A Study On The Short Term Compressive Strength Of Compressed Stabilised Earth Block With Waste Glass Powder As Part Replacement For Cement

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Abstract: This paper investigates the compressive strength of compressed stabilized earth block (CSEB) by partially replacing the cement (stabilizer) in the block with Waste Glass Powder (WGP). The soil sample was tested for moisture content and as well consistency limits which showed satisfactory characteristics. The two types of waste glass powders considered were those passing through sieve 150 µm with replacement levels varied at 0%, 20%, 40%, 60% and those passing through sieve 75µm with replacement levels varied at 0%, 5%, 10%, 15%, 20%, 25% and 30% respectively. 65 blocks were made with size 225 x 225 x 112.5 mm and cured for 7, 14 and 28 days. Irrespective of the WGP particle sizes used in this study, it was observed for the percentages of cement replacements used (up to 60%) that the compressive strengths recorded were higher than 3N/mm^2, the minimum recommended strength for CSEB at 28 days. As no optimum was observed for the addition of WGP to CSEB in this study (the higher the content of WGP in CSEB, the lower the strength), the result suggests that 20% replacement of cement with WGP whether at 150 µm or 75 µm could be used. The compressive strengths recorded at 28 days at this level were as high as 5.14N/mm^2 and there was no significant difference in strength performance when compared with the control mix (with 0% WGP) at early stages.

Index Terms: Compressed Stabilized Earth Block, waste glass powder, Compressive Strength, Pozzolanic, Cement.

1 INTRODUCTION

The percentage of glass waste in solid waste components in Nigeria is 2%, despite the low percentage, it is still causing nuisance to the environment because little or no provision is made for its reuse. It is well known that the growth in the world's population is physically taxing the world of its renewable and non-renewable resources with associated environmental impacts. The UN [1] reports that 5 million houses are needed annually to curb the current global housing backlog by 2050. The world is thus facing the dilemma of housing its ever growing population whilst preserving the environment for the needs of the future generation. Conventional construction methods use conventional construction materials (concrete, aluminium, steel and timber) which have high energy inputs and cost for the production of these materials and environmental impacts generated in the construction processes, including raw material use, waste generation, energy consumption and its associated air emissions.

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If the large amount of waste materials generated were used instead of man-made materials in the construction industry there would be three benefits: conserving natural resources, disposing of waste materials (which are often unsightly) and freeing up valuable land for other uses [2]. In line with sustainable development and the urgent need to provide shelter for the world's growing population, there is a need for alternative environmental benign and low cost technologies in construction that lessen demands on renewable resources. One such technology is the compressed stabilized earth block (CSEB) which is used alternative to traditional brick and mortar construction. The compressed earth block is the modern descendent of the moulded earth block, more commonly known as the adobe block. Cement is normally used in stabilising CSEB, however, due to high energy consumption with associated air emission in cement (which is the widely used stabilizer) production, it is imperative that alternatives to cement which are cheaper, environment friendly that should also improve the properties of the compressed earth block are produced. One material with such potential is waste glass. Glass is used in many forms in day-to-day life. Since glass is non-biodegradable, landfills do not provide an environmental friendly solution. Hence, there is strong need to utilize waste glasses. Many works have been done to explore the benefits of using waste glass in making and enhancing the properties of materials in the construction industry. Oliveira et al [3] examined the possibility of using finely ground waste glass of the three most common coloured glass bottles used in Portugal as partial cement replacement in mortar and concrete. The pozzolanic activity of ground glass was optimized as function of different particle size. Their results confirmed the pozzolanic activity of the ground waste glass of different colours collected in central region of Portugal. Shayan et al [4] in their laboratory work indicated satisfactory performance of glass powder (GLP) in concrete as a pozzolanic material. The powder used was manufactured from mixed colour waste packaging glass comprising soda-lime glass. In order to investigate the performance of GLP in concrete under field conditions, a field trial was conducted using a 40 MPa concrete mixture, incorporating various proportions of GLP (0%, 20%, and 30%) as cement replacement. Results showed that strength gain was slower in GLP-bearing concrete up to 28 days, but at the age of 404 days all the mixtures exceeded the 40 MPa target and achieved about 55MPa strength. The results demonstrated that GLP can be incorporated into 40MPa concrete at dosage rates of 20–30% to replace cement without harmful effects. Oyekan [5], investigated the strength characteristics of sandcrete blocks in which the sand is replaced partially with crushed waste glass (CWG) in the first test. In the second test the cement is partially replaced with crushed waste glass in the sandcrete block production. The results showed that the compressive strength values of sandcrete blocks increased with age for both mix proportions. It is believed that with this progress made in the application of waste glass in concrete production, similar results could be obtained when waste glass powder (WGP) is used as part of the stabilizing agent in CSEB and hence this study. The study was aimed at checking the performance i.e. compressive strength of CSEB by partially replacing the cement in the block with waste glass powder (WGP).

2 MATERIALS AND METHODS

The materials used in this study were soil, cement, waste glass powder (WGP) and water. Explanations on these materials follow.

2.1.1 Soil

The soil used for this research was collected along Iworoko-Ekiti road in Ifaki-Ekiti. The soil was screened using 12mm diameter mesh to remove large particles (see Fig. 1 for picture showing screening being carried out manually).

Fig. 1 *Screening of Soil through 12mm Wire Mesh*

The tests carried out prior to block production were; grain-size analysis test (see Fig. 2 for the grain size distribution of the soil), moisture content, field compaction test, compaction test, Atterberg Limit tests.

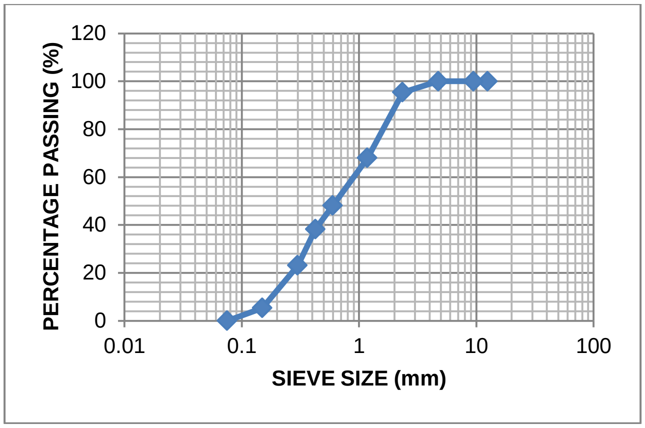

Fig. 2 *Gradation curve of the soil used in this study*

The Sample comprises of 0.008% gravel, 55.2% sand, 44.7% silt/clay which shows that the sample is very clayey sand and it is well graded.

2.1.2 Cement

The cement used for all the mixes was grade 42.5 Ordinary Portland Cement (OPC) produced by Dangote Cement Company complying with the requirements of BS 12 [6].

2.1.3 Water

The water used was not really potable, but fresh water, free from all forms of organic matters and obtained from nearby well in Ekiti State University.

2.1.4 Waste Glass Powder

The waste glass was collected at Dimako aluminium off Iyin-Ekiti road, Bashiri, Ado Ekiti, Ekiti State, Nigeria and washed before it was crushed into smaller pieces of size 5 mm manually using mortar and pestle. This was latter milled wet using ball milling machine, after which it was sieved into particle sizes of diameters less than 150µm and less than 75µm respectively. These were later air dried under the sun and used as part replacement for cement in CSEB in varied proportion. Fig. 3 shows the WGP being air dried under the sun.

Fig. 3 *Air Drying of Wet Milled Waste Glass under the Sun*

2.2 Production of the CSEB

The soil extraction site was very close to the production site along Iworoko-Ekiti road in Ifaki-Ekiti at Jaco-De-Queency Nigeria Limited, a CSEB production company. The soil extraction was done manually, using shovels and diggers.

The extracted soil was subsequently transported to the location of production machine, after which pulverisation and screening were done respectively. Batching was done by weight using ratio 1:12 for cement and soil respectively. For the control mixes, cement was not replaced at all, while for the CSEB with WGP, two sizes were used i.e. WGP passing through sieve size 150 µm but retained on 75 µm (referred to as 150 µm WGP), and WGP passing through sieve size 75 µm (referred to as 75 µm WGP). For mix type 1 in which the 150 µm WGP was used, cement was ambitiously replaced in a step wise manner of 20%, 40 % and 60%. However while moulding the CSEB with 60% replacement of cement with 150 µm WGP, cracks were noticed and this necessitated adjustment in mix type 2 in which 75 µm WGP was used. Thus for mix type 2, the percentage replacement of cement with 75 µm WGP was reduced to 5% step in producing the CSEB. While 0% replacement for cement again served as the control mix, varying percentages of 5%, 10%, 15%, 20%, 25% and 30% for cement replacement with 75 µm WGP were used. Calculation of precise quantity of water needed to reach the optimum moisture content for compaction became a challenge as this depended on the natural moisture content of the soil and this study was carried out during the wet season of the year (June- Sept). Thus field compaction test, having taken cognisance of the natural moisture content of the soil was carried in order to ascertain the required water for mixing and compacting the CSEB. These materials were mixed in cement/soil ratio of 1:12 with small quantity of water (depending on the natural moisture content of the soil). The soil proportion (i.e. 12) was measured in a wheelbarrow and emptied into Hydraform mixer pan. Cement proportion (or cement + WGP as the case maybe) was also added to the soil in the Hydraform mixer pan and dry mixed for 5 minutes till the materials were found well mixed. The required water was subsequently added slowly while mixing continued until the materials were well mixed. This mix was poured into the machine compression chamber and compressed to produce size 225 x 225 x 112.5 mm CSEB. Fig. 4 shows the CSEB Production machine.

Fig. 4 *Production of CSEB*

A mix of 10 litres was used to produce a block of 225 x 225 x 112.5mm. After the soil was compressed to block, it was ejected from the mould and carefully placed where it will be cured. Curing was done by wetting and then covered with plastic sheet. The wetting was done twice daily (morning and evening).

2.3 Compressive Strength Test

The blocks were tested for compressive strength at ages 7, 14 and 28 days curing age. Because of the shape of the blocks, each block is supported at the base by hard plate to ensure uniform distribution of imposed load. Fig. 5 shows the compressive strength testing machine with a CSEB placed on the machine for testing.

Fig. 4 *Crushing of CSEB on Compressive Strength Testing Machine*

3 RESULT AND DISCUSSION

3.1 Soil Tests

The mean moisture content for the soil used in this investigation was determined as 28.1%. The liquid limit, plastic limit and plasticity index of the soil were determined as 43%, 27% and 15.98 respectively. These results show that the soil is inorganic clay of medium plasticity. With the above result the soil has medium plasticity and thus it is good for the moulding of compressed stabilized earth block

3.2 Compressive Strength Test

The results of the compressive strength developed in the hydration period of 7, 14 and 28 days for all the percentage replacement are presented in succeeding sections.

3.2.1 Compressive Strength Test Results for CSEB with WGP of Particle Sizes less than 150 µm

The results of the compressive strength test for CSEB with WGP of particle sizes less than 150 µm but retained on sieve size 75 µm with curing ages of 7, 14 and 28 days are presented in Table 1 and Fig. 2.

TABLE 1

COMPRESSIVE STRENGTH OF CSEB BLOCKS WITH WGP OF LESS THAN 150 µM PARTICLE SIZE (N/MM^2)

Curing Age (Days)	Percentage Replacement of Cement with WGP (%)			
	0	20	40	60
7	2.84	2.71	2.11	1.71
14	4.27	3.42	2.82	2.13
28	6.20	5.14	3.85	3.94

The results showed that the higher the content of WGP in the mix, the lower the strength although there were strength improvements as the curing age increased. The results showed overall that the strengths recorded for all the mixes at 28 days were above 3 N/mm^2 recommended for stabilised earth blocks at 28 days [7]. The trend of strength development suggests a tendency for further strength gain as the curing age increases. The results also indicate that the use of 20% replacement of cement with WGP of particle sizes less than 150 µm but greater than 75 µm in CSEB can be adopted since at this level the developed strength recorded at 28 days was about 71.33% more than the minimum recommended strength for CSEB. More so, the strength at the early stages i.e. 7 days for 20% replacement of cement with WGP was not significantly different from the strength of the control mix. Higher percentages of cement replacement with WGP can only be used with caution as the strengths at early stages (7 and 14 days) were very low which could pose handling problems.

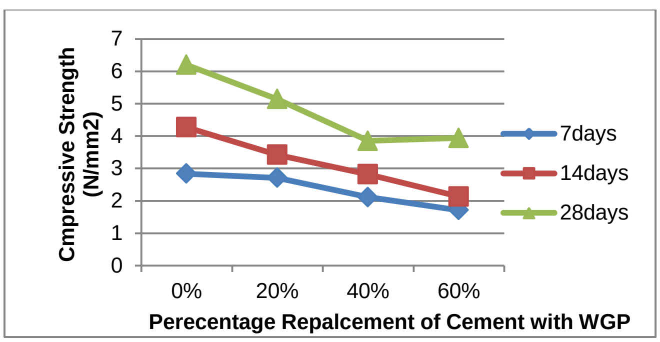

Fig. 5 *Compressive Strength of CSEB Blocks with WGP of Less than 150 µm Particle Size*

3.2.2 Compressive Strength Test Results for CSEB with WGP of Particle Sizes less than 75 µm

The results of the compressive strength test for CSEB with WGP of particle sizes less than 75 µm with curing ages 7, 14 and 28 days for percentage replacement of cement at 0, 5, 10, 15, 20 25 and 30% are presented in Table 2 and Fig. 6.

TABLE 2

COMPRESSIVE STRENGTH OF CSEB BLOCKS WITH WGP OF LESS THAN 75 µM PARTICLE SIZE (N/MM^2)

Curing Age (Days)	Percentage Replacement of Cement with WGP (%)						
	0	5	10	15	20	25	30
7	2.84	2.32	2.58	2.30	2.43	1.89	2.36
14	4.27	3.60	2.44	3.06	3.23	3.09	2.93
28	6.20	5.27	4.19	4.34	4.72	4.51	3.94

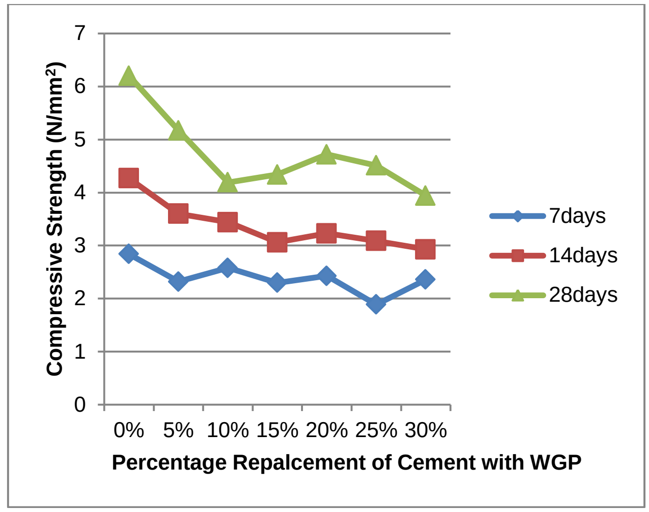

Fig. 6 *Compressive Strength of CSEB Blocks with WGP of Less than 75 µm Particle Size*

Table 2 and Fig. 6 both show that 5%,10%,15%,20%,25% and 30% cement replaced with WGP of particle sizes less than 75 µm in CSEB from 7 – 28 days had reduced strength development compared to the control mix. The trend of strength development here is similar to the trend recorded for the WGP particle size of 150 µm. Although the control mix indicated the best strength performance, all the CSEB with WGP had strengths of more than 3 N/mm^2 at 28 days, the recommended for the use of CSEB in the industry. This result showed that 20% replacement of cement with WGP with particle size less than 75 µm in CSEB should be adopted for the obvious reasons highlighted for CSEB with WGP of particle size 150 µm. Overall, the results suggest that there is no clear difference between the use of either 150 µm WGP and 75 µm WGP in CSEB. Based on this observation, it is likely that WGP is not really active in the CSEB and probably was just playing the role of filler. If it had been active, 75 µm WGP with higher surface area available for reaction should have enhanced the strength performance of the CSEB. Extending this research to microstructure studies should help in ascertaining the degree of activeness of the WGP.

4 CONCLUSION

From the results of this study, WGP added to compressed stabilized earth block reduces the strength. Although, the strength for CSEB without waste glass had the highest strength, CSEB with WGP indicated strengths higher than 3 N/mm^2 recommended as minimum strength for CSEB at 28 days for the percentage of replacements used in this study, the highest of which was 60%. No optimum value was observed for WGP addition to the CSEB as replacement for cement, however, sufficient strengths good enough for handling at early stages of the CSEB whether at particle size of 150 µm or 75 µm were achieved at 20% replacement of cement with WGP in CSEB. It could be concluded that the role of WGP in CSEB is more of filler than a binder. Extending this research to microstructure studies should help in ascertaining the degree of activeness of the WGP in CSEB.

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