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The influence of natural reinforcement fibers, gypsum and cement on compressive strength of earth bricks materials

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HIGHLIGHTS

- Un-fired earth bricks were made from biocomposites.
- The compression and flexural test were done for different samples.
- Fibers have greater effect on compression and flexural strength than cement and gypsum.

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ABSTRACT

This paper presents an experimental work on the compressive strength of earth bricks in particular the influence of additives. In total 21 different test series are carried out with different composition of earth, cement, gypsum, hemp and flax fibers. The earth material is characterized by geotechnical laboratory tests. The test results indicated that the compressive strength is highly dependent on the density of the bricks. The fibers hemp and flax have rather low impact on the compressive strength of earth bricks, but they have strong influence on the breaking behavior. Cement and gypsum as additive, as they seem to reduce the binding force of the clay minerals, lead to a highly decreased strength.

1. Introduction

The promotion of sustainable development has put pressure on all industries, including the construction industry to adopt and implement proper methods to protect the environment. Due to current global concerns for sustainable development that have arisen from extensive environmental problems such as climate change and the impoverishment of resources coupled with the rapid pace of technological advancement within the building sector, interest in alternative building materials such as earth has developed. Most building regulations have increasingly strict criteria for the thermal performance of buildings, including building ecology and sustainability. Soil as a building material has good physical properties when considering energy conscious and ecological design, and also fulfills all strength [1,2]. In developed countries, a new consciousness arises for organic and healthy building materials. The concept of sustainability is gaining importance. Earth as a natural building material is being received increasing attention. Compared with industrial building materials like concrete, earth material requires approximately 99% less energy in the production process. Moreover, earth as building material is recyclable, cost effective and regionally available making long transport routes unnecessary. Reuse the agricultural by-products presents clear advantages from economic (cost-reducing) and ecological (resource-saving) perspectives [3,4]. Natural fibers offer an attractive alternative to many synthetic materials building with natural fibers presents diverse markets for farmers, reduces the emission of carbon dioxide and minimize the volume

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of waste in landfill. Furthermore, natural fiber source is renewable and considered being green and environmentally friendly [5–7]. On the other hand the relation between earth bricks reinforced by agricultural wastes and environment conditions were studied. They found that, the equilibrium moisture content (EMC) for bricks under different conditions was less than 7% and it has a good physical and mechanical properties for different materials [8–13]. The use of natural fibers and in particular hemp fibers as reinforcing agents in composite materials offers many advantages such as low density and biodegradability [14–16]. On the other hand, faced with the worldwide shortage of forest resources, the industry is showing increased interest in the production of particle board from agricultural residues [17].

For unstabilized soils, the compressive strength between 0.60 and 2.25 MPa was shown by Delgado and Guerrero [18]. According to the Spanish Standards [19], Morel et al. [20] summarized the mechanical behavior of unstabilized rammed earth, where the compressed earth blocks produced with manual press usually possess compressive strengths in a range of 1.5–3.0 MPa and densities from 1763 to 2160 kg/m^3. Higher strengths can be achieved using hydraulic press and/or higher cement contents with typical compressive strengths in the range 2–3 MPa. Some in-situ measurements were reported by Bui et al. [21] in a rammed earth house erected near Thiers (France). The densities obtained were about 1980 kg/m^3 and compressive strengths about 1.65 MPa. Stabilizers such as lime, cement or bitumen, were added to improve the earth properties [22]. In some countries such as Papua New Guinea clayey soils are stabilized with native materials, e.g. volcanic ash, finely ground natural lime, cement and their combinations. The influence of stabilizers was studied by Hossain et al. [22]. The compressive strength in this case varies between 0.39 and 3.10 MPa. According to Ngowi [23], the strength of cement stabilized bricks is about 70% higher than the bricks stabilized with lime, as the strength of lime mortar is only a third of the cement mortar. Atzeni et al. [24] added stabilizers such as hydraulic cements, hydrated lime and polymers (acrylic latex and an aqueous solution of naphthalene–sulfonate) and increased the compressive strength from 0.9 MPa (unstabilized) to 5.1 MPa (polymer impregnated) [25].

Minke [26] suggested that for dry building elements made of earth the compressive strength of 2–5 MPa should be used. Note that poor earth materials may have strength as low as 1 MPa while optimum loam products can have strength as high as 10 MPa. According to Schröder [27] there are numerous influence factors on the dry compressive strength of earthen building materials, such as grain distribution, grain quality, quality of clay minerals, quantity of clay minerals, binding strength of the clay minerals, preparation, amount of water used in production, compaction work, surcharges and additives. Ashour et al. [28] showed that fiber has positive effect on both the strength and ductility of earth plaster materials. While the fiber has remarkable effect on the strength and ductility of plasters, its effect on the elastic modulus of plasters is relatively small. Cook [29] showed that the chemical composition and morphological properties of coir fiber provide better protection against decomposition than sisal fiber. Guimaraes [30] reported that the impregnation of sisal fiber with 0.375% polyvinylalcohol (PVA) aqueous solution heated for 60 min led to tensile strength about 78% higher than unimpregnated sisal fibers after 140 days under lime solution exposure. On the other hand, Agopyan [31] showed that subjecting the coir fibers to tap water followed by drying at laboratory environment or oven at 105 °C caused significant reduction in the tensile strength and in elongation. This can be attributed to biodeterioration [32], but the leaching of extractive may also be considered Our paper represents a systematic investigation on the influence of hemp and flax fibers as reinforcement materials for earth bricks. Moreover, the effect of stabilization materials such as cement and gypsum on the compressive strength of earth bricks is discussed.

2. Materials and methods

2.1. Materials tested

Five different materials are used, i.e. cohesive soil, flax, hemp, gypsum and cement. The fibers were selected because of their positive impact on the thermal properties of earth building materials and the mineral binders because of their strength properties. The composition of the cohesive soil texture is as follows: 26% clay (<2 µm), 66% silt (20–63 µm), 5% sand (63–2000 µm) and 3% gravel.

The Atterberg limits were determined in a geotechnical laboratory with W_L = 32% (liquid limit), W_P = 17.3% (plastic limit) and I_P = 14.7% (plasticity index). According to the unified soil classification system the soil can be defined as low plastic clay. To analyze the composition of clay minerals, X-ray diffraction clay mineral analysis was performed. Type and amount of these clay minerals have large influence on the binding force and therefore also on the bending and compressive strength. The content of clay minerals can be given as follows: 50% smectite (low binding force), 30% illite (high binding force), 10% kaolinite (high binding force) and 10% vermiculite (medium binding force). Fig. 1 shows the grain size distribution of the tested soil.

2.2. Sample preparation

At first, the oversized gravels were removed from soil. The soil was then moistened to the liquid limit, a state in which you can squeeze the earth through the fingers by pressing it. During mixing the consistence of the earth needs to be carefully

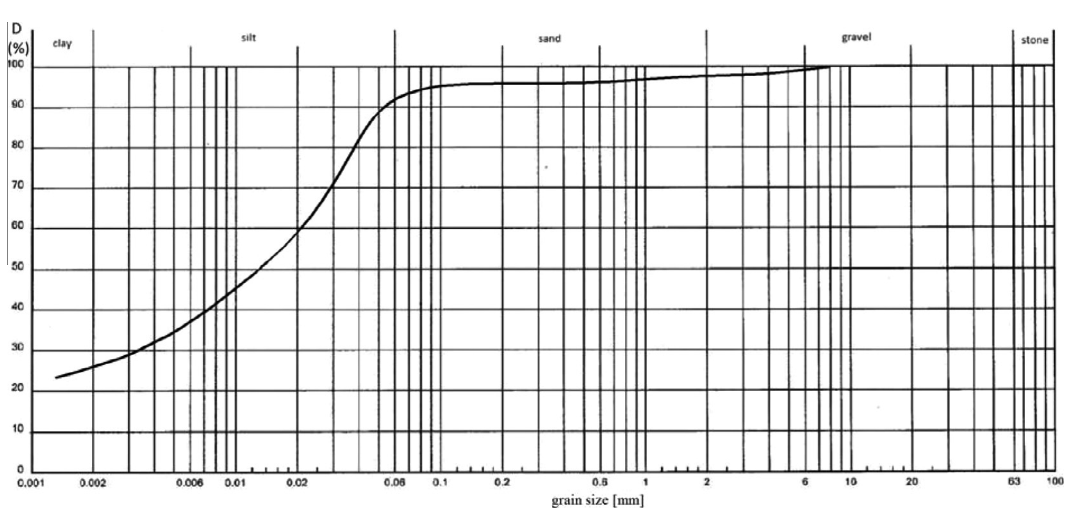

Fig. 1. Grain size distribution of soil.