THE STABILIZATION OF COMPRESSED EARTH BLOCK USING FLY ASH

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ABSTRACT

The research described in this paper focused on the study of earth bricks made with fly ash known as compressed stabilized earth block (CSEB). This earth block was made by using 50% of laterite soil, 30% of fine aggregate, 20% of coarse aggregate and few percentages of fly ash as a stabiliser. The laterite soil, which was taken around Infrastructure, University of Kuala Lumpur was classified as well graded with about 73% of fine soil and 27% of course soil. Optimum moisture content and maximum dry density of the soil compaction test were 20% and 1.60 Mg/cm^3 respectively. The CSEB with 10% fly ash had the highest compressive strength which was 1.09 MPa after 28-day curing. Durability tests improved the compressive strength of the earth block with 10% of fly ash after 21 days of freezing and drying, 21 days of drying and 24 hours of heating in the oven. The lowest water absorption percentage was 12.17%. Abrasive test showed that the earth blocks with 10% of fly ash gave the lowest amount of particle abraded away. Finally, conclusions were drawn and further works were proposed.

Keywords:

CSEB, laterite soil, fly ash, compressive strength, water absorption, freezing, drying, heating, abrasive.

INTRODUCTION

With the increase in population and high demand for dwelling houses the price of such houses has increased and is increasing tremendously in recent years. This is compounded by the fact that the available land for this development is becoming scarce, especially in the urban and sub-urban areas. Many people, especially the lower and middle income groups can no longer afford to buy them. One of the factors which contribute to the problem is the high cost of building materials which at the present time use the conventional materials and method of construction.

One of the ways to alleviate the problem is to use cheap building materials available locally. This can be done either by using re-cycled or sustainable raw materials for houses which are comparable to the conventional materials made from cement, sand and aggregates to give an acceptable level of quality and comfort.

This paper reported an attempt on the possibility of using building blocks made from earth stabilised with fly ash known as compressed stabilized earth block or CSEB. Laterite soil is easily available in Malaysia while fly ash, which is a by-product in the manufacture of cement can be obtained from cement factories. The earth blocks would replace the conventional bricks normally used in building houses.

In this study laterite soil was chosen as one of the components for CSEB because it was readily available in Malaysia and it was cheap. This study is expected to have a significant impact on the building industry in terms of design, cost and level of comfort. It would also give a wider choice for designers and contractors on the availability of building materials in the market. This would result in cheaper house price which many people could afford to buy.

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The objectives of the study can be summarised as follows:

- To produce earth block comprised of laterite soil, coarse aggregate, fine aggregate and stabilizer (fly ash).
- To determine the compressive strength of CESB at different ratios of fly ash added to laterite soil, fine aggregate and coarse aggregate.
- To assess the water absorption and durability of the compressed stabilized earth blocks.

The study was limited to earth soil available locally and all tests were conducted in IUKL laboratory. The tests were divided into two parts, i.e. firstly the soils were subjected to engineering tests and finally to more specific tests which were strength and durability tests.

LITERATURE REVIEW

Laterite soil comprised of iron, aluminium oxides and other mineral. The laterite soil was easily identified by its colour which could come yellowish to reddish colour depending on the iron oxides concentration. Laterite usually found in subtropical area or tropical climate and the formation of laterite was through decomposition and weathering process. In order to enhance the Geotechnical properties of the CSEB in term of strength and durability, mechanical and chemical stabilization method should be applied Keller, (2011). The mechanical stabilization method was carried out by mixing and compressing the CSEB components in order to eliminate the void or gap between the CSEB components Makusa, (2012). This could increase the strength and durability of the CSEB. However, mechanical stabilization could not withstand water and due to that chemical stabilization was needed to provide water resistant properties as well as to improve the strength and durability. Fly ash was chosen as a chemical stabilizer in this study as it was able to improve strength, durability and water resistant properties.

Previous study described various results of compressive strength after 28 days of curing from different combinations of earth block with stabilizer as shown in Table 1. This research study was compared closely to a research study by Chimuanya (2014) that using lime and cement incorporated with various proportions of CSEB with its basic proportion of laterite soil, fine and coarse aggregate that showed outstanding results. This study could be said as a continuation of a research study by Chimuanya (2014) taken into account the best CSEB basic proportion but considered fly ash as a stabilizer. His study indicated that the best basic proportion of CSEB was the combination of 50% of laterite soil, 30% of fine aggregate and 20% of coarse aggregate. This proportion also was the best proportion to be incorporated with 10% of cements that given the maximum compressive strength after 28 days curing period as stated by Chimuanya, (2014). Thus, this research study focused on the same material and mix proportion of CSEB but considering different stabilizer which more economical and environmentally friendly in order to see its performance whether could give better outcomes or not. There were a lot of researches regarding earth block with fly ash, but yet the chemical composition of the earth element could vary due to weather processes on that particular sole location, as well as implementation of the method of testing and different chemical composition of fly ash which made this research study differed from other study involving earth block incorporated with fly ash. All of this could affect the results of testing for both compressive strength and durability testing. The findings of this study also were compared with other researchers. The comparison was done to see the performance of CSEB incorporated with fly ash and other stabilizers instead of comparing within fly ash categories in order to see it can perform better or about the same range of strength to other stabilizers.

Table 1: Compressive Strength Result From Previous Research of CSEB

Author/Year	Stabilizer	Test	Result (N/mm^2)
Chee Ming & Liang-pin (2010)	Cement at 5%, 8% and 10%.	Compressive Strength Test	1.2, 1.9 and 2.4
Raheem et al. (2010)	Cement at 5%, 10%, 15%, 20% and 25%	Compressive Strength Test	1.63, 2.60,2.78, 2.82 and 3.12
Raheem et al. (2010)	Lime at 5%, 10%, 15%, 20% and 25%	Compressive Strength Test	0.92,1.25, 1.15, 1.06, and 0.94
Chimuanya (2014)	Cement at 5%,10% and 15%	Compressive Strength Test	4.19, 6.00 and 8.55
Chimuanya (2014)	Lime at 5%,10% and 15%	Compressive Strength Test	1.03,1.34 and 2.34

For water absorption test, Akeem, Olugbenro & Kehinde (2012) reported their findings of laterite interlocking block incorporated with cement stabilizer at 5%, 10% and 15% were turned out to be 7.62%, 6.07% and 5.32% of water absorption respectively. While for the durability testing, the results from previous study were tabulated in Table 2.

Table 2: Durability Test Result From Previous Research

Author/Year	Earth Block & Stabilizer	Test	Result (N/mm^2) / %
Chimuanya (2014)	CSEB with cement 5%,10% and 15%	Durability Test: 21 days freezing & drying	4.87, 7.35 and 9.94
Chimuanya (2014)	CSEB with lime 5%,10% and 15%	Durability Test: 21 days freezing & drying	2.16, 2.23 and 2.72
Chimuanya (2014)	CSEB with cement 5%,10% and 15%	Durability Test: 21 days drying	4.61, 6.91 and 9.67
Chimuanya (2014)	CSEB with lime 5%,10% and 15%	Durability Test: 21 days drying	1.88, 2.04 and 2.17
Chimuanya (2014)	CSEB with cement 5%,10% and 15%	Durability Test: Abrasive Test	0.09, 0.06 and 0.02
Chimuanya (2014)	CSEB with lime 5%,10% and 15%	Durability Test: Abrasive Test	0.23, 0.20 and 0.17.

RESEARCH METHODLOGY

There were five major classes of experiment that were carried out in the laboratory as shown in Table 3. The selected soil was subjected to preliminary tests in order to determine the physical properties of the soil and an optimum amount of water needed for making the CSEB. Three major tests were done on CESB i.e. compressive strength test, water absorption test and durability test.

Table 3: List of Experiments on CSEB

Major Class Testing	Activities/Testing
Preliminary Test / Physical Properties Test (Classification of Soil)	1. Moisture Content 2. Plastic Limit 3. Liquid Limit 4. Hydrometer Analysis 5. Sieve Analysis
Compaction Test (Determining Optimum moisture content & the maximum dry density)	1. Compaction Test
Engineering Test	1. Compressive Strength
Water Absorption Test	1. Water Absorption Test
Durability Test	1. Freezing & Drying 2. Drying 3. Heat / Oven Dry 4. Abrasive

The composition of materials that involved in this research study in forming CSEB were laterite soil, fine and coarse aggregate, fly ash and water. Soil compaction test was one of the most important testing in order to determine the exact amount of water to be added to mix proportion of CSEB formation to ensure they achieve their optimum performance in engineering, water absorption and durability tests. The mix proportion of the main component for CSEB as well as stabilizer was shown in Table 4. This proportion was selected based on previous research studies done by Chimuanya, (2014) where his study was about the compressed of stabilized earth block using cement and lime that focusing on the best ratio of the CSEB main component as well as the best percentage of stabilizer that given the optimum performance of that particular CSEB. Due to that, the same basic proportion of earth block has been chosen due to its outstanding performance as stated by Chimuanya, (2014). The proportion of CSEB main materials was based on the total weight of all materials for that particular block formation. This was due to the amount of water to be added to the mix proportion was considering based on the total weight of the soil not the volume. The typical average weight of CSEB was 3.4 kg, which made of 50% of laterite soil, 30% of fine aggregate and 20% of coarse aggregate which equal to about 1.7 kg, 1.02 kg and 0.68 kg of laterite soil, fine aggregate and coarse aggregate respectively. As for the amount of water to be added to the mix would be based on a certain percentage of the total weight of total soil exist in the CSEB sample which will be discussed further in result and discussion section.

Table 4: Mix Proportion of CSEB Incorporated With Fly Ash

Sample	Mix Proportion (%) Laterite Soil : Fine Aggregate : Coarse Aggregate	Fly Ash (%)
C(i)F0	50:30:20	0
C(ii)F5		5
C(iii)F10		10
C(iv)F15		15

Fly ash was selected as stabilizer in order to see its optimum performance to compare with the previous study by Chimuanya, (2014), that using lime and cement as stabilizers to produce the maximum strength and highest durability of the block. Consequently, this research study incorporated various percentages of fly ash to be mixed with CSEB to study their performance on compressive strength, water absorption and durability. The main proportion of CSEB were dried for 24-48 hours under infra ray before it can be tested. The main materials together with stabilizer and water were mixed homogeneously altogether manually by using a couple of trowels. The mixture then was filled inside the mould with a size of 225mm x 113mm x 75mm that specially carpentered. The mixture was poured into three equal layers and each layer were compacted up to 25 times using a manual computer. The mixture inside the mould was then compressed up to 60 kN by using compressing machine. Once finished with the compression process, the mould was disassembled and CSEB samples were air dried for 24 hours before proceeding with the curing process. The curing process for 28 days was done by sprinkling water at the sample along the duration of the curing period. The blocks were covered with wet fabric in order to avoid water loss along the curing process which might affect the strength build up process within the CSEB. After curing, the engineering test, water absorption test and durability test were carried out. Table 5 demonstrates compressive strength, water absorption and durability test conducted on the blocks.

Table 5: Detail of Engineering and Durability Testing

Engineering Test		
Test	Duration (Days)	Description
Compressive Strength	7, 14, 28	The compressive strength of the sample was conducted at 7 days, 14 days and 28 days
Water Absorption	1	Tested after 28 days of curing. The sample was immersed in the water for 24 hours where the weight of the sample was taken before and after immersion to see the percentage of water absorption.
Durability Test		
Test	Duration	Description
Freezing and Drying	21	Tested after 28 days of curing. 7 days in refrigerator, 7 days normal air dry and 7 days in refrigerator. Tested for compressive strength.

Drying	21	Tested after 28 days of curing. Dried at room temperature before being tested for compressive strength
Heat	1	Tested after 28 days of curing. Samples were oven dried at 800℃ before being tested for compressive strength.
Abrasive	-	Tested after 28 days of curing. The surface of the block was stroked for 50 times back and forth by using metal comb.

RESULTS AND DISCUSSION

Preliminary and Compaction Test Results

From preliminary testing, the results of liquid limit, plastic limit, moisture content and plasticity indices were 39.0%, 30.0%, 28.0% and 9.0%.

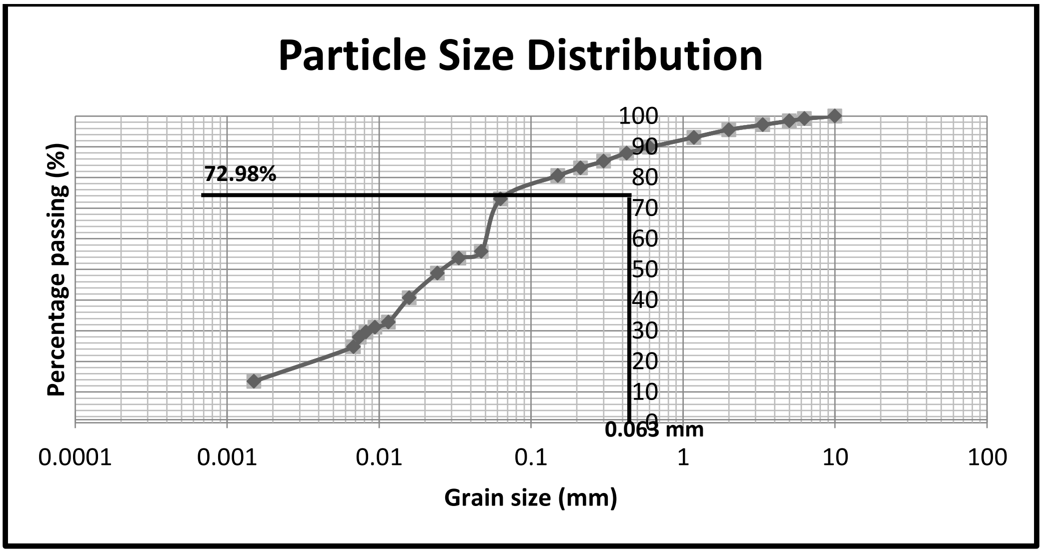

Figure 1: Particle Size Distribution

Based on the data obtained from sieve analysis and hydrometer analysis, the particle distribution curve was produced. The curve showed that it was a well graded curve that comprised of 72.98% of fine soil and 27.02% of coarse soil. According to BS 882 (1973), the soil can be classified as fine soil due to more than 35% of soil was finer than 0.06 mm which was 72.98% as can be seen in Figure 1. Major component of this fine particle was silty material since the percentage of silt was about 61%. Therefore, the soil was classified as silt with intermediate plasticity or can be said plasticity subdivisions as for the clays. The other way of classification was by referring to the plasticity chart where liquid limit and plasticity indices of the soil were considered. The soil was classified as MI which represents silt with an intermediate plasticity. Both ways represented the same outcome on soil classification. For the soil compaction test, the optimum moisture content is 20%, while the maximum dry density of the soil is 1.60Mg/cm^3. The amount of water added to the CSEB mix was 20% of the total weight of the soil during the mixing process.

Engineering Test Results

Engineering test involved of two types of testing, which are compressive strength and durability test. The mix proportion of CSEB with 50% of laterite soil, 30% fine aggregate, 20% aggregate was then mixed with 5%, 10% and 15% of fly ash.

Compressive Strength Test

For the compressive strength of the block at 7, 14 and 28 days, the results were shown in Table 6 and illustrated in Figure 2.

Table 6: Compressive Strength of CESB of Different Fly Ash %

Fly Ash Percentage (%)	Compressive Strength (MPa)		
	7 days	14 days	28 days
F0	0.40	0.84	0.97
F5	0.83	0.87	1.00
F10	0.85	0.92	1.09
F15	0.44	0.46	0.51

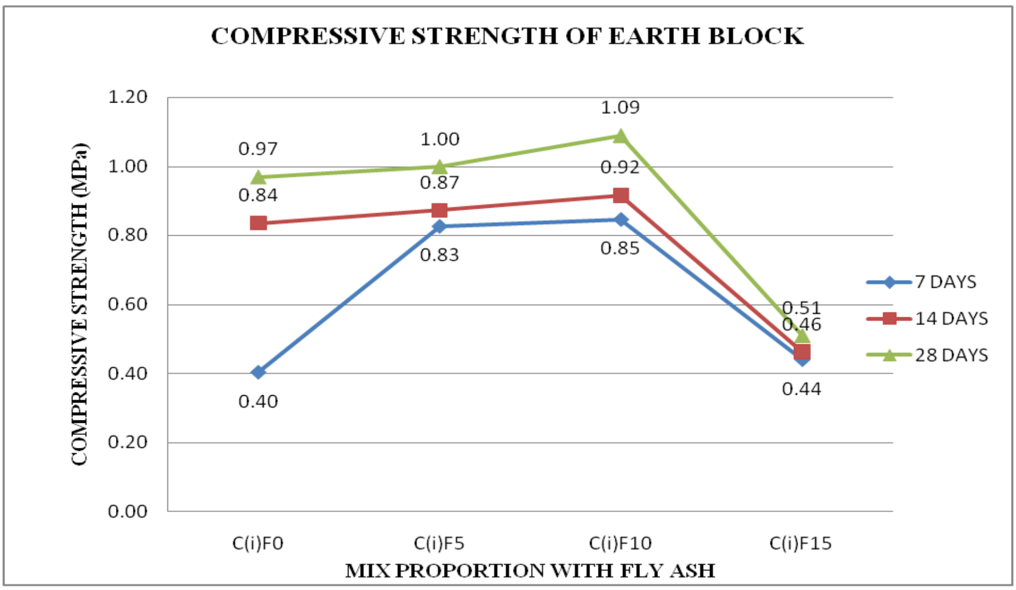

Figure 2: Compressive Strength Test of Earth Block With 0%, 5%, 10% And 15% Fly Ash

Table 6 and Figure 2 above illustrated the change in strength of CESB at different ratios of fly ash. The highest compressive strength obtained was 1.09 MPa with fly ash of 10%, and after 28 days of curing. In comparison with the previous study from Chimuanya (2014) showed that when 10 % of cement and lime incorporated with CSEB has given the compressive strength of 6.00 N/mm^2 and 1.37 N/mm^2. Thus, the highest compressive strength from this study still lower compared to CSEB incorporated with cement and lime stabilizer. In addition, the results did not achieve the minimum requirement based on MS72 for earth brick which supposed to be 5.2 MPa.

Water Absorption Test

For the water absorption test, the finding was demonstrated in Figure 3 below.

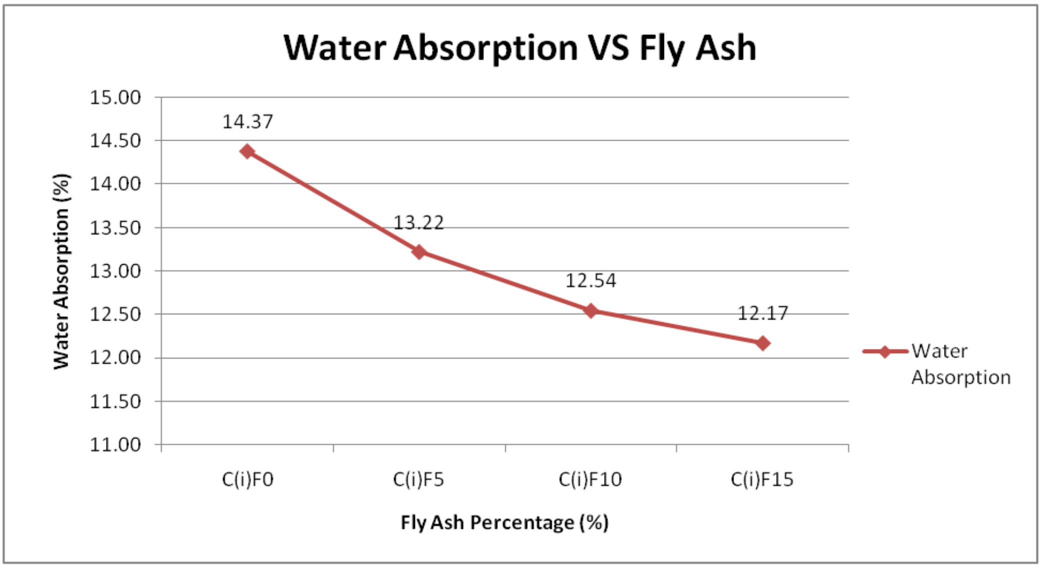

Figure 3: Water Absorption for All CSEB Samples

Based on the result obtained from water absorption test as plotted in Figure 3, the lowest water absorption experienced by CSEB was when it was incorporated with 15% of fly ash. This is due to the higher amount of fly ash that would cause to higher amount of void been eliminated. Consequently, it would reduce the amount of water penetrates the CSEB sample as most of the voids have been occupied by fly ash.

Durability Test

Four different durability tests were carried out involving 21 days of freezing and drying, 21 days of drying, heat test and abrasive test. These durability tests have been carried out to see the performance of CSEB under extreme condition and how the durability and strength of the block were affected compared to the previous normal condition.

Freezing & Drying, Drying, Heating (Oven Dried)

Table 7 demonstrates the result of durability tests at 21 days of freezing & drying, 21 days of drying and heating (oven dried) after 24 hours.

Table 7: Compressive Strength of CSEB after 21 Days of Freezing & Drying, 21 Days of Drying, Heating (24 hours)

Mix Proportion (%) Laterite Soil: Fine Agg: Coarse Agg	Fly Ash (%)	Compressive Strength (MPa)		
		21 Days Freezing & Drying	21 Days Drying	Oven Dried 24 hours
50 : 30 : 20	F0	0.98	0.98	0.99
50 : 30 : 20	F5	1.07	1.01	1.10
50 : 30 : 20	F10	1.12	1.07	1.14
50 : 30 : 20	F15	0.54	0.52	0.56

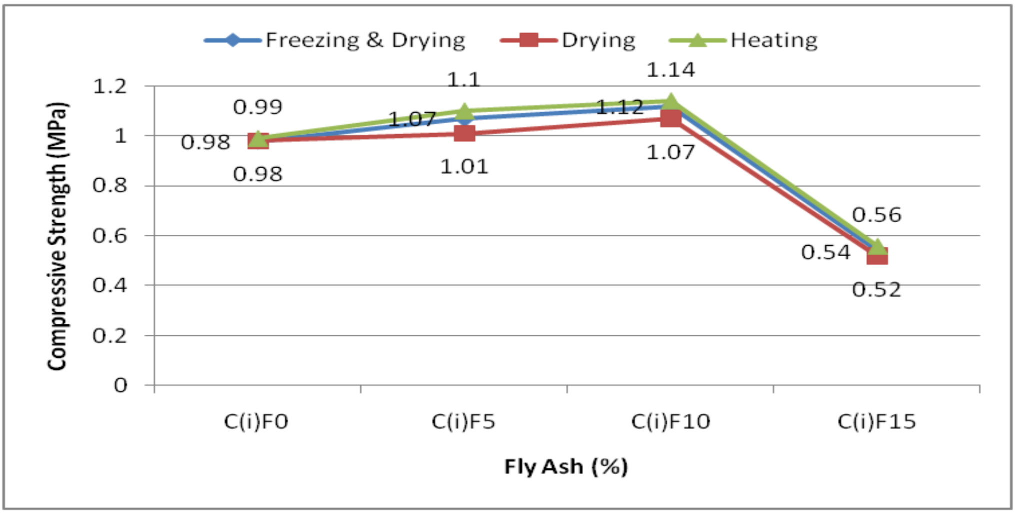

Figure 4: Compressive Strength of 21 Days Freezing & Drying, 21 Days Drying and Heating

Results obtained from the freezing & drying and drying test showed that the highest values of compressive strength were 1.12 MPa and 1.07 MPa. Whereas the heat test has encountered the highest compressive strength was 1.14 MPa. All of this result was obtained when the CSEB incorporated with 10% of fly ash. Freezing test was considered for durability test in this study because its funding would be useful by other researchers in four seasons country which, considering the innovation of earth block stabilized with fly ash. However the properties of laterite soil still need to be analysed since it could be different from one country to another taking into account the decomposition and weathering process involved. Even though most of the testing has enhanced the strength of the CSEB sample, but it still did not achieve the minimum requirement of MS72 standard for compressive strength that should reach up to 5.2 MPa for earth brick. Previous studies conducted by Chimuanya (2014) on freezing and drying test, the CSEB with 10% of cement and 10 % of lime have obtained compressive strength of 7.35 MPa and 2.23 MPa. As for the drying test, the results of compressive strength of cement and lime at 10% were 6.91 MPa and 2.04 MPa. Both testing showed obviously higher value compared to results obtained from this study. There could be certain reasons that lead to such results, such as improper equipment for compaction test, insufficient quantity of water, improper material as stabiliser and other reasons.

Abrasive Test

Another durability test was abrasive test. The results were shown in the graph below.

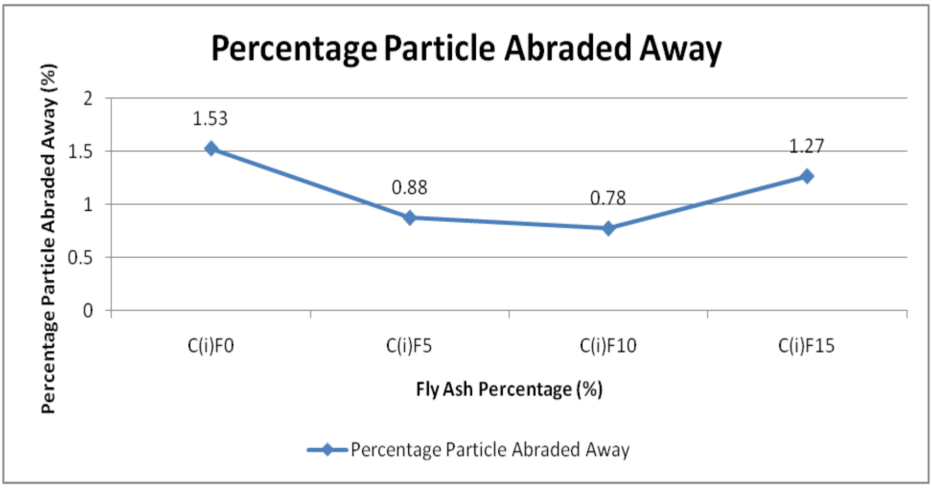

Figure 5: Percentage Particle Abraded Away With Fly Ash

Abrasive test results illustrated in Figure 5 show that CSEB had the lowest percentage of particle abraded when it was incorporated with 10% of fly ash which was 0.78%. In comparison with the previous study from Chimuanya (2014), CSEB incorporated with 10% of cement and lime showed that the particles abraded away were 0.06% and 0.20% respectively which were slightly lower compared to the result obtained from this study. It seems that fly ash did not have high cement-like element when mixed with laterite soil in order to bind the particle of CSEB strongly.

CONCLUSION

From the results obtained from engineering and durability testing, the compressed earth blocks that stabilized with fly ash gave a better compressive strength and durability to the earth block compared to the control sample. The result obtained from 28 days of curing with 10% of fly ash incorporated into the mix proportion showed the highest compressive strength of CSBE which was 1.09 MPa but did not reach the standard by MS72 with minimum amount of of 5.2 MPa. This result was better than the control sample which only 0.97 MPa. However, CSEB had the lowest water absorption rate when added to the fly ash at 15%, which is 12.17% compared to control sample with a higher percentage of water absorption of 14.37%. In terms of durability testing that obtained after freezing & drying, drying and heating process demonstrated that the highest compressive strength from all of this testing was when fly ash was at 10%. The compressive strengths attained were 1.12 MPa, 1.07 MPa and 1.14 MPa respectively. Even the durability testing has enhanced the strength of the CSEB but the strength still did not reach the minimum standard of MS72. Lastly, the abrasive test encountered that the lowest percentage of particles abraded away was 0.78% when fly ash was at 10%. From this research study, 10% of fly ash is recommended in term of providing better strength and durability to the earth block.

RECOMMENDATION

There are few improvements that can be considered in future research in order to enhance the performance of the CSEB by using fly ash or other elements of stabiliser.

The compaction process must be carried out with the presence of all elements in CSEB to avoid insufficient quantity of water which would affect CSEB in term of strength and durability. Moreover, a flaky and elongated shape of coarse aggregate must be avoided as they break easily when force is applied upon them which affect the strength and durability. For further study, any fine aggregate that could affect the durability of the CSBE sample like sea sand which would highly absorb water and fragile when in a dried state must be avoided which made the CSEB sample to break easily when force applied upon them. It is very essential to confirm the class of the fly ash to be used for CSEB as the class C is self-cementing and class F required activator such as lime to produce cement-like properties.

Besides, the curing day should not be skipped and curing process must be carried out properly to avoid problems such as the insufficient amount of water which could affect the strength and durability of CSEB sample. Likewise, a compressor machine is recommended to be used during the moulding process to standardize the force that will be applied in order to mould the CSEB sample.

Lastly, freezing & drying and heating should be applied in the future in order to enhance the strength, durability and water resistant characteristic of the CSEB sample. This has been proved in this research and previous research with the enhancement of compressive strength after durability test. This compressed stabilized earth block should be encouraged to be used in many countries and not only for developing country in order to reduce the cost of construction, environmental impact and many other benefits.

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