The effect of using different percentages of soil and fine aggregate on stabilized earth bricks

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Abstract. In this research, the production of stabilized earth bricks with cement using different percentages of soil, and sand has been studied. Earth brick are used as a replacement of fired clay bricks and concrete bricks. To estimate the effect of these different percentages of component, four percentages with (40% sand, 50% soil, 10% cement), (30% sand, 60% soil, 10% cement), (10% sand, 80% soil, 10% cement) and (0% sand, 90% soil, 10% cement) were used. On the other hand, water curing was used for these mixtures. Modulus of rupture, compressive strength, bulk density and water absorption, for different ages (7, 14 and 28 days) have been tested. There was an improvement in properties of Compressive strength, modulus of rupture and decrease in bulk density.

1. Introduction

A brick is a building material used for walls, pavements and different components in brick work. Historically, the term brick alluded to a unit made out of clay, however it is currently used to signify any rectangular units lay in mortar. A brick is made out of clay-bearing soil, sand, and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes that differ with district and time period, and are made in bulk quantities. Two essential classes of bricks are fired and non-fired bricks.

There are many forms of clay bricks but the common used one is the rectangular, it may take its solid shapes by drying or burning it, and bricks may be made solid or perforated. It is possible to estimate its quality according to (its shape regularity, dimensions, hardness, color consistency and quantity and absorption of water) [1].

Fired bricks are one of the longest- enduring and strongest structure materials, sometimes alluded to as artificial stone, and have been utilized since 4000 BC. Air-dried bricks, otherwise known as mud bricks, have a history older than fired bricks, and have an extra ingredient of a mechanical binder like straw. The most important features of earth brick are availability of basic raw materials in most countries, ease of construction, low construction cost and good strength.

Most of the researches focussed on enhancing the clay brick quality and properties. The present trend in bricks production has significant attention on the utilization of low-cost and regionally available new materials or post-consumer wastes from by-products in production industry.

In several countries, the necessity for locally produced building materials will barely be overemphasized as there is an imbalance between the requests for housing and typical, expensive
building materials combined with the consumption of traditional building materials to deal with this case, consideration has been focused on another low-cost building materials.

The production of fired clay bricks is significant intensive. The applied process of firing often uses given species of trees that could lead to their extinction and deforestation. Firing also often uses, black oil which will also pollute the environment. Firing of bricks needs great quantities of firewood and energy loss as heat is about 40-50%. Besides the environmental issue, clay bricks will only be made in areas where ever appropriate clay soil deposits exist. Extensive lateritic soil deposits exist which may be controlled for brick production.

Earth bricks, is a building material made principally from damp soil compacted (compressed) at high pressure. For making compressed earth bricks, a mechanical press is used make bricks from an acceptable mixture of fairly dry inorganic subsoil, non-expansive clay and aggregate. If the bricks are stabilized with a chemical binder such as Portland cement they are called compressed stabilized earth bricks or stabilized earth bricks. Commonly, around 21 MPa is applied in compression and therefore, the original soil volume is diminished by about 50%. Earth bricks may be made available in places wherever adobe producing operations are non-existent.

Compared to fired bricks and concrete blocks, the manufacturing of earth bricks doesn’t involve the firing process, very little cement is needed and the expenses of transportation is eliminated as manufacturing takes place on site. For curing the earth bricks, they are covered with tarpaulin (canvas) and waterproof devices thereby which make the process to be more environmental friendly.

In India, Compressed Stabilized Earth Bricks with cement stabilization have demonstrated to be useful. The ascertained flexural strength, compressive strength after 28 days of time with 9% cement stabilization has been observed to be 1 MPa and 3.2 MPa, respectively [2].

Earth bricks are the ideal solution for the balancing of concrete bricks and soil bricks. Concrete bricks lead to the emission of carbon dioxide gas in the cement industry. It is estimated that 1 ton of cement production produces 1 ton of carbon dioxide [3].

2. The aim of research
The aim of this research is to study the effect of using cement and sand with clay in different percentages on some properties such as: compressive strength, modulus of rupture, absorption, and bulk density. The other aim is to get an acceptable and sustainable earth brick without using firing, thus reducing the cost of clay brick production industry by eliminating the cost of burning process. Study also aimed at improving the environment by reducing CO₂ emissions in atmosphere by using large quantities in cement industry which uses in concrete blocks production and the process of burning of clay bricks.

3. Experimental work
3.1 Raw Material
3.1.1 Soil Clayey soil of brown color was used. The details of the soil characteristics are given in table 1. Figure 1 shows the soil grain size distribution of the soil that was used in this study. The soil is classified as (CL) due to (U.S.C.S) Unified Soil Classification System [4].

3.1.2 Ordinary Portland cement Ordinary Portland cement (OPC) was used for earth bricks mixture throughout the present work. The physical properties of used cement are complied with the Iraqi specification (IQS, No.5) [5]. Also, the chemical analysis compounds of cement determined according to Bogue equations, ASTM C150 [6].
Table 1. The used clay physical characteristics.

| Test                  | Magnitude | Specification |
|-----------------------|-----------|---------------|
| Classification        | CL        | ASTM D 2487   |
| Activity              | 0.41      | Skempton formula* |
| Clay %, < 0.005 mm    | 42        |               |
| Silt %, 0.005-0.075 mm| 28        |               |
| Sand %, 0.075-4.75 mm | 30        |               |
| Gravel %, > 4.75 mm   | 0         |               |
| Specific gravity (sg) | 2.7       |               |
| Liquid limit (LL)     | 33        |               |
| Plastic limit (PL)    | 18        |               |
| Plasticity index (PI) | 15        |               |

Skempton formula*: \( At = \frac{PI}{\text{percent of clay} < 0.002\text{mm}} \)

Figure 1. Clay material grain size distribution curve.

3.1.3 Sand Natural sand from Al-Ukhaider was used with maximum size 4.75 mm, the grading of fine aggregate is shown in table 2, where it is within the requirements of the Iraqi specification No.45/1984 [7] zone 2.

Table 2. Properties of fine aggregate

| Sieve size (mm) | Passing by weight (%) | Limits of IQS No.45/1984 Zone 2 |
|-----------------|------------------------|---------------------------------|
| 4.75            | 100                    | 90-100                          |
| 2.36            | 88                     | 75-100                          |
| 1.18            | 70.2                   | 55-90                           |
| 0.60            | 59                     | 35-59                           |
| 0.30            | 24.4                   | 8-30                            |
| 0.15            | 3.2                    | 0-10                            |

3.2 Mixing and proportion of earth brick samples
3.2.1 Mixing Procedure To find the amount of water added to soil for formation to get formable clay paste with less losses of strain or formability according to ASTM D4318-00[8], different percentages of water was made on four different mixtures (40% sand, 50% soil, 10% cement), (30% sand, 60% soil, 10% cement), (0% sand, 90% soil, 10% cement) and (10% sand, 80% soil, 10% cement). The required water for these mixtures are shown in table 3.

The following mixing procedure was carried out:
1- Add both dry soil and aggregate and mix thoroughly.
2- Add the cement to the mixture and mix again.
3- Add mixing water and mix all constituents for 120 sec.
4- Put 300 gm of the mixtures in the mold with dimensions (9.5 x 4.5 x 3.5) cm.
5- Press the mixture into the mold with rate of load (14 N/mm per min) until reaching the top surface of the mold.
6- The samples were demolded. Specimens were covered with polythene sheets for curing, preventing loss of moisture from the surface and to avoid plastic shrinkage cracking till testing time.

Some of specimens that produced in this work are shown in figure 2.

| Mixtures                  | Symbol | Tin wt. (gm) | Tin+ Wet Sample wt. (gm) | Tin+ Dry Sample wt. (gm) | w % |
|---------------------------|--------|--------------|--------------------------|--------------------------|-----|
| 50% soil +40% sand + 10% cement | A      | 27.9         | 64.5                     | 59.6                     | 15.5|
| 60% soil +30% sand + 10% cement | B      | 20.2         | 62.1                     | 55.8                     | 17.7|
| 80% soil +10% sand +10% cement   | C      | 27.2         | 62.1                     | 56.0                     | 21.2|
| 90% soil +0% sand +10% cement     | D      | 22.5         | 78.8                     | 68.1                     | 23.6|

Table 3. Water percentage required for plasticity of clay mixtures

Figure 2. Some of specimens produced in this work
3.3 Specimens and Tests

3.3.1 Plasticity Testing The test procedure was according to ASTM D4318-00 [9]. Samples were prepared to test by utilizing about 20 gm of every mix and permitted to lose moisture till it is plastic enough to be formed into a ball without adhering to the fingers. Roll the cylinder under the fingers of one hand on a smooth glass surface, applying enough pressure to decrease the diameter to about 3 mm in about 5 to 10 complete forward and backward rounds. Maintain a steady pressure. Pressure must not decrease till the 3 mm diameter is approached. Use a metal bar of 3 mm diameter to gauge the thread diameter. Weigh and record the mass of the sample and container before drying. After that dry the soil sample in container to a constant mass in a 110°C (230°F) oven and weigh the mass.

3.3.2 Compressive Strength Test Compressive strength test was measured by a device shown in figure 3. Device capacity s 1560kN. Strength was measured by brick samples till failure. An average of (3) samples were tested for each mixtures A, B, C and D, carried out according to Iraqi Specifications [10].

3.3.3 Modulus of rupture (M.O.R.) It is an indirect method to measure tension strength for samples through loading them with concentrated load with fixed supports with rate of load (14 N/mm per min) as shown in figure 4. Test was carried out for three samples with dimensions (9.5 x 4.5 x 3.5) cm. The modulus of rupture was carried out according to Beech [11].
3.3.4 Water Absorption procedure An average of three sample were tested for all proportions. The absorption ratio was carried out according to the Iraqi specification No.24/1988.

3.3.5 Bulk Density It was carried out of lab bricks after measuring 3 dimensions of sample with weight sample in balance having (0.1) gm, the bulk density was calculated as in equation (1):

\[
B.D. = \frac{W_f}{V_f} \quad \text{………………… (1)}
\]

Where:
- \( B.D. \): Bulk density (g / cm\(^3\)).
- \( W_f \): Sample weight (gm).
- \( V_f \): Size of sample (cm\(^3\)).

An average of 3 samples were tested for all mixtures.

4. Results and Discussion
The results are presented in tables and plots as average for 3 specimens.

4.1 Discussion of test results of earth bricks specimens
Compressive strength, modulus of rupture, water absorption and bulk density were tested at 7, 14 and 28 days for all mixes, the results of these tests are shown in table 4.

The results in figures 5 (a) and (b) indicate the compressive strength and modulus of rupture of samples for different mixtures A, B, C and D. In spite of clay percentage increment, compressive strength and modulus of rupture samples for different mixtures increased with the increase in age; this may be due to the continuous hydration process. The mixture D has best results as compared to others. The other results for A, B and C were very close.
Table 4. Properties of different earth bricks mixtures

| Mix | Age (Days) | Compressive Strength (MPa) | Modulus Of Rupture (MPa) | Density (gm/cm³) | Absorption (%) |
|-----|------------|-----------------------------|--------------------------|-----------------|---------------|
| A   | 7          | 2.55                        | 0.240                    | 2.026           | 10.08         |
|     | 14         | 2.91                        | 0.263                    | 2.005           | 11.42         |
|     | 28         | 6.47                        | 0.305                    | 1.934           | 13.54         |
| B   | 7          | 1.63                        | 0.305                    | 2.084           | 12.18         |
|     | 14         | 2.89                        | 0.335                    | 2.021           | 13.20         |
|     | 28         | 5.48                        | 0.371                    | 1.886           | 13.36         |
| C   | 7          | 1.63                        | 0.288                    | 2.053           | 19.08         |
|     | 14         | 3.38                        | 0.341                    | 1.930           | 15.01         |
|     | 28         | 6.23                        | 0.385                    | 1.722           | 20.78         |
| D   | 7          | 2.20                        | 0.282                    | 1.973           | 20.18         |
|     | 14         | 2.75                        | 0.340                    | 1.918           | 14.30         |
|     | 28         | 7.52                        | 0.472                    | 1.738           | 18.20         |

A difference was observed in the behavior of the samples used in the absorption test and indicated in the results, as in figure 5(c), when using different percentages of soil and sand when the quantity of cement is constant. An incremental increase of absorption was indicated when using mixtures (A and B) with soil ratios (50 and 60) % for different ages due to shrinkage, which increases over time. This increase is not high due to the presence of hydration products of cement that fill some of these cracks. Mixtures (C and D) have soil (80 and 90) %, which is more than the two previous mixtures (A and B). In the early ages, mixtures (C and D) have high absorption percentages. After that, there was a decrease in the absorption percentage due to the homogeneity and bonding of constituent in the mixture more than mixtures (A and B). This leads to decrease of voids in samples. However, as the age increases, the absorption percentages increase due to the higher shrinkage due to drying of wet soil compared to other mixtures, despite the presence of cement hydration products.

In figure 5(d), the results indicate the effect of increasing soil on the density of specimens, for different mixtures A, B, C and D. Despite the increase of clay percentage, density of the specimens for different mixtures decrease with the progress of the age; this may be due to the fact of the continuous shrinkage and drying processes. This shrinkage increases the voids inside samples, which decreases the density.
5. Conclusions
This study was performed to estimate the effect of using different percentages of soil and sand on different properties of earth bricks. Four mixtures were used viz. (40% sand, 50% soil, 10% cement), (30% sand, 60% soil, 10% cement), (10% sand, 80% soil, 10% cement) and (0% sand, 90% soil, 10% cement). Constant percentage of ordinary portland cement (10) % was used. The investigated properties included: compressive strength, modulus of rupture, bulk density, and absorption. Based on results presented in this study it can be concluded that:

1- Compressive strength and modulus of rupture for mixtures with high soil were improved and close for all other mixtures.
2- Almost all mixtures decreased in density test at the same age. The mixtures (A and B) were better than the mixtures (C and D) in density.
3- An improvement in absorption percentages for mixtures (A and B) was noticed, which is less than that for mixtures (C and D).

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