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THE STABILISATION OF COMPRESSED EARTH BLOCK USING LATERITE SOIL

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ABSTRACT

This research essentially focused on studying the performance and strength improvement of compressed stabilised earth block (laterite block) to reduce cost of conventional block production. The laterite soil used was from Infrastructure University of Kuala Lumpur (IUKL) and mixed with fine and coarse aggregates stabilised with Cement and Lime in percentages of 5, 10 and 15 with four different mix ratios. C(i) 50%: 40%: 10%, C(ii) 50%: 35%: 15%, C(iii) 50%: 30%: 20%, C(iv) 50%: 25%: 25%, (C represents Category); these ratios were employed to keep laterite constant up to 50% to determine that which will yield the best sustainable strength. Soil test and classification was done with the following, dry sieving and hydrometer analysis, plastic limit, liquid limit and moisture content - were conducted to classify the type of soil and its content for the benefit of producing building blocks. The results from those tests show that the soil was a laterite soil and clay of intermediate plasticity, fine grained and an inorganic soil. Comparison of compressive strength was carried out with the result from this study and the findings from past researches. Durability test was conducted using abrasive test and the result proved that the percentage of soil particles that were abraded from the resultant block samples after striking with wire brush was low. The compressive strength result shows that cement stabilised sample had higher compressive strength than the lime stabilised and that the strength increased as the curing age increases, also compressive strength increases as the content of stabiliser increased. Category (iii) had the highest strength among the other mix categories.

Keywords:
Compressed Stabilised Earth Block, Laterite Soil, Earth Block, Infrastructure University Kuala Lumpur

INTRODUCTION

Every human deserve a comfortable shelter, as a matter of fact the provision of housing is the duty of both privet and government housing authority, and even at that both developing and developed country still have problem of both affordability and availability of houses in their society [1], this demand affect the cost of building, though demand is not the only factor that affect the cost of building but other factors like cost of building materials for example the building blocks (conventional blocks) which depends wholly on excessive use of cement at the same time making this building blocks expensive for most population (citizens) with a very low income [2]. As population increases so does the demand for housing increases in both the developed and the underdeveloped countries, studies have been done on how to provide affordable shelter for the citizens. In Malaysia housing have been observed to be a big problem due to population increase caused by immigration of people from the undeveloped rural to the urban centres and these people are those with low income group (Bumiputera) that came in search of greener pastures and most of them cannot afford good shelter due to the cost of the houses in the urban region [3]. According to the “Third Malaysian Plan (TMP)” which was created in aim of eradicating poverty by providing affordable housing to the citizens, there is thus the very need to address such challenge through the proper implementation of affordable housing programmes with a more cheaper but durable material due to its link to income level.

In effect it has come to the notice of both the government and individual housing developers to find an alternative to the conventional materials and this quest brought most researchers to the idea of using laterite in making building blocks [4]. However laterite which have been neglected by many building professionals and the public as a whole due to its intensive maintenance because of high absorption rate when in contact with water, this process of excessive water intake will make the wall made with laterite soil to detorate within a short period of time leaving it soft and with time the walls will start to crack [5], also unawareness of the general public to know the economic benefits of building with laterite because of low acceptance by majority of the social group is also a big challenge of its own. Another setback in using laterite block for walling is due to its low strength when used as a building block. Notwithstanding the studies on laterite block that have been done to improve its strength, although the outcome have been a gradual success but there is still a need to improve it so that it would be generally utilised in all part of the world to minimise high cost of housing having known the economic benefits of laterite block.

The aim of this study is to use laterite soil, mixed with fine aggregate and coarse aggregate stabilised with lime and cement to improve the strength of compressed earth block to minimise the cost of materials used for building and block production.

i. Comparing the compressive strength between compressed earth block stabilised with cement and lime after 7, 21 and 28 days of curing with equal proportion of material used.

ii. To determine the compressive strength when laterite is kept constant in all mix up to 50% and to know the mix that will yield the best compressive strength result.

iii. Comparing the result of compressive strength from this study with the result of compressive strength from other study.

Laterite block have been in use for years ago starting from the ancient days until now. In some rural areas they are seen as the only affordable material around the environment and believed to be dependable for building of houses, though its maintenance is high but its availability and very low cost have made it the only material for building in these area. In most developing area it is used extensively for construction purposes. It was stated that housing is very important in everyone’s life but up to 50 of the world population in the rural areas still lives in shack houses. Furthermore, there have been several attempts made to develop walling units that will serve as alternative to the modern and more expensive fire bricks and concrete blocks. The use of laterite (cheap and durable material) was supported and introduced by the United Nations [6]. Notwithstanding its low strength and durability, laterite is still an environmental friendly material for building because the materials that are used for the building are all natural materials and its production does not require a special skill or techniques in building the traditional houses.

A. Laterite

Laterite soil from the past studies have been ranked as one of the historical building materials and its use have already made history in most countries, building like Temple of Ankor Wat in Cambodia, the Pyramid in Egypt which still stand tall for the admiration of our present day and at same time bring revenue to the country through tourism. Laterite soil is of great important when it comes to building and construction among the other soil that are in the tropical and non-tropical regions. It is said to be a high weathering soil that is made of a high proportion of iron and aluminium oxides and some other minerals. "Laterite soil if found in subtropical and tropical region below the surface of wide grassland that have high rainfall and that it is also produced by an in-situ (laterite) weathering process of a basement rock, such process occur mostly under a tropical climate conditions" [7]. The rate of laterite dark appearance determines how much resistance to moisture [8]. Laterite is defined as a "high weathering soil that occurs by the concentration of hydrated oxide of iron and aluminium" [9]. Some Asian countries have known laterite as a building material for more than 1,000 years. But when traced back its use where extensive and where the soil cohesion and its concentration of carbonates are high, such process is commonly found in tropical region where laterite soil gives a durable building material. While in some region laterite soil appears harden when exposed to air and sunlight due to a chemical reaction with the soil and air and this reaction is called carbonation reaction and such occurrence is known as induration, these kind of soil is found mostly in west coast of India. In India moist soft soil is cut directly into blocks or brick size and dried under intensive heat of the sun and allows hardening and after that it will be used for building as a building block, such soil is characterised as been practically irreversible and impermeable after drying [10].

B. The Occurrence of Laterite

Laterite soil occurs under a hot and wet climate condition in the tropic and subtropics region with three different stages in-situ, decomposition and weathering process [11]. Some researches have been done on classification of laterite to be able to differentiate laterite from other soil. Laterite is classified as soil that has a "reddish to yellowish colour, and the colour appearance is based on the water region during origin and its mineralogical composition of the parent rock" [12]. But unfortunately, the term reddish tropical soil still refers as laterite and laterite clay by some engineers. Some soil may appear like laterite but will not have the entire engineering properties requirement as laterite but fortunately, for engineering purpose, it does not matter if the classification is right or wrong, what matters is that the engineering properties of the soil would be classified and derived from testing that is reliable [13].

C. Laterite Soil Composition

With the view of laterite soil characteristics, there are factors that affect soil suitability for blocks production, and these factors are the moisture content of the soil, soil composition and the soil plasticity. A suitable laterite soil would be composed of clay (15-20%), contain silt roughly 25-40 percent by volume and roughly 40-70 percent by volume of sharp sand. The soil plasticity are said to depend primarily on the function of the clay content soil with plasticity index up to 20-30 which is suitable to apply for the production of building blocks [14]. When an accurate soil mix design and the optimum moisture content are established, blocks can then be ready for production. Proper compaction of the soil and a stabiliser like cement or lime can still be used to enhance the performance of the block. It should be highlighted out that different laterite soils may be seen in such a form that might be unsuitable for block production, for example, soil that was collected from borrow pit might be containing lumps which will require crushing for a more homogenous mix [15].

D. Compressed Earth

Compressed earth can be defined as the process of improving soil mechanically by pressing the earth particles in a very tight contact, and expelling air that is in the soil mass. This process increases strength properties of the soil at the same time making the soil to be less permeable and increases its stability. The effect of compressing a soil in a block form differs from each other and they are affected by different variables. One of these effects is the effort used to compress the block - higher effort used to compress the block results in higher or greater density [16]. Another effect is the elapse time between mixing and the period of compressing which has a negative effect on the strength of the laterite soil that is being stabilised with lime or cement; that is to say that a soil mix that was compressed within 60 minutes immediately after mixing will have more strength than the sample compressed after one day of mixing [17, 18]. This means that delay after mixing soil with the stabilising agent affects the strength and development of the mix. However, earth soil was formerly compacted with wooden tamps, which was the first form of compressing an earth block in some parts of the world. The machine that was used for compressing this soil was developed around the 18th century in France by Francious Cointeraux, an advocate of "new pise" (rammed block). Then latter a manual compressing machine was introduced around 70's and 80's, and this machine made the production of compressed earth block more energy saving and economical to produce [19]. Compressing block (CB) is a recent form of earth block manufacturing which came into use all over the world about 30 years ago. Thereafter a more modern compressing machine was manufactured in 1952 by "Engineer Raul Ramirez" of the CINVA in Bogota.

E. Soil Stabilisation

Soil stabilisation is simply the addition of a chemical treatment in a soil mix to improve its stability and its engineering properties, this process can take place when a stabilising agent like cement, fly ash or lime is administered to the soil mix, the pozzolanic reaction between the stabiliser and the soil develops a bind between the soil molecules and make soil durable for engineering purposes [9]. Soil stabilisation has numerous effects on soil, it reduces plasticity index; this makes it change from its sticky nature to a crumbly or grainy and this makes the soil easy to compact. This process help to make soil which was known to be unstable for most engineering work turn out to have useful values. McNally highlighted stabilisation to be a way of improving soil strength, stiffness, durability and reducing water absorption. Soil can be stabilised in three ways by mechanical, physical and chemical [20].

Physical stabilisation which is the alteration of properties of a soil by bringing together the missing size fractions, the soil texture in this manner can be altered by calculation and mixing of different fractions of soil together, after which most of the void that existed earlier are closed because of the close-packing of the grains, and this process limits the movement of the grains in the soil [21]. Mechanical stabilisation is done by a physical process of changing the physical nature of the soil by compacting or vibrating the soil and changing its density and reducing porosity. The procedure of compaction is what brings the soil particles closer in a way that the air is eliminated from the soil void. The application of method of stabilisation alone is not permanent because it can be easily reversed when the soil is in contact with water. The water will cause the soil grain to move within, and in this method the need for binder is highly imperative to override the reversible effect when in contact with water [22]. Chemical stabilisation occurs when a stabilising agent (cement, fly ash, lime, bitumen or a combination of these stabiliser s) is mixed with a soil, to improve the soil strength, lower permeability and lower compressibility that the natural state of the soil or the native soil cannot provide [23].

F. Compressed Stabilised Earth Block

Compressed stabilised earth block (CSEB) is a construction material which contains earth (laterite) mixed homogenously with a stabilising agent, be it cement or lime, into a compressed block. It has been revealed in pass literatures that the use of compressed stabilised earth block has been of rising interest in the provision of low cost houses, and stabilised earth building materials shall be of immense value as society progresses with respect to ecological design imperatives in building. This means that a proper use of mix with high amount of stabiliser content (lime or cement) produces a very good building material with an outstanding chemical behaviour, while well planned application of mixture with low content of those stabilisers will be used to achieve an economical and efficient solution to earth building and construction [24]. Building with earth is the cheapest material and practically more economical due to its local availability and abundance in the environment and some analyses have been carried out to prove that earth as a building material is cheaper and it is proven by comparing cost of wall made with CSEB and the wall made of fired bricks in India [25]. This comparison proved that CSEB is more economical than the country fired brick and it is also more environmental friendly than the country fired brick because no fire is required but only curing. Another comparison on compressed earth block, concrete block and adobe for thermal test by "Biology Department of Southwest Texas Junior College, Del Rio Texas " [26], and the result proved that the internal temperature of compressed earth block was lower than the adobe and concrete block which gives CSEB advantage over others.

G. Stabilising Earth Soil with Cement

Cement in in the field of building and construction work is a very important material and it could be divided into different types namely: Portland cement (ordinary Portland cement) Stag cement, Pozzolonic cement and High Alumina cement. Furthermore, each of the cement types differs from one another in respect of their rate of strength, rate of heat evolution, resistance to sulphate attack, and dry shrinkage. However in all the different types of cement the one most widely used in building is the Portland cement (ordinary Portland cement). The major purpose of the OPC is to bind the soil particles together in a strong, dense, dimensionally durable and stable form. There are still some other binders that are commonly used which include, Lime Gypsum, Pozzolans, Resins and Bitumen. Superior, unique and faster binding capacity was why OPC was selected as one of the stabilising agent in this study, and secondly its availability in all parts of the world. OPC is unique in comparison with other binders because of its binding ability to gain maximum strength in about 28 days unlike most other binders [27, 28]. It is stated that "stabilising block varies in OPC quantity and amount and that can drastically affect its properties and behaviour" [29].

H. Stabilising Earth Soil with Lime

Lime has been one of the oldest stabilisers that were used to treat soil to improve its engineering properties; workability and load bearing features. Many literatures have revealed that lime reacts with medium fine soil or fine-grained soil to have an increased workability, decreased plasticity and increased strength. The strength gaining is practically based on the chemical reaction due to the involvement of immediate change in the soil visual property caused by cation interchange. Calcium in the lime exchanges with the cation of the soil that was absorbed, which will cause the water layer around the soil particles to reduce in size and the process allows the soil particles to come in close contact with each other, causing agglomeration of the soil particles [30]. Furthermore another chemical reaction in lime Stabilisation is the pozzolanic reaction within the lime and soil mixture, which results in gaining strength [31]. It is good to underline here that the amount of lime that will be used for stabilisation depends on the type of soil to be stabilised and the quantity of lime is based on the analysis of effect that different lime percentages have on the reduction of plasticity and high increase in its strength on that soil [32]. That is to say that a proper laboratory test should be conducted on the soil to know the properties of the soil, the right quantity of stabiliser and the right stabiliser to use.

I. Compressive Strength of CSEB

The result of compressive strength of CSEB have been very encouraging to understand the benefits of using laterite to make blocks, not only for the economic benefits of low cost housing but also the environmental benefits as a walling materials. In a study, a maximum compressive strength of 1.2, 1.9 and 2.4 N/mm² for cement content of 5%, 8% and 10% were achieved respectively [33]. The result of the compressive strength did not meet the Malaysian Standard [34], but advised that additional 13% of cement should be added to achieve the standard strength required by the Malaysian Standard. It was reported that bricks made of laterite, admixture with 45% sand and 6% cement gained a compressive strength of 2.12 N/mm² with increase in cement content after 28 days of curing [35]. Six percent (6%) cement content is economical for the production of laterite bricks for low cost housing and that such strength of bricks could be used best for one storey building [36].

Table 1: Result of Compressive Strength [36]

Cement Content (%)	**0**	**3**	**6**	**9**
0% Sand Content				
Weight of Bricks (kg)	11.40	12.42	12.67	12.82
Density of Bricks (kg/m^3)	1534.3	1671.6	1705.2	1725.4
Load at Failure (kN)	12.4	35.0	63.0	82.0
Compressive Strength (N/mm²)	0.25	0.70	1.27	1.66
45% Sand Content				
Weight of Bricks (kg)	11.33	13.48	13.59	13.74
Density of Bricks (kg/m^3)	1524.9	1814.3	1829.1	1849.3
Load at Failure (kN)	10	41.0	105.0	164.0
Compressive Strength (N/mm²)	0.20	0.83	2.12	3.31

It was reported a compressive strength of 2.5 N/mm² and 1.8 N/mm² according to Nigerian Industrial Standard NIS: 87:2004 [37]. The results proves that laterite cement mix is an economical building material due to less cement content, and also that the cost of block depends so much on cement content.

J. Water Absorption of CSEB

Every mass of absorbed water is different in mass between saturated surface-dry (SSD) in CSEB after being placed in water for 24 hours. This process is always expressed in percentage [38]. However, the absorption of water is greatly influenced by the porosity and surface texture of that particular material. Water absorption of interlocking block decreases with increase in percentage of cement stabiliser. The result proved that the cement binds the laterite particles together and reduced the size of pores where water will flow into the block. The block without stabiliser (control sample) disintegrated in the water [39].

Table 2: Water Absorbtion of Cement Stabilised Interlocking Blocks [40]

Cement Stabilisation (%)	Dry Mass (kg)	Wet Mass (kg)	Water Absorbed (%)	Av. of Water Absorbed (%)
0	-	-	-	-
5	14.440 14.530	15.530 15.648	7.55 7.69	7.62
10	14.092 13.871	14.987 14.675	6.35 5.79	6.07
15	14.120 14.333	14.842 15.098	5.11 5.34	5.23

K. Effect of External Water on CSEB

Many traditional walls suffer from deterioration and there have been so many ways whereby water has effect on an earth block or walls made of laterite. Notable type of water with this effect is rain water and rising dampness from the ground. Water also has a negative effect on blocks, for it erodes the base of the walls of earth buildings making them to crumble and fall apart easily [40, 41]. However observations have been made on how earth blocks deteriorate and it occurs in different forms, such as solvent, abrasive and swelling of earth blocks. This will leave the block to be weak and cause it to fall apart [42, 43]. Solvent is seen as a common failure that occurs in earth blocks [44].

Abrasion of the block or walls of a building in some cases is caused by constant rain water drop on the surface of the block with a force [45]. It is stated that abrasion, which is caused by rain water has been identified by many as one of the common deterioration agent. The only place that really feels the impact of the surface erosion is mostly the region that experience frequent rainfall such as the Tropical areas [46]. The process and the rate at which rainfall drops with force on the block and removes the loose particles of the block that was not properly stabilised, and with water splashing on the surface of the block, the impact will cause the block particles that are not properly bonded with a stabiliser to fall apart and leave the block surface to get wet [47, 48]. It is stated “the rate of the rain drop on the blocks as the drop size, wind speed, fall and impact velocity energy which can impact on the surface of the block and cause the soil particles that are not stabilised to fall apart (removing the particles on the block that are not stabilised)" [49].

METHODOLOGY

Soil from IUKL was classified using atterberg limit, moisture content, particle size distribution [50] and moisture content [51].

A. Compaction test (Standard Proctor test)

Compaction test was carried out by the use of standard proctor test method for the purpose of achieving the moisture content of the laterite soil or water content on each of the laterite mix that will be administered when molding the cubes for compressive strength test, a laterite soil passing through number 4 sieve that was air dried was used, the compaction test was carried out [52].

B. Mix proportion

Before the moulding took place, the moisture content that was derived from the compaction test was employed in all the mix with the percentages of the stabilisers when casting. The proportion of the materials with water that was derived from the moisture content test was used throughout the molding process. To ensure uniformity in the production of compressed stabilised earth block, the weight or volume of each material used in making the block was measured at the same physical state for all batches of the blocks.

Table 3: Total Percentage for each Category

Sample Number	Laterite soil	Fine Agg.	Coarse Agg.
C(i)	50%	40%	10%
C (ii)	50%	35%	15%
C(iii)	50%	30%	20%
C(iv)	50%	25%	25%

252 cubes were moulded (including the control), nine laterite block was produced for each batch mix that will be tested for compressive strength at 7, 21 and 28 days. Mixing was done repeatedly for lime and cement stabilisation with same percentage of stabiliser cement and lime in increase at 5, 10 and 15% respectively to be able to compare their strength in same curing age. The letter C in the sample number represents Category.

C. Batching and Mixing

Batching was done in a bone dry condition for all the materials. Mixing was done thoroughly to ensure consistence and a mechanical tilting mixer was used to mix the soil. The mixer was emptied and cleaned to ensure there was no foreign materials left in the mixer, and the mixed materials was then added to start the mixing proper. 252 number of 150 mm^3 cubes were cast after mixing for compressive strength test for a curing duration of 7, 21 and 28 days for cement and lime stabiliser to compare the strength of lime with cement of same curing age.

The laterite cube sample was removed from the mould immediately after casting and kept to dry in a shade on a wooden pallet leaving it to air dry for 24 hours. It was then covered with a polythene sheet for curing to start properly. Thereafter, curing took place by the means of sprinkling (sprinkling water on the specimen). Covering was necessary to avoid the laterite sample from having a rapid drying, which will cause the blocks to start shrinking and cracking.

D. Water Absorption

Cold water absorption was conducted according to British Standard [53]. Water absorption was done to determine the amount of water that the sample will absorb within 24 hours, and this test was performed by a random selection of 72 specimens that was moulded for compressive strength that attended 28 days curing age.

E. Abrasive Test

Another durability test was also conducted by abrasive test method. 56 numbers of specimens were collected for abrasive test, two samples from each category after attending 28 days of curing in all percentages of cement and lime. The test was conducted to know the percentage of the soil particle that will be abraded away from the specimens. The specimens were weighed with a balance and the weight was recorded, however this was done so as to obtain the initial weight of the specimens before abrasion takes place. The specimens were then placed on a wooden surface, having the specimens balanced on the wooden surface, thereafter a wired brush was stroke 50 times through the surface of the specimens backward and forward motion, the backward and forward motion was seen as one stroke. After brushing through, the specimens were weighed on a balance and the weight after abrasion was taking.

RESULTS AND DISCUSSION

A. Summary of Preliminary Test Result

Table 4: Summary of Test Result

Test	Result
Liquid limit %	49.7
Plastic limit %	24.32
Plasticity index %	25.38
Specific gravity	2.65
Natural moisture content %	25.15

From Table 4, the result of plastic limit of laterite soil from IUKL had a PL of 24.32%, an LL of 49.7% with PI of 25.38%, these tests were helpful in classifying the laterite soil used in this study.

B. Sedimentation by Hydrometer and Sieve Analysis method

The laterite soil from IUKL satisfies the requirement of fine aggregate with 92.44% passing 2 mm sieve to 68.26% passing through 63 µm sieve which satisfy that the laterite is fine according to [54].

IKRAM CENTRAL GEOTECHNICAL LABORATORY

GRADING TEST (SEDIMENTATION BY HYDROMETER METHOD)

PROJECT: The Stabilization of Compressed Earth Block Using Laterite — PROJECT NO.:

SAMPLE: Laterite soil from IUKL — SAMPLE NO.: **MXM**

SIEVES (MM)	WT RETAINED (g)	% RETAINED	% PASSING
10.000	0	-	100.00
6.300	0.86	1.72	98.28
5.000	0.13	0.26	98.02
3.350	0.93	1.86	96.16
2.000	1.86	3.72	92.44
1.180	1.53	3.06	89.38
0.600	1.62	3.24	86.14
0.425	1.06	2.12	84.02
0.300	1.51	3.02	81.00
0.212	1.46	2.92	78.08
0.150	2.08	4.16	73.92
0.063	2.83	5.66	68.26
0.046		-	58.08
0.033		-	55.65
0.025		-	38.66
0.010		-	16.82
0.007		-	8.74
0.005		-	7.93
PAN	34.13	68.26	-
TOTAL	50	100.00	

Remarks:

Tested by: ODIMEGWU TEMPLE

Date: 2/18/2013

Figure 1: Sieve Analysis and Hydrometer Analysis Chart

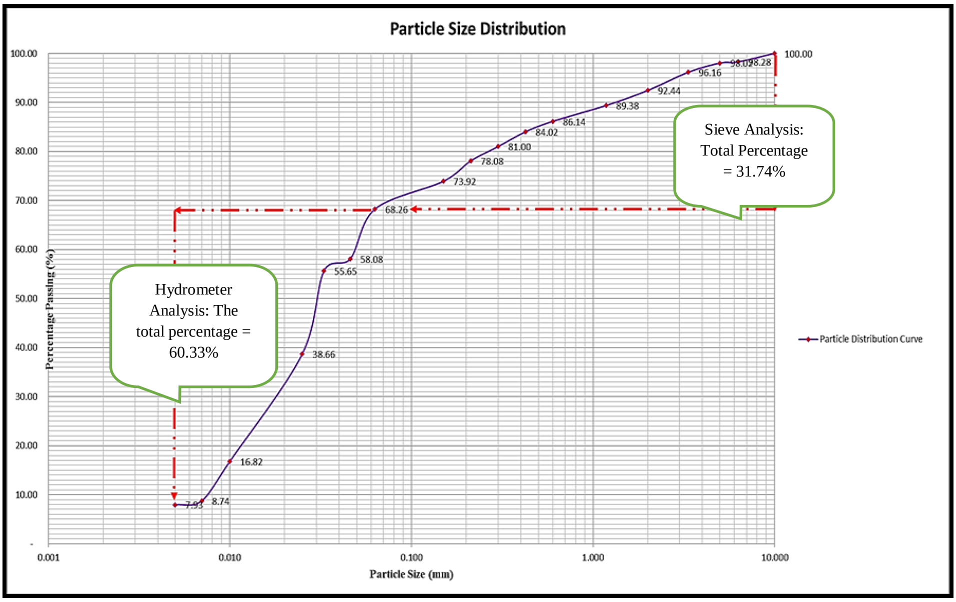

Figure 2: Particle Size Distribution Curve of Laterite from IUKL

The laterite soil from IUKL ranged from 6.3 mm to clay size with a large percentage of fine particles, the result of the test shows that the soil is distributed from medium gravel up to clay as shown in Figure 2. From the particle size distribution curve; Having 68.2% passing 63 µm sieve, the soil is considered as "fine – grained" [50].

According to "A line" classification chart for fine soil, is clearly shown that the soil from IUKL falls above the "A line" with a segment symbol CI with the soil being Clay of Intermediate Plasticity (CI) and more than 35% of the material is finer than 0.06 mm, hence the soil falls under fine – grained soil according to British soil classification system for engineering purposes. The soil is not a coarse grained soil or an organic soil [55].

C. Compaction Test

Table 5: Compaction Test Result

Mix proportion	MDD	OMC
C(i)	1.9 Mg/ m³	12.95%
C(ii)	1.86 Mg/ m³	12.25%
C (iii)	1.85 Mg/ m³	14%
C (iv)	1.85 mg/ m³	12.5%

The graph presented in Figures 3 to 6 indicates that C(i) had an MDD of 1.9 with the best OMC of 12.95, C(ii) MDD of 1.86 with an OMC of 12.25, C(iii) MDD of 1.85 with an OMC of 14 and C(iv) MDD of 1.85 and OMC of 12.5. respectively. It was observed that the slight increase in water helped the soil particle mix to compact tightly giving rise to a maximum dry density and optimum moisture content. However, this behaviour was observed in all the mix.

D. Water Absorption

The results of water absorption test are presented in table 6 to 11 for cement and lime stabilised samples.

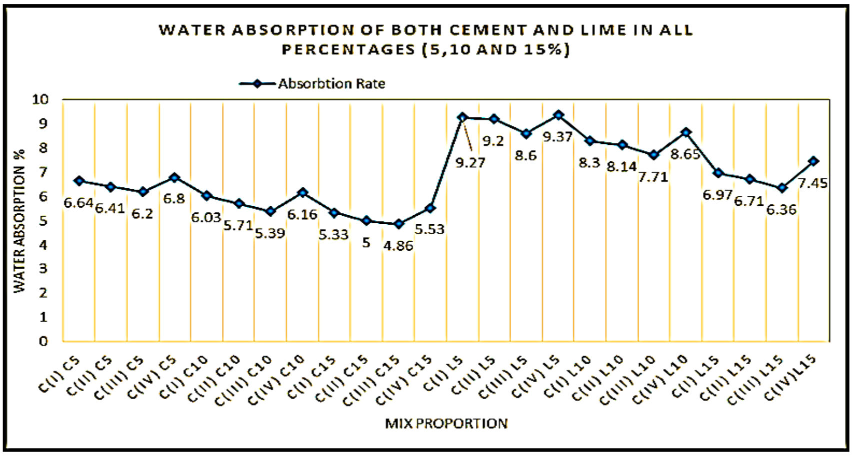

Figure 3: Water Absorption for Cement and Lime Samples in all Pecentage

The result shows that the water absorption decreases with increase in percentage of stabilisation in both cement and lime respectively, the behaviour was expected because the stabilising agent (cement or lime) binds the soil particles together and then reduces the size of pores where water could penetrate through to the sample. There was no result for the control sample because the sample breaks apart inside the water after 24 hours. The cement stabilisation and lime stabilisation in all percentages 5, 10 and of C(iii)C and C(iii)L (meaning category(iii) Cement 5, 10, 15% and category(iii) Lime 5, 10, 15%) had the lowest absorption rate among the other mix ratio. This low rate of absorption might be because of the percentage increase in coarse aggregate and decrease in fine aggregate.

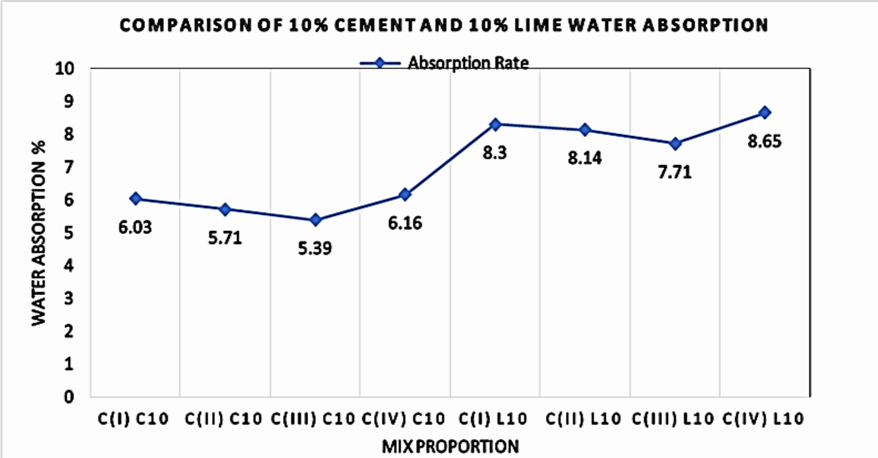

Figure 4: Water Absorption of 10% Cement and Lime Stabilised Sample

Figure 4 show 10 % comparison of lime and cement stabilised sample and from the graph it shows that lime in all percentages was more permeable than the cement stabilised specimen of same percentage of stabiliser. However the maximum water absorption of 7%, in category of Engineering Bricks [53] was satisfied by cement stabilised sample in all percentages but lime stabilised specimens did not meet the specification, although for load and non-load bearing walls there is no specific requirement for its water absorption.

E. Compressive Strength

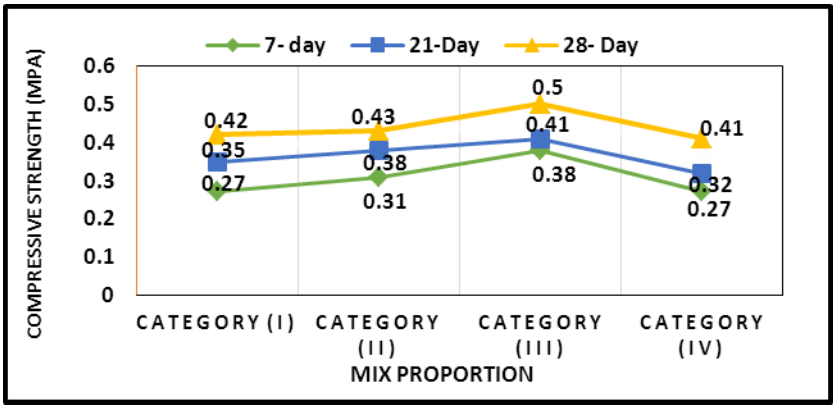

Figure 5: Compressive Strength Test of Control Sample

This behavior of the compressive strength shows that the strength increases with increase in curing age in all categories of both the stabilised and unstabilised sample (control sample) and 28 days curing age achieved the highest strength in all percentages as shown in Figure 5 to 8.

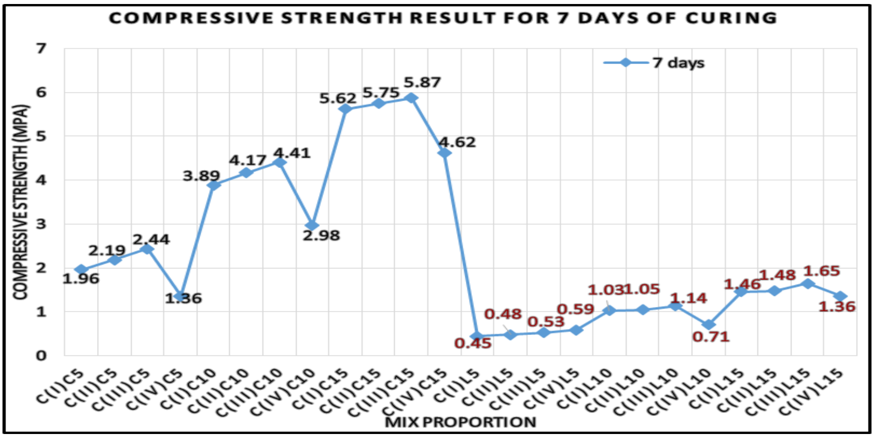

Figure 6: Compressive Strength of 7 days Curing for Cement and Lime Stabilised Specimen in all Percentages

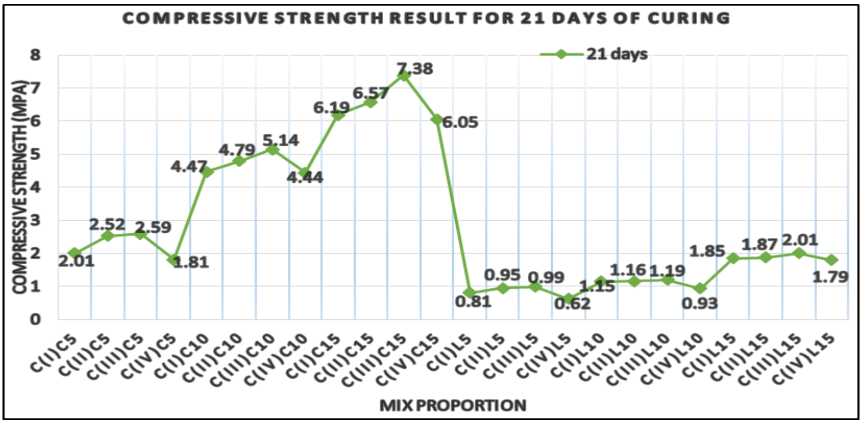

Figure 7: Compressive Strength of 21 days Curing for Cement and Lime Stabilised Specimen in all Percentages

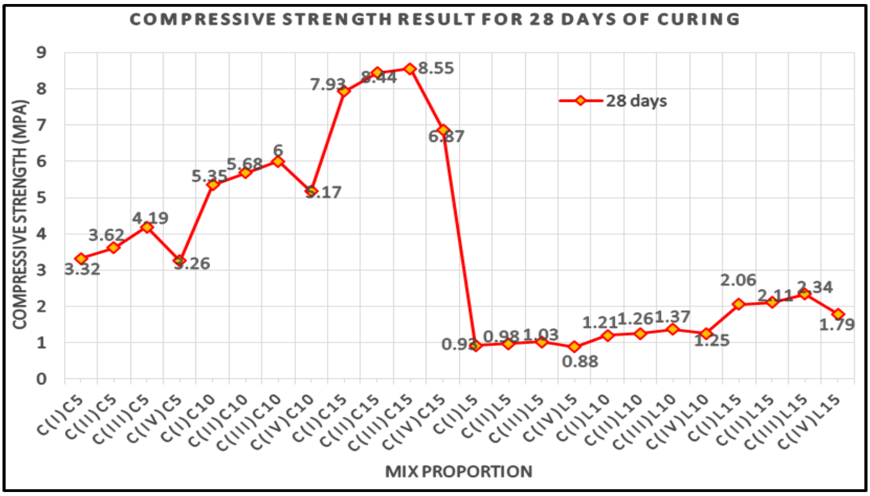

Figure 8: Compressive Strength of 28 days Curing for Cement and Lime Stabilised Specimen in all Percentages

In both cement and lime stabilisation it was observed that the compressive strength increases as the percentage of stabilisation increases. From Figure 6 to 8 it shows that the strengths of lime specimens were far lower than their counterparts in cement stabilised specimen. Eg, 10% cement specimen of the third category C(iii), which is 50%: 30%: 20%, was 6.0 MPa at 28 days curing while that of 10% lime was 1.37 MPa which was lower with a difference in percentage above 100%. In the case of lime stabilisation, the compressive strength achieved could not satisfy the minimum strength requirement of 5.2 MPa set by Malaysia Standard [34].

Cement stabilised specimens showed higher compressive strength than the lime in all percentages and curing age, and this might be because lime being pozzolanic, due to lime was not left beyond 28 days curing age to achieve its maximum strength [31]. When compared with result from other studies, a research work has shown an achievement of a maximum compressive strength of 2.78 MPa for 28 days curing age with 10% cement stabilisation [56], meanwhile in a different research work using laterite soil and fine sand to produce interlocking bricks, the researcher had achieved a maximum compressive strength of 3.31 MPa for 28 days curing age with 9% cement stabilisation [35]. Lastly a maximum compressive strength of 2.5 MPa result was reported in a study for 28 day with 10% cement stabilisation which also had a lower strength when compared with the result of 10% cement stabilisation achieved in this study.

A. Abrasive Test

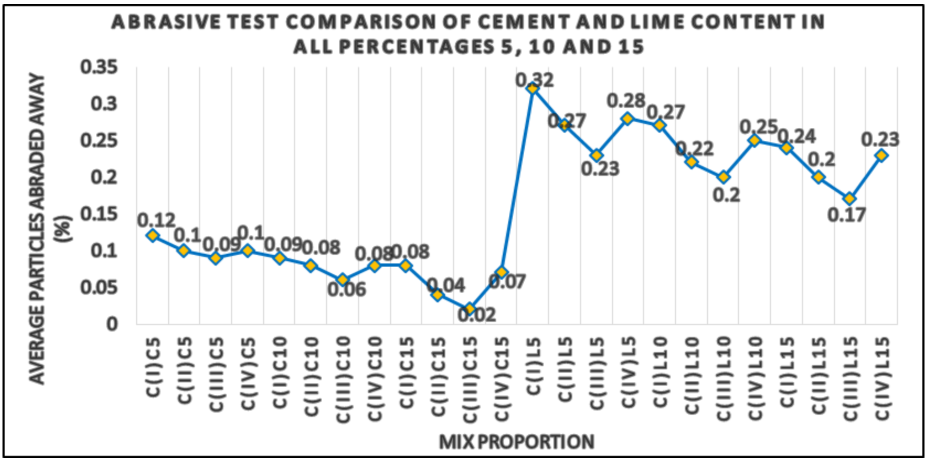

Figure 9: Abrasive Test of Specimen without Stabiliser

Figure 9, presented above proves that the rate of the sample to resist abrasion increases with an increase in percentage of stabilised content. However when compared between cement and lime from the chart it was seen that cement in all percentages showed a higher resistance to abrasion than the lime stabilised specimen which means that cement stabilised specimen is more durable than the lime stabilised specimen. Among the mix proportion category (iii) in all percentages show a higher resistance to abrasion than the other mix which means it is a more durable mix.

CONCLUSION AND RECOMMENDATION

A. Conclusion

The compressive strength of the specimen increases with increase in percentages of cement and lime stabilisation and curing age. Coarse aggregate should be used in production of CSEB, the addition of coarse aggregate to laterite mix up to 20 percent increased the compressive strength but reduces the strength with increase in coarse aggregate above 20 percent. The stabilisation of CSEB with cement is more efficient than stabilising with lime and 10% cement stabilised compressed earth block is an economical building block because little percentage of stabiliser still gave an adequate strength. Abrasive test shows that cement is more durable than lime for the production of blocks because little soil particles abraded away when the specimens stabilised by cement were subjected to abrasive test.

B. Recommendations

Compressing machine should be used for future test in molding and compressing the soil particle mix into block rather than compacting machine. Block stabilised with lime should be extended beyond 28 days of curing age because of its pozzolanic reaction and it needs longer time to achieve its maximum strength, and that of cement should also be extended beyond 28 days to compare with lime stabilised sample. Atterbeg limits, sieve and hydrometer analysis should be conducted on laterite soil to assist in classifying the soil before using it.

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