Construction and Building Materials 166 (2018) 531–536

Contents lists available at ScienceDirect

Construction and Building Materials

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

Utilization of granulated blast furnace slag and cement in the manufacture of compressed stabilized earth blocks

Darshan C. Sekhar *, Sitaram Nayak

Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore 575025, India

HIGHLIGHTS

- An attempt to utilize granulated blast furnace slag in soil stabilization is made.
- Significant improvement in strength is observed with granulated blast furnace slag stabilization.
- Reduction in cement content is possible, when GBFS is used in the manufacture of CSEBs.
- Compressed stabilized earth blocks made from granulated blast furnace slag and cement can be used in construction of load bearing wall.

ARTICLE INFO

Article history:
Received 5 May 2017
Received in revised form 3 January 2018
Accepted 23 January 2018

Keywords:
Compressed stabilized earth blocks (CSEBs)
Lithomargic clay
Lateritic soil
Granulated blast furnace slag (GBFS)
Cement
Stabilization

ABSTRACT

This study involves the investigation on utilization of granulated blast furnace slag (GBFS) and cement in the manufacture of compressed stabilized earth blocks (CSEB). Two locally available soils from Dakshina Kannada district, Karnataka, India were tested for their index and strength properties with replacement of granulated blast furnace slag (GBFS). An optimum percentage of replacement of GBFS was established and then varying percentages of cement was added for the production of compressed stabilized earth blocks (CSEBs). This stabilized soil was used for the manufacture of blocks of size 305 mm × 143 mm × 105 mm. All the blocks were cast to a target density, followed by the curing for 28 days. The blocks were subjected to compression test and water absorption test according to Indian Standard (IS) specifications. The test results showed that the CSEBs prepared with GBFS and cement can be utilized in masonry for load bearing wall construction. A small percentage of cement is sufficient for manufacturing the CSEBs when optimum GBFS content is replaced with that of soil, thereby reducing the energy consumption.

1. Introduction

Shelter is one of the basic needs of humans, especially for the lower income groups. Lack of resources and ever-increasing cost of materials have motivated engineers to find new alternatives to conventional building materials. Cost reduction in the housing sector especially with the lower income sections can be achieved by innovating new construction materials, which can be locally made, and with ease of construction. Among sustainable construction techniques, stabilized earth seems to be noteworthy. From the past 50 years, compressed stabilized earth blocks (CSEBs) are used for load bearing masonry construction in various countries. CSEBs are manufactured by compressing a wet soil mixture and a suitable stabilizer in a manually operated press to get a high-density block. For meeting the requirements for building codes, cement is generally used as a stabilizer as it is easily available and gives the necessary strength and durability properties to these blocks. The term block is used to differentiate from brick, which is usually fired. The main advantage of these blocks is that they can be locally made with simple construction methods with semi-skilled labour, not requiring a very specialized equipment, offering high thermal and acoustic insulation. These CSEBs are 2.5 times larger than conventional fired clay bricks and therefore construction is faster with lesser joints. Moreover, they consume lesser energy when compared to that of fired clay bricks or concrete masonry, thus making them cheap and affordable [1,2]. Regardless of these advantages, the use of CSEBs are restricted due to its below par performance in durability, tensile strength, impact and abrasion resistance when compared to conventional fired clay bricks. Moreover, the lack of guidelines for both manufacturers and builders converts it into low acceptance of these CSEBs in housing sector.

* Corresponding author.
E-mail addresses: darshancsekhar@gmail.com (D. C. Sekhar), snayak65@yahoo.com (S. Nayak).

https://doi.org/10.1016/j.conbuildmat.2018.01.125
0950-0618/

Utilization of industrial wastes in construction activities provide social, economic and environmental benefits. Granulated blast furnace slag (GBFS) is a byproduct acquired from the manufacture of iron in the furnace and is formed by the combination of iron ore with limestone flux. When this molten slag is quenched by water for rapid cooling, it prevents the crystallization leading to granular glassy aggregates usually of sand size particles. The physical and chemical properties of these slags depends on the method of production. These slags mainly consist of calcium, magnesium, manganese and aluminum silicates in different combinations. This slag has latent hydraulic properties due to high CaO content about 35–45% forming cementitious pozzolanic reaction products upon exposure with water. The only drawback is that the reaction rate is slow when compared to that of cement. When these slags are ground to a finer size, they can be utilized in the production of Portland slag cement. With the increase in the production capacities of these industries and with the increase in cost for grinding of these slags, for their utilization as slag cement, there is large stacking of these slags in the vicinity of these iron industries which consumes large areas. Hence, there is a need to increase the rate of disposal of these slags [3,4]. Because of these slags comprising mainly of sand size particles and having pozzolanic properties, they can be effectively utilized in the manufacture of CSEBs.

2. Previous studies and scope of the work

Compressed stabilized earth blocks (CESBs) are eco-friendly, having sufficient strength and durability properties with good insulation properties. The use of CSEBs promotes healthier living for lower income section of the society [5]. Cement stabilized soil blocks are ideal for low-rise residential construction, where minimum strength requirements are often dictated by handling rather than load carrying requirements. For this purpose a minimum unconfined characteristic saturated compressive strength of 1.0 MPa may be considered satisfactory [6]. Lateritic soils are found to be suitable as materials for compressed earth blocks (CEB) with good compressive and durability strength, which qualifies them as sustainable and cost-effective materials for low-cost housing development [7]. Density significantly affects the strength and durability properties of CSEBs [8]. Strength and durability of cement stabilized blocks is dependent on soil gradation and their plasticity characteristics. In addition, by their clay type and the amount of clay content [9].

CSEBs stabilized with cement is found to have good strength and durability properties when compared with that of lime stabilized CSEBs [10]. Significant improvement in strength can be achieved with little addition of cement and the strength gain increases with cement content and curing time [11]. Cement content >4% provides good strength and durability properties for CSEBs. The strength at 10% cement is almost double that of 4% cement [12]. The amount of cement to be used will depend on the composition of the soil. Sandy soils require 5–9% cement by volume. Silty soils need 8–12%, and clayey soils require 12–15% cement as stabilizer. Cement content more than 15% is uneconomical [13]. Higher cement content leads to better stabilization and hence higher wet strength to dry strength ratio. Higher cement dosages lead to more cementitious material available to establish water insoluble bonds with the silt and sand particles and hence leads to higher strength for CSRE [14]. It is the binding of sand particles, and the self-hydration products of the cement that contribute to the early strength of the blocks [15]. The acceleration of pozzolanic reactions due to addition of cement is less when compared to lime is due to the lower alkaline environment provided by cement. Cement in the activated PC–GGBS–soil mixture improves the strength by largely covering the clay particles with an insoluble and impermeable coating [16].

In the sand–clay matrix, since the sand is coarser and the clay finer, the clay particles will fill the void of the sand particles resulting in an increase in density and reduction of void spaces. The CSH gel formed also fill the void spaces and result more impermeable structure. Thereby resulting in an effective binding of particles with significant improvement in strength [17]. The improvement in dry compressive strength would be due to the increasing amount of C_2S and C_3S brought about by increasing cement content [18]. Hydration reactions take place when cement is blended with soil in presence of water. The C_3S and C_2S present in cement react with water forming complex calcium silicate hydrates. This C-S-H gel formed will fill the void spaces and binds the soil particles together imparting rigidity to the mixture. When cement is blended with GGBS and soil in the presence of water, the amount of gel formations increases that bind the particles more efficiently [19].

As clay content increases, strength of blocks are reduced. Reduction in compressive strength with immersion in water for 48 h is due to the development of pore water pressures and the liquefaction of unstabilized clay minerals in the block matrix [20]. The reduction of compressive strength upon saturation goes up to 60% for cement-stabilized samples. The reduction in strength was lower with higher cement content. Higher increase in cement content does not give any positive effect in the wet samples [21]. Strength reduction due to saturation is due to the softening of binders by water and development of pore water pressures. For an unstabilized soil block, the compressive strength when immersed in water is zero. The wet compressive strength is nearly half of the dry compressive strength for stabilized blocks [16]. Water absorption capacity reduces with time for stabilized blocks. The decrease in water absorption of stabilized blocks is due to the interactions of cement with the alumino-silicates in the soil to form cementitious products that consequently bind the soil particles together and harden with time, thus reducing the interconnectivity of the voids [22]. Finally, it was observed that the studies regarding the use of granulated blast furnace slag (GBFS) in manufacture of CSEBs were limited and hence motivated the authors to take up the present study. Hence, this study is mainly focused on the utilization of GBFS and cement in manufacture of CSEBs.

3. Experimental investigations

3.1. Materials and methodology

3.1.1 Soils

Two different types of soils are used in the current study, as these were the locally available soils. One is lateritic soil which is reddish/brownish in colour having hard and porous nature, while the other being lithomargic clay, which is whitish, pinkish/yellowish in colour, mainly consisting of silt/sand particles. Lithomargic clay is found below hard lateritic soil at depths varying from 2 to 5 m all throughout the Konkan belt of southern India. The properties of these soils obtained from laboratory testing are provided in Table 1 and their particle distribution curves in Fig. 1. All the tests were conducted according to SP 36 (Part 1) – 1987 of the Indian Standard (IS) specifications.

3.1.2 Granulated blast furnace slag (GBFS)

These slags are mainly consists of sand size particles and their physical and chemical properties are given in Table 2.

3.1.3 Ordinary Portland cement (OPC)

The cement used was of 53 grade cement.