

High Carbon Fly ash and Soil in Shelled Compressed Earth Masonry Units

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Abstract: High carbon fly ash is a waste material, which has not been adequately utilised. This research explored the possibility of utilising the material in conjunction with soil for wall construction of low cost housing. An optimum quantity of high carbon fly ash was added to the shell and a substantial quantity to the core of a shelled compressed earth block. Appropriate laboratory tests were conducted to investigate the behaviour and properties of the masonry unit. Results of Tests showed adequate compressive strength of 4.2 N/mm² and a stable condition of masonry unit upon exposure to moisture. This is a part of the expanded construction opportunities of an on-going research in compressed earth technology.

Keywords: Compressed Earth, High-carbon Fly-ash, Shelled Compressed Earth Block, Durability, Sustainability.

I. INTRODUCTION

Ash from thermal power stations which are classified as Coal Combustion Residues (CCRs) or Coal Combustion Products (CCP), and include Fly ash (FA), bottom ash (BA), boiler slag (BS), fluidised bed combustion ash (FBCA), flue gas desulfurization (FGD); have been a subject of study in major producer countries for decades [1]. Research data showed an in-balance between production and utilization of CCP [2], [3], [4], [5]; with utilisation ranging between 27 per cent in India in 2005 and 97 per cent in Japan in 2006 [6], [7].

The Coal combustion products (CCP) are not hazardous wastes [2]. This scientific evidence has widened the scope of safe applications of the product. The high costs of management and treatment associated with disposal of coal combustion products, has prompted significant modern research to take interest in finding beneficial uses for these by-products particularly in the construction field [8]. Only 40 percent are utilized as construction material in cement production, road construction, structural fills, concrete products, and other applications [2]. This paper is aimed at increased utilisation of coal combustion products - high carbon ash in unbaked earth block production using the shelled compressed earth concept.

The Shelled Compressed Earth Block is of an inner core of 'earth' with less cement content and an outer shell of the same earth composition but with higher ratio of cement for adequate durability, compressed into a single piece [9]. It is a concept that enhances the compressed earth masonry unit by concentrating the cement content on the outer layer of the block for ultimate weather resistance and overall strength at lower cost. The shell so formed by the strengthening the outer layer constitutes of about 35 per cent of the overall volume of block and the inner core of less cement content is about 65 per cent of the volume of block.

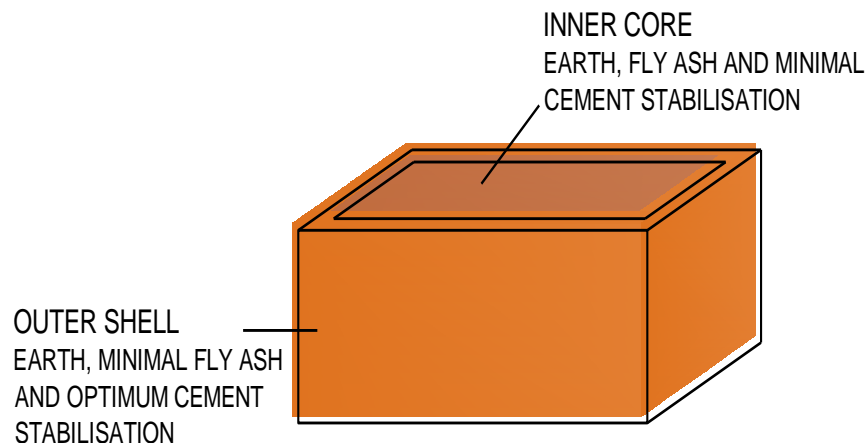


Fig. 1: Shelled Compressed Earth Block

The following experimental research utilised high carbon fly ash in different proportion for the shell and core of a shelled compressed earth block with a viable result in the context of a sustainable building construction.

II. MATERIALS AND METHODS

A. Material:

Soil samples with suitable characteristics for compressed earth block were chosen for this experiment [10] specified appropriate range of soil composition as 8 to 30 per cent of Clay, and 10 to 25 per cent of silt. The soil used for this experiment was the Aviele laterite soil of combined Clay and Silt content of 30 per cent; and Plasticity index (PI) of 15 [9]. The fly ash sample was from STI High Carbon Ash from Processing Ash LLP, West Burton Power Station, Retford, Northinghamshire, UK; taken on 9th May, 2011.

B. Mix Composition:

Inner Core: Mixes of soil and high carbon fly ash added at different proportion were adopted in a preliminary test aimed to understand the effect of fly ash in the composite. A cement content of 2 per cent was made common to all the mixes but fly ash content was varied from 20 to 50 per cent. This experiment was intended to establish an optimum content of Fly Ash which allows substantial utilisation of fly ash while maintaining a compressive strength of 2 N/mm² or higher for a simple single story building. A mix for the inner core of the shelled block was deduced as 52 per cent of 'earth' with 25 per cent high carbon ash, 2 per cent of cement and 21 per cent Water. Further tests were conducted with the fly ash content kept at 25 per cent, cement content was varied from 0 to 10 per cent.

Shell: The fly ash content was reduced considerably in the mix composition of the shell which is the protective component of the masonry unit. Fly ash content of the shell was kept at 10 per cent due to its affinity to water. The same soil was used for the shell and the inner core of the shelled compressed earth block to reduce differential expansion.

C. Sample and specimen preparation:

Materials were measured and mixed with the Soil sample mixer. Tests samples were produced with a compressed earth block making kit which produced blocks of 150 x 100 x 75mm, and an applied pressure of about 3.5 N/mm². Pressure was maintained with a relieve valve of limited accuracy. The Air dry method of conditioning was used in the preparation of the samples. Block samples were cured for 7 days and air dried to 14 day. It was oven dried to constant mass at 75⁰C.

D. Testing:

Compressive strength tests of specimen blocks with different percentages of high carbon fly ash content (20 to 50%) and cement content (0 to 10 %) were carried out in accordance with BS EN 772-1:2011. Furthermore, the behaviour of samples in contact with water was assessed in an initial rate of water absorption tests conducted in accordance with BS EN 772-11:2011. A measured area of a face of block was immersed in water to a depth of 5 mm +/-1 mm for a timed interval, removed, wiped and weighed.

III. RESULTS AND DISCUSSIONS

A. Compressive Strength:

The preliminary test was aimed at understanding the behaviour of soil with high carbon fly ash. The result of adding high carbon fly ash at different proportions while keeping the cement content as 2 per cent, is shown in Figure 2.

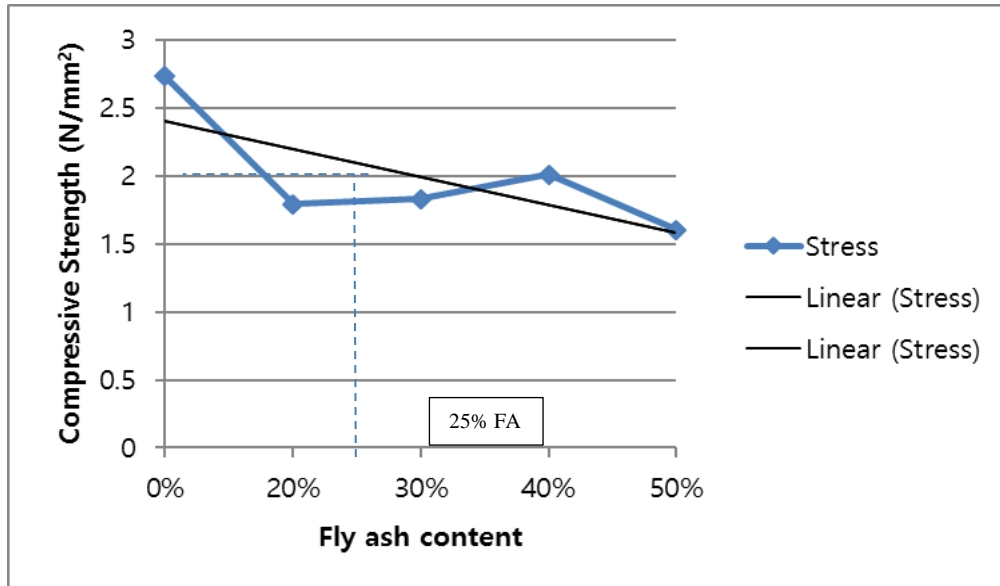


Fig. 2 - Compressive strength with increase of high carbon fly ash content

The compressive strength of sample cube reduced as the high carbon fly ash (HCFA) content increased. The deviation of readings from a linear configuration in figure 2 is due to small differences in compaction pressure resulting from a wide tolerance in the relieve-valve of the hydraulic jack used. A 25 per cent of FA content gave a compressive strength of 2.2 N/mm²; a compressive strength which can adequately sustain the load of a simple masonry structure [11], [12]. It was hence adopted as the maximum HCFA content appropriate for the model. The 25 per cent of HCFA was kept constant while varying the cement content from 0 to 10 per cent for higher compressive strength and higher load bearing capability. The result is shown in Figure 3.

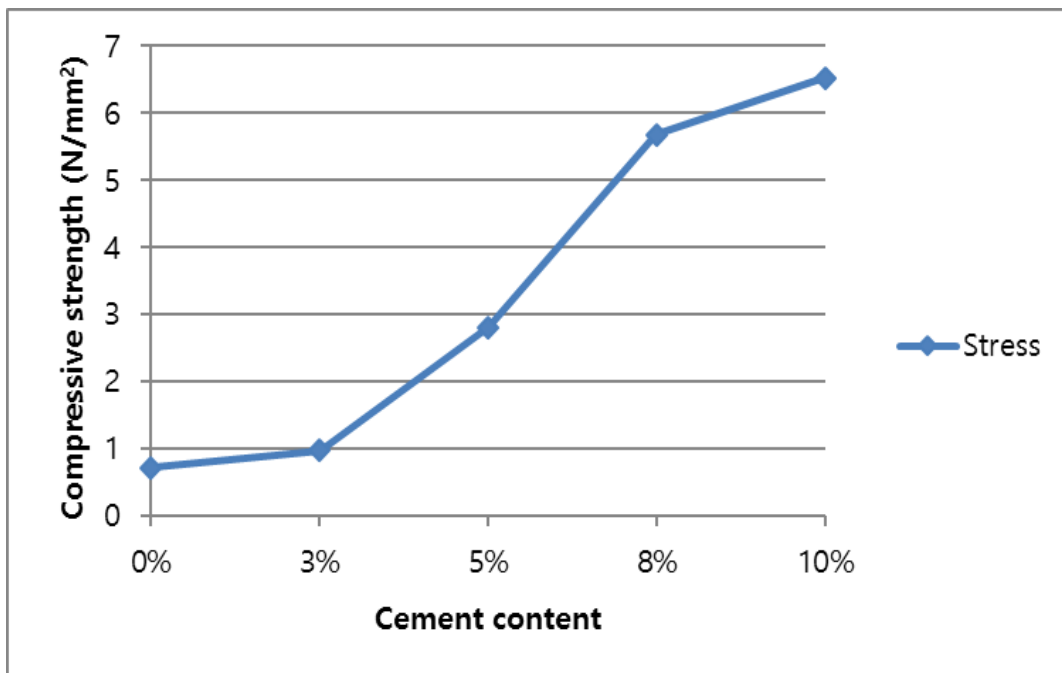


Fig. 3 - Compressive strength of specimen of 25 per cent HCFA with different cement content

The compressive strength increased with an increase in cement content.

B. The initial rate of water absorption by capillary action:

The result of the initial rate of water absorption by capillary action test was conducted to assess the behaviour of the specimens to water, with varying content of HCFA is as shown in Figure 4.

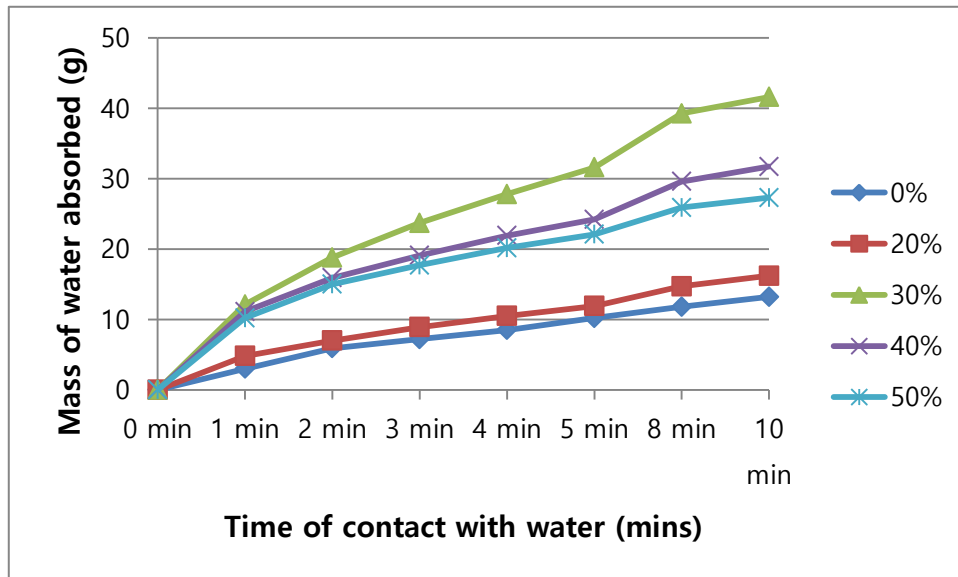


Fig. 4 - Initial rate of water absorption of specimens with varying percentages of HCFA content

The excessive absorption of 30 per cent HCFA and inconsistencies in rate of absorption of 40 and 50 per cent is attributable to differences in compaction due to the wide range of tolerance of the hydraulic pressure relieve valve used. The 25 per cent of HCFA which gave optimum compressive strength was also found to have an average water absorption coefficient of $0.0108 \text{ kg}/(\text{m}^2 \times \text{min})$.

C. A Model of shelled compressed earth masonry unit:

Following the above test results a model of composite compressed earth block was produced of a core of 25 per cent fly ash and 2 per cent cement stabilisation; and an outer shell of 10 per cent fly ash and 10 per cent cement stabilisation with satisfactory water absorption properties. The compressive strength of the model was $4.2 \text{ N}/\text{mm}^2$ and a low coefficient of water absorption of $0.0000026 \text{ kg}/(\text{m}^2 \times \text{min})$. Figures 5 and 6 show the surface texture and pattern of deformation, respectively, after the compressive strength test.



Fig. 5 - Shelled compressed earth block of High carbon fly ash, soil and cement

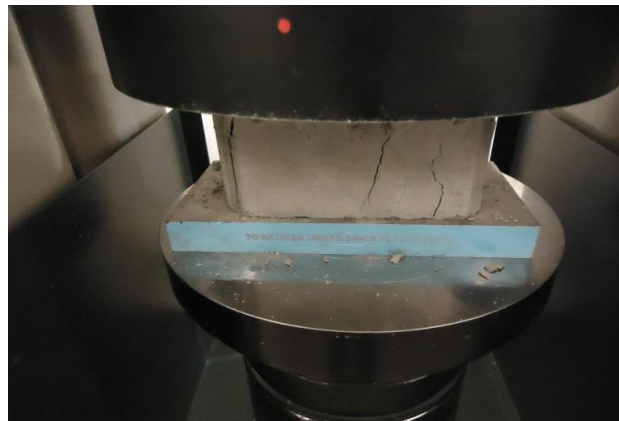


Fig. 6 - Deformation pattern of shelled compressed earth block [13]

IV. CONCLUSION

Specimens of compressed earth blocks made by the addition of 25 per cent of high carbon fly ash (HCFA) with 2 per cent cement content gave a satisfactory compressive strength of 2.2 N/mm^2 . Thus it was adopted as material for the inner core of Shelled Compressed Earth Block. A low content of 10 per cent HCFA was added to the protective shell, to minimise water absorption, but a higher cement content of 10 per cent for increased strength. The model gave an impressive compressive strength of 4.2 N/mm^2 and coefficient of water absorption of $0.0000026 \text{ kg}/(\text{m}^2 \times \text{min})$.

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