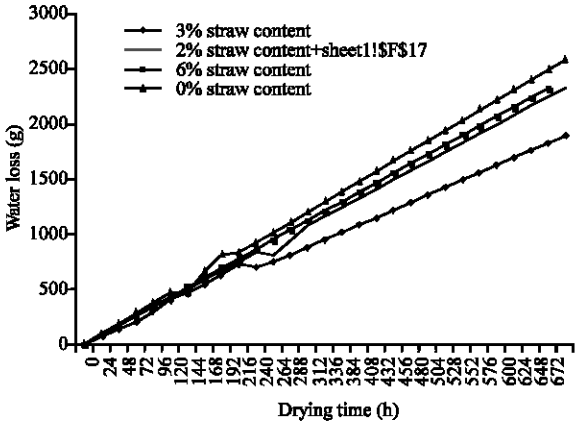

Fig. 2: Drying rate of cob specimen

Ease on mixing: From the mixing processes carried out, the soil was clayey but required less time for mixing and it was easier for straw to adhere to it, this is due to the plasticity index and the liquid limit results which are 23.8 and 40.5%, respectively, while the plastic limit is 16.7%. The Atterberg limit graph of the sample is shown in Fig. 1.

Rate of drying, shrinkage and cracking: The drying rates for the parts specimens are shown in Fig. 2. As the specimens were of similar initial dimensions, the actual water losses have been provided to provide a comparison. The drying rates do not appear to be influenced by straw or moisture content and are relatively uniform until linear shrinkage ceases. The moisture content at which shrinkage ceased in relation to straw content, for the part 1 and 3 specimens are given in Fig. 3. The mixes that contained the most straw and required the most water to provide a suitable mix tended to shrink the most.

Variation of strength with moisture and straw content: The variation in compressive strength of the specimen produced a scattered graph shown in Fig. 4. This is partly due to no allowances for densities and the inclusion of

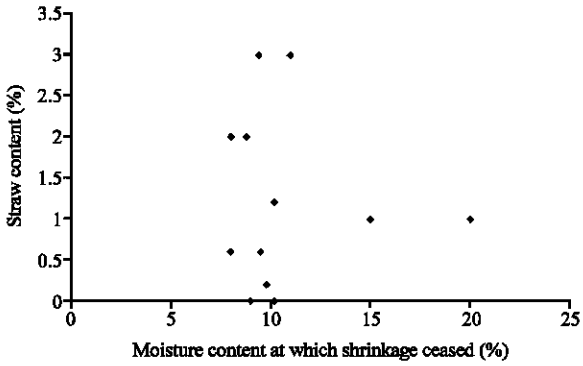

Fig. 3: Drying shrinkage of cob specimen

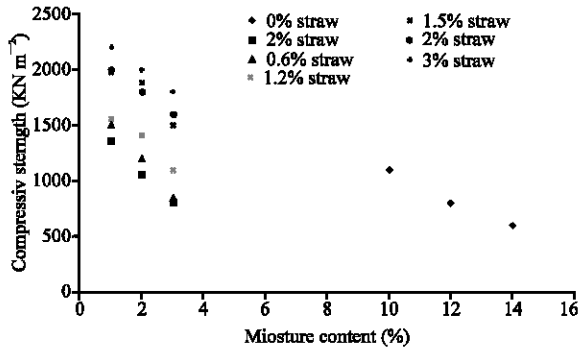

Fig. 4: Variation of compressive strength with straw and moisture content

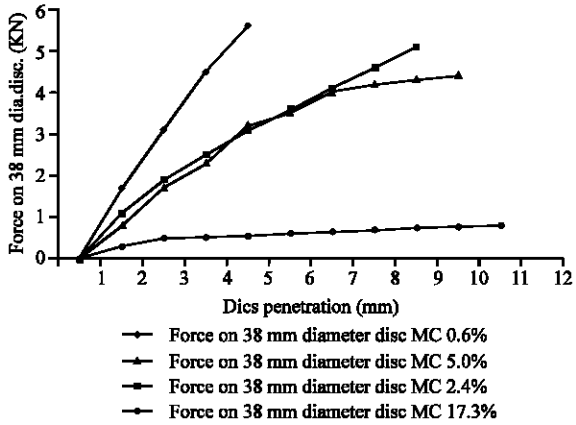

Fig. 5: Indentation due to concentrated force on cob

weak specimens made too dry and lacking adequate bond. The general trend is an increase in strength due to a reduction in moisture content and an increase in straw content. Below a moisture content of about 10.7% similar to the shrinkage limit, all strength were greater than 600 KN m^{-2} irrespective of straw content. This strength is probably sufficient to provide a margin of safety for structural loads with dwellings up to three storeys high.

As can be seen from the Fig. 4, there is possibility of a lower characteristic compressive strength below 4% moisture content. However for straw content of 1.5% there is no indications strength reduction.

Evidence of the ability of 'dry' Cob to support relatively high concentrated loads without excessive deformation is shown in Fig. 5. The higher the straw content, the higher the strain at failure due to loadings, this was observed during the testing of the specimens. The straw provided significant tensile strength.

CONCLUSIONS

It is a well known fact that, when the moisture content of clayey soils increase, they become weaker. At higher moisture contents, the addition of straw is of beneficial effect on the strength provided it is well bonded. If too much straw is added, the extra water needed also leads to increased volume changes during drying however the straw reduces the size of cracks. The straw does not appear to affect the rate of drying as can be seen in Fig. 2.

If water is allowed to soak directly into cob, or a gradual build-up is allowed to occur behind a cracked surface, collapse would result. Collapse is likely to be less dramatic if straw is adequately incorporated provided the straw still has required strength. High moisture content will also affect and eventually reduce the durability of straw, leading to a greater potential loss in strength for cob with higher straw content.

A straw content of about 1.0 to 1.5% is probably optimal when all of the above factors are considered. This amount may vary for different soil types and could be a topic for future work.

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