

Thermal conductivity of cement stabilized earth blocks



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HIGHLIGHTS

- Thermal conductivity of cement stabilized earth blocks (CSEB) increases with bulk density.
- Thermal conductivity of CSEB slightly varies with the addition of cement.
- Compressive strength of CSEB increases with increasing cement content.

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ABSTRACT

The present study examines the effect of bulk density and cement content on the thermal conductivity of cement stabilized earth blocks (CSEB). The experimental results show that the thermal conductivity increases as a function of bulk density; changes in cement content result in a small variation in thermal conductivity of CSEB at a given bulk density. No obvious linear relationship between the thermal conductivity and cement content of CSEB has been observed. However, a significant increase of compressive strength of CSEB caused by the addition of cement has been observed; moreover, the compressive strength of CSEB increases with increasing cement content. CSEB show potential in earth buildings due to their improved compressive strength and reduced thermal conductivity.

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1. Introduction

Along with the development of both rural villages and cities in China, which is the fastest growing economy in the world, the progressive increase in the demand of residential buildings requires a huge building materials to be prepared and used. Nowadays, energy shortage and pollution have become the main problems in the society, the modern building materials which have high energy costs and CO₂ emissions should be replaced by the sustainable and environmental building materials which are abundant and inexpensive. Earth construction, which is warm in winter and cool in summer, is one of the oldest and most widespread buildings in human history. It can contribute to improve living comfort and reduce environmental problems.

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Earth blocks are one of the earth building techniques and have widely been used in China. Its abundant source benefits from direct site-to-service application to reduce the costs caused by acquisition, transportation and production [1]. No specialized instrument and specific surroundings are required during the production. In addition, earth buildings provide good sound and thermal insulation, and they may also help in regulating the indoor humidity [2]. Unfortunately, earth materials have been ignored for many years in the modern construction sector; this is mainly due to the lack of strength and durability. The compressive strength represents the load-bearing performance of earth blocks; lower compressive strength means earth blocks can only be used for self-bearing members and the storey of building has been restricted. The lack of durability leads to earth buildings are vulnerable to weathering and rainfall and regular repair will cost human and financial resources. In recent years, a growing interest in overcoming the mechanical defects has been appeared and the technique of stabilization has been used in order to enhance the durability and compressive strength of earth blocks. Bahar et al.

[3,4] conducted experimental studies to present the effect of stabilization methods on mechanical properties. The results indicated that the combination of compaction and cement stabilization is an effective choice for increasing strength of earth blocks. Amoudi et al. [1,5,6] carried out a series of experiments on mechanical properties of cement stabilized earth blocks (CSEB); the results showed that cement in the presence of water tends to form hydration products in order to wrap the soil particles and occupy the voids. The compressive strength, dimensional stability, total water absorption and durability were improved significantly and thus became technically acceptable. Heathcote [7] presented that there was a strong relationship between mechanical properties and cement content. The compressive strength, modulus and durability were enhanced by increasing cement content [8–10]. The thermal insulation of earth buildings provides a comfortable environment for residents in order to reduce heating and cooling energy consumption. Compared with the mechanical properties, fewer studies on the thermal property of CSEB have been reported so far. Adam and Jones [11] measured the thermal conductivity of lime/cement stabilized hollow and plain earth blocks by the guarded hot box method; the results indicated that the thermal conductivity is highest for cement stabilized soil building blocks. Ashour et al. [12] measured the thermal conductivity of earth bricks consisting of soil, cement, gypsum and straw; the results showed that the addition of fibre positively improved the thermal property and the thermal conductivity slightly increased with cement content.

In this context, this study reports an experimental investigation to evaluate the effect of both bulk density and cement content on the porosity of CSEB and consequently on the thermal conductivity. Microstructure of CSEB has been pictured to assist the analysis of correlation between bulk density/cement content and porosity. The aims of this study are to guide the manufacturing for low thermal conductivity and sufficient compressive strength CSEB in the process of earth construction.

2. Experimental

2.1. Materials

2.1.1. Soil

The soil used in this study was collected from Turpan of Xinjiang Uygur Autonomous Region. The grading curve and the particle size of the soil were determined by grain size analysis, according to GB/T 50123-1999 [13]. The test results are presented in Fig. 1. The Atterberg limits of the soil are: Liquid limit (LL = 23.7%) and plasticity index (PI = 5.5%). X-ray diffraction analysis determines the mineralogical composition, as shown in Fig. 2. The results show that the CSEB soil includes quartz

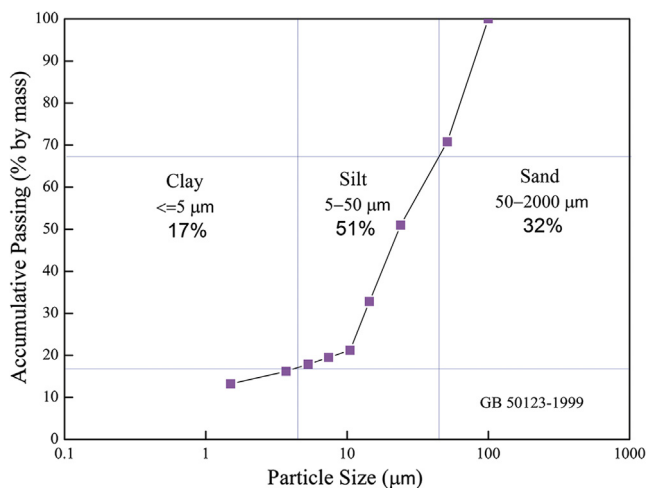


Fig. 1. Grain size distribution of soil used.

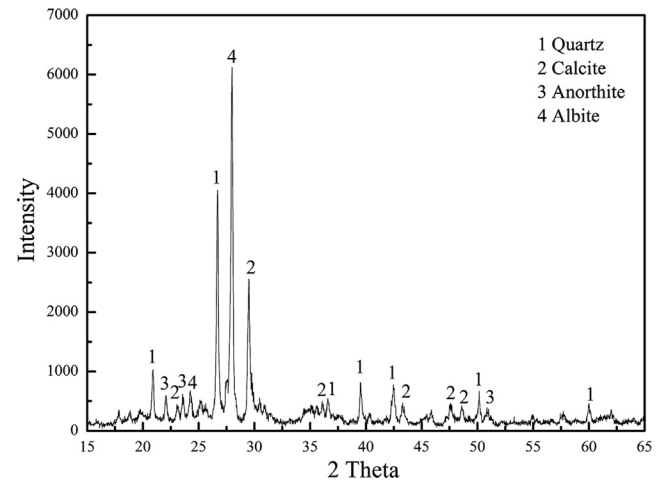


Fig. 2. X-ray diffraction of soil used.

(SiO_2), calcite (CaCO_3), anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$) and albite ($\text{NaAlSi}_3\text{O}_8$) minerals. Chemical composition of the soil is shown in Table 1, the chemical composition analysis is on the basis of X-ray fluorescence.

2.1.2. Cement

In this study, Portland cement was used as stabilizer for production of cement stabilized earth blocks (CSEB). The Portland cement used complied with GB 175-2007 P O 42.5 grade [14], equivalent to CEM II/A-M(S-V) 42.5 N according to BS EN 197-1 [15]. As this cement has enough strength after hydration to enhance the compressive strength of CSEB [16], it was used in our work. Also, this cement is widely used in the construction industry, i.e. supporting the choice of material composition in our research. The chemical composition of the Portland cement is presented in Table 2.

2.2. Cement stabilized earth block

Before preparation of stabilized earth samples, the soil was sieved to remove the oversized particles (2 mm). The sieved soil was dried in air at 105 °C for 24 h. The dried soil and cement were mixed at different ratios between soil and cement (97:3, 95:5, 93:7 and 91:9), the ratio and amounts of materials were controlled by weights. Water was added at a content of 13 wt% to mass mixture and mixed for 10 min until the mixture was uniform by wetness. Samples were prepared by a hydraulic press, as shown in Fig. 3. The mixture was compacted at different bulk densities and the classification of bulk density includes 1.5, 1.7, 1.9 and 2.1 g/cm³. The bulk density can be identified by mass of mixture pressed into the mould divided by volume of samples. Two groups of sample dimensions were selected according to the purpose of the testing to be carried out. The dimensions of the samples which were used for thermal conductivity tests were 50 mm × 50 mm × 25 mm, while the dimensions for both compressive strength and bulk density tests were 50 mm × 50 mm × 50 mm.

Samples were wrapped with plastic foils to assure the cement hydration and placed in the laboratory for 28 days. The temperature and relative humidity (RH) in the laboratory were 20 ± 1 °C and 60 ± 1% RH.

2.3. Characterization

2.3.1. Thermal conductivity

The thermal conductivity was measured by using a Hot Disk apparatus (TPS-2500 S) which was calibrated with an expanded polystyrene board in order to ensure the accuracy of the experimental results. Each measurement was repeated three times and the mean value was reported. Before the measurement, flatness of specimens was checked in order to make a good contact between the sensor and the sample. During the measurements, a sensor probe was placed between two specimens, as shown in Fig. 4.

2.3.2. Porosity

The porosity values of CSEB were determined by Le Chatelier Flask, according to GB/T 208-2014 [17]. In order to obtain porosity values of CSEB at different bulk density and cement content values, the CSEB examples were broken and grinded into powder by both mortar and pestle after thermal conductivity testing. The mass percentage of the small-sized particles increased after grinding. The CSEB powder was placed in an oven at 105 °C for 24 h.

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