Construction and Building Materials 142 (2017) 137–147

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Experimental investigation on mud bricks reinforced with natural additives under compressive and tensile tests

Asghar Vatani Oskouei *, Mohammad Afzali, Mohammadreza Madadipour

Department of Civil Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran

HIGHLIGHTS

- Effect of natural fibers on the compressive strength, Young's modulus, proper durability against water and tensile strength of brick.
- The durability against water of fibrous specimens is more than simple specimens.
- Specimens with wood chips, showed no significant reduction and increasing in compressive stress.
- Wood chips excess amount makes disorder of the clay cohesion performance and the particles friction by making distance between the soils components.
- The compressive strength of palm fiber additive specimens showed the best performance among the natural additives.

ARTICLE INFO

Article history:
Received 11 November 2016
Received in revised form 19 February 2017
Accepted 9 March 2017
Available online 17 March 2017

Keywords:
Brick
Diagonal tension tests
Straw
Mortar
Mud brick wall
Fiber

ABSTRACT

In this paper, the experimental behaviour of mud brick reinforcement is present. The effect of natural fibers such as straw, wood chips carpentry, rice husk and palm fibres on the compressive strength, Young's modulus, proper durability against water and tensile strength of brick samples were given. Different amount of fibres were selected to test: 0.3 and 0.6 and 0.9 percentages of specimens' weight. The amounts of each component which may be effect the mechanical behaviour of mud bricks were investigated. In accordance with the results, the best sample in terms of compressive strength and durability against water is determined.

In this investigation, the compressive strength and tensile strength of mud brick is studied. For the compressive strength the cubic samples with dimensions of $22 \times 22 \times 7$ cm and $22 \times 11 \times 7$ cm, and for the tensile strength the cylindrical samples with a diameter of 15 cm and height 30 cm were tested. The compressive strength of simple sample mud brick is 4.4 MPa. The compressive strength of the samples with natural additive is between 2.67 and 16.53 MPa. The durability against water of simple specimen is 255 min and the sample with 0.9 percent of weigh rice husk is 560 min. The natural additives increase the tensile strength from 57 to 281 percent.

1. Introduction

Mud brick buildings incur lots of monetary and death damages during the past recent years earthquakes in Iran and other regions of the world [1]. Lack of building code and standards for mud brick buildings is another aspect which makes it necessary to construct and test mud brick walls in order to examine their behavior.

Mud brick constructions are common in our country and many other countries all around the world. Good adaptability, being cost-effective, feasibility and speed in construction are of the positive features of these materials [2] and today many regions of our country use this kind of materials for economic problems. However, the important problem in these buildings is lack of their design against earthquake loads. Recent quakes showed that in general, non-reinforced structures are vulnerable against earthquake and need to be reinforced [3].

Around 30%–50% of the world's population (approximately 3 billion people) live or work in earthen buildings [4]. Approximately 50% of population in developing countries, including a majority of the rural population and at least 20% of the urban population, live in earthen dwellings [5]. For example, in Peru, according to the 2007 Census, almost 40% of houses are made of earth. (That's 2 million houses inhabited by around 9 million people.) In India, according to the 2001 Census, 30% of all buildings are made out of earth

* Corresponding author.
E-mail addresses: asvatani@gmail.com, vatani@srttu.edu (A. Vatani Oskouei).

http://dx.doi.org/10.1016/j.conbuildmat.2017.03.065
0950-0618/

(this includes 73 million houses inhabited by almost 305 million people).

The need for housing poses significant strains on the society in terms of costs, especially in developing countries. The rising costs of Portland cement and steel also leads to significant challenges in the housing needs. In this regards, earth is considered as the cheapest material readily available for construction in rural areas of Asia, South America and Africa. This simplest form of construction material also finds applications in developed countries due to its environmental friendly nature. Furthermore, in several countries, preservation of historic structures is a rising awareness, where some of these structures are made from adobe [6].

The key reasons to use mud brick are: a) it is a material available everywhere; b) there is no need for high technology and skill to produce mud brick and mud brick structures. c) There is no need to certain labs to maintain and repair the mud brick structures and d) inherent properties of the soil makes it acoustic and heat insulator [7–9].

In an experiment carried out on silt soil-clay and silty-sand, if the optimum fiber ratio used, it would reduce shrinkage and curing time and increase the compressive strength. Bending and shear strengths also increase and plasticity is most possible before failure [10].

Different methods have been proposed by researchers for the production of adobe bricks [11,12]. The durability of mud bricks treated with soluble sodium silicate followed by water-based silane/siloxane emulsion was found to be increased significantly compared to that of the untreated substrate [13]. In an experiment by Bouhicha et al. [14] the following results obtained.

If a favored percentage of straw is used, positive effects proved for reduction of shrinkage, curing time, increased compressive strength, increased bending strength and increased shear strength. In addition, the specimens with straw sample caused more damages with more flexibility. In addition to reinforcement effects, straw can make homogen dryness of the material. Using clay required for the composition coherence increases shrinkage. Adding straw to the composition minimizes shrinkage and prevents occurring cracks on specimens.

According to the statistics, 70% of the residential houses with these types of materials in Iran are low durable or lack of durable which provide no time for escape of the residents once an earthquake happens [6]. But it is not possible to ignore mud brick buildings only for their low strength against quakes, indeed an appropriate solution can be introduced for their reinforcement and maintenance. To do this, it's been tried in this paper to examine compressive and tensile strengths of the bricks as blocks and cylinders by adding natural additives.

2. Experimental program

2.1. Materials

To make mud bricks of clay, sand and gravel were used to be same as available materials for brick construction.

Aggregate (sand – gravel) played filler role and prevented shrinkage and cracking from the brick and water used for liquefying and mixing the materials together. In order to reinforce the blocks, natural fibers such as straw, wood chips carpentry, rice husk and palm fiber were used.

Starting from the production of some bricks of only earth (Clay-C),[1] in addition to clay, sand (S), gravel (G), natural fibers such as straw (St), palm fiber (P), wood (W) and rice husk (Rh), synthetic fibers such as polypropylene (PP), polyester (Ps) and glass (Gl) were used. The natural additives and synthetic fibers were in 0.3, 0.6 and 0.9 percent of the total weight of the components. In this paper, samples are named by using the first letters of their names, for example, this sample C + S + G + 0.9P contains of: Clay, Sand, Gravel and Palm, 0.9 is the percent of total weight of sample.

2.1.1. Clay

In order to prepare the mortar and the brick a type of clay used. The clay properties is shown in Table 1 regarding to the experiments. These experiments on clay were all carried out according to ASTM standard [15]. According to unified system classification for soil, the soil is clay with low plasticity (CL).

2.1.2. Aggregates

Aggregate used in mud brick is made of sand and gravel. Sand and gravel features are shown in Table 2. The sand and gravel humidity varies with temperature variations. Sand and gravel moisture was 1.53 and 2.4% when used in the bricks.

2.1.3. Natural additives

The materials used to manufacture the adobe bricks have been earth, coarse sand and short natural additives. The natural additives are straw, palm fiber, wood chips and rice husk.

Straw: This additive fiber is hollow with coarse surface as it is the stem of the plant. Average length of specimens is 2.5 cm in a range of 1–4 cm (Fig. 1 and Table 3).

Palm fiber: This additive is a product of tree bark which is called palm fiber as its length is 10 times longer than its diameter. This fiber is a solid structure. (In order to crash the fiber first, it is wet in water then its warp and woof is separated and it is crashed after full length fiber obtained) (Fig. 2 and Table 4).

Wood chips carpentry: This additive is the waste of carpentry products, the structure of which depends upon the original wood. In this study the wood chips were spring shape and the average specimen length was 1 cm (Fig. 3).

Rice husk: This additive is a product of rice wastes which is almost a powder.

Note: since natural additives used for reinforcement were selected for their fiber, hollow or solid, as mentioned above, no ash was used in the experiments (Fig. 4 and Table 5).

2.2. Specimens preparing

2.2.1. Preparation of mud blocks with natural additives

The purpose of this study is to evaluate the influence of natural fibers on mechanical properties of mud bricks. In this regard, clay, sand, gravel and water percent were assumed constant and the percentage of fibers was assumed variable.

Material percentage of this experiment is shown in Table 6. The percentages calculated based on soil weight. Abbreviations used in Table 6 are: C as clay soil, S as san, G, as gravel, W, as wood chips carpentry, P as palm fibers, R as rice husk and St as straw.

The water added to the mixture was determined according to the clay amount and saturation status with the materials surface dryness (SSD). Each mud specimen was dried in lab conditions and under the same temperature (average 23 °C). In order to dry the specimens, they were displaced every 24 h in order to dry all the parts of the bricks and to do this uniformly, a plastic layer put on the specimens to prevent quick vaporization and cracking. 28 days was spent for drying entire specimens. Material grading used in the mud bricks are shown in Fig. 5. The materials were reported well graded according to ASTM D422-87.

The studied dimensions were $22 \times 22 \times 7\ cm^3$ for the mud brick and $22 \times 11 \times 7\ cm^3$ for the half brick. Mud block is used to do experiments of compressive strength and duration against

[1] In the following, if the symbol C stands alone, it is referred to the name of the type of mixture made by only earth.