EFFFECT OF ALKALINE SOLUTION ON COMPRESSIVE STRENGTH OF CEMENT LATERIZED CUBE WITH DIFFERENT SOIL GRAINS SIZE

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EFFECT OF ALKALINE SOLUTION ON COMPRESSIVE STRENGTH OF CEMENT LATERIZED CUBE WITH DIFFERENT SOIL GRAINS SIZE

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A thesis submitted in partial fulfillment

of the requirement for the award of the degree of

Bachelor of Civil Engineering

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JULY 2015

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I hereby declare that I have checked this project "Effect of Alkaline Solution on Compressive Strength of Cement Laterized Cube with Different Soil Grains Size" and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering

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بسم الله الرحمن الرحيم

Dedicated to my beloved family,

fellow friends and to all my lecturers

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ABSTRACT

There are many factors that can increase the compressive strength of cement laterized cube. For example, it can be affected by the influence of additives, mix ratio of materials, grains size of aggregates and many other factors. This paper report the effect of alkaline solution concentration on the compressive strength of cement laterized cube which made by different laterite soil grains size. Besides that, there were two curing method that has been carried out which were air curing method and also dry in oven method. This research is also with a view to recommending the production of blocks from cement laterized in supplementing sandcrete blocks in the building construction industry, especially for low cost or rural building. For sample preparations, the crushed laterite soil was sieved into three different grains sizes which are, 1.18mm, 600 micro and 150 micro sizes. Then, each soil sizes will be mixed with a mix ratio of 1:2:6 (cement: soil: sand). Sodium hydroxide, (NaOH) solution with concentration of 1, 2 and 3 molar will be added in the mix and then cast the cube samples for each curing method. The compressive strength of the cube samples were recorded at the age of 14 days and 28 days of curing. The effect and relationship between the soil grains size, alkaline solution concentration, and curing method can be seen clearly. It can be concluded that, for this soil sample and for the mix ratio of 1:2:6, only 1 mol of alkaline solution is recommended. Addition of higher concentration of alkaline solution will reduce the compressive strength of the cube. In term of grains size effect, control samples made from 600 micro sizes produce the highest average compressive strength which is 3.602 MPa and 3.745 MPa for air curing and oven dry curing respectively. With addition of 1 mol of NaOH, sample with grains size of 1.18 mm produce the highest average compressive strength of 4.364 Mpa and 4.035 MPa for air curing and oven dry curing respectively. In tem of curing method, the cube samples for each grains size which undergo air curing method produced higher strength than sample undergo oven dry method at the age of 28 days.

ABSTRAK

Terdapat banyak faktor yang dapat meningkatkan kekuatan mampatan bagi kiub simen laterit. Contohnya, melalui pengaruh bahan tambahan, nilsbah campuran untuk bahan, saiz butiran aggregat dan sebagainya. Kertas kerja ini membincangkan mengenai kesan kepekatan larutan alkali terhadap kekuatan mampatan kiub simen laterit yang dihasilkan dengan saiz butiran tanah laterit yang berbeza. Selain itu, terdapat dua jenis kaedah pengawetan yang akan diuji iaitu, kaedah pengawetan udara serta kaedah pengawetan pengeringan ketuhar.Projek ini juga bertujuan untuk mencadangkan penghasilan blok dari campuran simen laterit dalam menggantikan blok campuran simen pasir dalam industri pembinaan terutamanya bagi pembinaan bangunan kos rendah atau bangunan luar bandar Untuk penyediaan sampel, tanah laterit yang talah dihancurkan akan ditapis kepada tiga saiz butiran tanah yang berbeza iaitu, 1.18mm, 600 mikro, dan 150 mikro. Kemudian setiap sampel tanah tersebut akan dicampurkan dengan nisbah campuran 1:2:6 (simen: tanah: pasir). Larutan alkali dengan kepekatan 1, 2, dan 3 molar akan dicampur kedalam bancuhan dan kemudian menghasilkan sampel kiub untuk setiap kaedah pengawetan. Bacaan kekuatan mampatan sampel kiub tersebut akan direkodkan pada usia 14 dan 28 hari selepas pengawetan. Kesan dan hubungan di antara butiran saiz tanah, kepekatan larutan alkali dan kaedah pengawetan dapat dilihat dengan jelas. Dapat disimpulkan bahawa, untuk jenis tanah ini, dan nisbah campuran 1:2:6, hanya 1 molar alkali yang disarankan. Penambahan larutan alkali yang lebih pekat akan menyebabkan kekuatan mampatan sampel kiub berkurang. Berdasarkan kesan saiz butiran tanah, sampel kiub terkawal yang dihasilkan dengan tanah bersaiz 600 mikro menghasilkan purata kekuatan mampatan yang tertinggi dengan kekuatan 3.602 MPa untuk kaedah udara dan 3.745 MPa untuk kaedah oven, Manakala, untuk sampel kiub yang dicampur 1 molar NaOH, kiub yang dihasilkan dengan saiz tanah 1.18 mm menghasilkan kiub yang paling kuat iaitu dengan kekuatan 4.364 MPa untuk kaedah udara dan 4.035 untuk kaedah oven. Dari segi kesan kaedah pengawetan pula, sampel kiub yang menjalani kaedah pengawetan udara menghasilkan kiub yang lebih kuat berbanding sampel kiub yang menjalani kaedah pengeringan ketuhar pada usia 28 hari.

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LIST OF ABBREVIATIONS

AASHTO	American Association Of State And Transportation Officials
CIDB	Construction Industry Development Board Malaysia
CLC	Cement Laterized Cube
IBS	Industrialized Building System
LL	Liquid Limit
OPC	Ordinary Portland Cement
NaOH	Sodium Hydroxide
PI	Plasticity Index
PL	Plastic Limit
PWD	Public Work Department

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In construction industry, cost is considered one of the important elements for constructing a project. Cost in construction includes the initial capital cost, and also the subsequent operation cost and maintenance cost. Generally, running a construction project will involve a lot of budget. Furthermore, the increasing rate of inflation by years, will affect the price of raw materials, transportation, fuel, machinery, man power and others. ot will be a bothers for the clients such as developer to invest money for a project. Hence, to overcome this problem, an alternative material or a new system will be the best option. Construction Industry Development Board Malaysia (CIDB) proposes cost saving methods which are the Industrialized building System (IBS) where the building component or the building systems are pre-fabricated and then install on site. Moreover, it is proven not only reducing the cost but also reduce the construction time.

Further information by CIDB, there is five types of IBS that were introduced for the construction industry to practice which are pre-cast concrete framing, panel and box system, steel formwork system, steel framing system, prefabricated timber framing system and finally the block work system. This report will focus on the block work system or in detail for interlocking block made from cement laterized. The usage of interlocking blocks as the construction materials has been proven to provide a lot of benefits. By implementing the cement laterized interlocking block for buildings will greatly reduce the wastage, volume of building materials, reducing unskilled workers, provide better quality control, promote a safer and more organized site, and last but not least will greatly reduce the construction cost and time (Nasly et al., 2009).

Lateritic soil has been used as a construction material for a thousand years before and by enhancing this material, it can replace some material without dropping the required quality standard and of course reducing the cost. It can be recognized from it well-graded reddish brown state, with sandy-silt clay of medium plasticity and compressibility type of soil. It also has fines content ranging from 27 to 49.5% and contains extremely low gravel percentage of less than 10%. (Elarabi et al., 2013). Hence, this research is in view to recommend the production of blocks from cement laterized in supplementing the conventional sandcrete blocks.

1.2 PROBLEM STATEMENT

Research by Adepegba (1975) indicates that by comparing the properties of conventional concrete with concrete which sand replace by laterite, it shows that, concrete containing laterite could be used for structural member. Besides that, with addition of cement and sand as stabilizer, cement laterized block has a potential to be the alternatives building material which can achieved required strength of 2.8N/mm^2 for non-load bearing wall, 5.2N/mm^2 for load bearing wall and 7.0 N/mm^2 for load bearing wall specified for exterior wall based on the Public Work Department (PWD) standard. With a proper study, the laterite soil can be enhanced and use as one of the material in construction.

There are several factors that affect the mechanical properties of cement laterized block or cube especially in term of compressive strength. Some of the factors are the mix proportion for the block or cube, curing method, soil grains size, presence of additives, water content for the mixture, and many more. Basically, this research were carried out to determine the effect of alkaline solution as additives, effect of grains size and effect of curing method in term of compressive strength of cement laterized cube, (CLC).

1.3 RESEARCH OBJECTIVE

The research will cover on the effect of additives concentration, sodium hydroxide (NaOH) on compressive strength of cement laterized cube (CLC) wwith different soil grains sizes which are 1.18mm, 600 micro and 150 micro. The objectives are as follow:

i. To identify the effect of concentration of alkaline solution (NaOH) on CLC in term of compressive strength.
ii. To determine the relationship between soil grains size and the concentration of alkaline solution in term of compressive strength.
iii. To compare the effect of curing method between air curing method and oven dry method in term of compressive strength.

1.4 SCOPE OF STUDY

i. Laterite soil will undergo mineralogy test, sieve analysis test and atterberg limit test to determine their properties. Then the soil will be sieved through a 1.18mm, 600 micro and 150 micro sieves for sample preparation.
ii. The mixed proportions that will be tested are 1:2:6 (cement: soil: sand).
iii. 8 sets of CLC samples will be produced based on the grains size, alkaline solution concentration and curing method.
iv. Concentrations of NaOH that will be tested are 1, 2 and 3 molarities.
v. The curing methods that the CLC samples will undergo are air curing method and oven dry method.

1.5 SIGNIFICANCE OF STUDY

Based on the current situations, the demands on sands as fine aggregate is high, thus proposing a new potential material which will reduce the cost is one of the options. Using laterite soil as replacement of sand will gives a lot of benefits. The significant of this study are:

i. Proposing the usage of laterite soil as one of the construction material. laterite soil can be easily obtain n in Malaysia and proven by researcher as a potential material to be used in construction.
ii. Recommending the production of block from cement laterized in supplementing sandcrete block which will greatly reduce the usage of cement and sand.
iii. Improvising the cement laterized block to achieve the required strength for multipurpose usage in construction.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Interlocking block system are usually practices for a small low rise building suach as houses and it is known as an effective technique that can reduce cost, and less time consuming compared to the conventional method. Furthermore, the interlocking blocks are different from conventional sandcrete blocks since they do not require mortar to be laid during bricklaying process where it will interlock with each other to to retain load or stress, this research will focus on the usage of laterite soil as the main material in the production of cement laterized blocks or cube.

Using cement laterized materials will give environmental benefits where it can reduce the usage of cement thus decrease the amount of CO_2 emitted and the energy used for construction (Radhi, 2009). The amount of world's cement-carbon-dioxide was recorded at 1 and 1.8 billion tons in years 1988 and 2000 respectively. By considering the trend from cement market and industry production, these CO_2 emissions are expected will reach 3.5 billion by the year 2015 (Davidovits, 2008). The reduction of CO_2 is very important as this harmful gas contributes to global warming through greenhouse effect.

The testing that include in this research are based on the past researches. The test for compressive strength, workability, and water absorption are commonly tested to the block. This section will discuss on the origin and definition of laterite soil and reviews from previous researches that are related with the objectives of this research.

2.2 CEMENT LATERIZED

Generally, cement laterized is an implementation on using both cement and laterite soil as one of the material in construction. This section will discuss about the materials consist in the production of cement laterized materials.

2.2.1 Cement

In construction industry, cement is considered as the most important material especially in production of concrete. Cement will act as stabilizer in the production of cement laterized materials. It cohesive behavior when mixed with water provides binds between aggregates. Thus, with a certain proportion of cement, soil and sand, we can produce a better quality blocks that achieved the required strength state by PWD.

There are many types of cement that are used in construction and it is varies based on their function for the construction. In the production of cement laterized cube, Ordinary Portland Cement (OPC) is selected as a stabilizer.

2.2.2 Laterite Soil

Laterite is a product of tropical or subtropical weathering which occurs abundantly in such regions in South America, Asia, Australia and Africa. The main constituents of laterite soil are oxides of Iron, Aluminum and Silicon. Besides that, it was stated that, laterite is a red tropical soil that rich in iron oxide and usually derived from rock weathering under strongly oxidizing and leaching conditions (Raheem et al., 2012). In Malaysia, laterite soil is easy to find and a cheap raw material. This type of soil has a good thermal and heat insulation value. Furthermore, its capability as a fire resistance when used as a wall structure also give an advantage as a housing construction compared to timber (Raheem et al., 2012).

The stabilizers that usually used for soil in improvement of soil strength are cement and lime. This has been proved in a study by (Raheem et al., 2010) which is cement stabilization involves the addition of small amount of cement while lime stabilization refers to the process of adding burned limestone product in order to improve the laterite soil properties. However, in their study it mentions that cement stabilized blocks is better quality in term of compressive strength, water absorption and durability compared to those stabilized with lime.(Raheem et al., 2010).

Besides that, the most suitable proportion of laterized concrete for structural purposes is by keeping the laterite content below 50 percent of the total fine aggregate (Balogun and Adepegba , 1982).

2.2.3 Water

Generally, clean water is needed in the production of concrete and it includes in the production of cement laterized blocks or cube. Any impurities will affect the mechanical properties of concrete or the mixture. Potable water or other relatively clean water, free from harmful amounts of alkali, acids, or organic matter, may be used. For this project, distilled water was used. Water is necessary for the hydration process of Portland cement and also to help the mixture achieving the maximum compaction.

2.3 ADDITIVES

Additive is a chemical method that can be used to improve the engineering properties of a material. Additives act as stabilizing mechanism. For laterite soil, an alkaline solution was used as additives.

2.3.1 Alkaline Solution

In this study, the distilled water will be added with some proportion of additives which is Sodium Hydroxide (NaOH) to produce alkaline solution. The alkaline solution will be used to determine their effect on mechanical properties of cement laterized cube. These additives will have reaction with clay which will stabilize the soil. Alkaline solution has been proven to give a boost for the cement laterized block in term of their compressive strength. (Rashdan, 2014).

Sodium hydroxide and carbonate was an effective chemical additive for laterite soils stabilized by cement or lime. Besides that, cement, lime, and alkali sodium chemical additives were used to find the optimum combination that produces the best unconfined compressive strength and C.B.R. results. (El-Rawi and Al Samadi, 1995).

2.4 GRAINS SIZE

Grains size is also one of the factors which affecting the compressive strength of cement laterized cube. There is several researches that have proven this statement where most of the result shown an increasing strength for finer soils.

2.4.1 Soil Grains Size

- It was proven that the higher the laterite/cement ratio, the lower the compressive strength. Besides that, the finer the grain size range, the higher the compressive strength. (Lasisi and Ogunjide, 1984)
- Finer grains size has higher cohesive forces that exist between the lateritic particles as the particles get smaller and smaller (Lasisi and Osunade, 1984).

2.5 CURING

Curing is one of the important processes for a mix design sample to go through which can determine their quality and may affect their mechanical properties if not carried out properly. Curing can be defined as a method to maintain moisture on the surface of concrete. It also involves the chemical process between cement and water called hydration which provides the cement adhesive properties to bind the aggregate. With a perfect proportion of water, the mix design sample can achieved their required strength.

2.5.1 Curing Method

From previous study, there are many curing method that are tested by the researcher in production of cement laterized block sample such as, air curing, cured under the shade, cured under the sun and others. For this research, two methods have been selected to be carried out.

- Air Curing
  - Water/air cured specimens gained the greatest strength values at all ages. But the air cured specimens gave the least values at all ages irrespective of the mix proportion. (Falade, 1991)

- Oven dry method.
  - Cured under the sun show a promising result where the compressive strength of the sample applied with this method is higher compared to others. (Wan Abdullah, 2014).
  - For temperature curing (TC), the samples will be wrapped with a plastic membrane preventing moisture loss and then oven cured at 40 °C for 24 hours. Then, the samples will be demoulded and kept in a 23 °C room. (Pangdaeng et al., 2014)

2.6 MECHANICAL PROPERTIES OF CEMENT LATERIZED CUBE

2.6.1 Compressive Strength

The compressive strength of cement laterized block depends on the soil type, type and amount of stabilizer, and the compaction pressure used to form the block. The maximum compressive strengths of the block are obtained by proper mixing of suitable materials and proper compacting and curing. The previous study (Razali, 2013) for the interlocking block using red laterite soils shows that the mix proportions that give the highest value of compressive strength is the 1:2:6 mix proportion of cement-laterite-sand.

The minimum requirement from the Ministry of Work for non-load bearing blocks is 2.8 MN/m2 and for load bearing blocks is 5.2 MN/m^2 (Nasly et al., 2009) and according to the Malaysia Standard MS 7.6: 1972 / British Standard BS 3921: 1985, for General Brick specifications, the average compressive strength for Load Bearing Brick Class 1 is 7.0 MPa.

$f = F/A_c$ [MPa]

Where:

f = compression strength (MPa)

F = ultimate crushing force (N)

A_c = sectional area (mm^2)

2.7 DISCUSSION

From previous research, the optimum mixed design is not determined yet for load bearing wall that is (5.2 N/mm2) and also for (7.0 N/mm2) at exterior part. The most promising mixed design is 1:2:6 of cement, soil and sand which shown higher compressive strength form others mixed design. Besides that, from previous research, by increasing proportion of soil it will reduce the strength of block. Moreover, soil grains size also give effect towards the mechanical properties of CLC Hence, by producing CLC with different grains size, we can determine the best sizes that can produce a high quality CLC with maximum strength. Furthermore, addition of alkaline solution in the mixture shows that it will produce a stronger laterized interlocking blocks in term of compressive strength. Thus, by increasing the concentration of alkaline solution we can determine the optimum additives concentration and the suitable grains size as the solution to improve the mechanical properties of cement laterized cube. Curing method is also one of the factors that can improve mechanical properties of the CLC.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter reports on clear insight to the study as well as the methodology that will be implement for this research. The materials, method to produce cement laterized cube, procedure for testing, data collection method and machineries involves in this research are describe in detail in this section.

3.2 RESEARCH MATEERIALS

This section will mainly focus on the preparation of raw materials needed to produce the cement laterized cube and the instrument used for this research. The raw materials include Ordinary Portland Cement (OPC), laterite soil, alkaline solution and fine sand.

➢ ***Ordinary Portland Cement***

There are varieties of Portland cement available in the market. In this study, Ordinary Portland Cement is chosen to be used in producing the sample due to their economical value and widely used in construction industry.

Figure 3.1: Ordinary Portland Cement

➢ ***Laterite Soil***

The laterite soils were obtained from Kerteh, Terengganu. Before undergo mixing process, the soil will be crushed and sieved through a 1.18mm, 600 micro and 150 micro. Each size will be used to produce sets of cubes with addition of different concentration of alkaline solution.

Figure 3.2: Laterite soil

- ***Additives (NaOH)***

Alkaline solution will be used as the additives in the cube mixture. For this research, Sodium Hydroxide (NaOH) will be used to produce the alkaline admixture. The controlled molarities that had been used are 1 until 3 molarities and each molar will be used to produce a set of cubes.

Figure 3.3: NaOH Pills

Figure 3.4: NaOH solution

- ***Sand***

River sand is one of the aggregate for cement laterized mixture and it ratio will be depend on laterite soil proportion. River sand must first go through sieve process where they must pass through the sieve size of 1.18 mm.

Figure 3.5: Fine sand being dried

3.3 RESEARCH PROCESS & PROCEDURE METHOD

This section describe the process flow of this research which involves five phases which are material characterization, basic laboratory test, production of cement laterized cube (CLC), compressive strength test and data reporting.

3.3.1 Material Characterization

The soil taken from the site must undergo a material characterization test or simply called mineralogy test. This test is very important in order to ensure that the soil to be used is a laterite soils. A small amount of soil sample was send to the Centre Laboratory to determine the minerals content in the soil. The minerals that a laterite soil should have are oxide of iron, oxide of aluminum, quartz and kaolinite. After the soil sample was confirmed for having those minerals then it is ready to be used in the next phases.

3.3.2 Basic Laboratory Test

The objective of having a basic laboratory test is to establish the properties of laterite soil that being used in this study. The test include in this study is sieve analysis test, atterberg limit test and direct shear test.

- ***Sieve Analysis Test***

Sieve analysis was conducted to determine the grading of laterite soil particles. The particle size distribution of the laterite soil will be used as data control of the production of laterite interlocking blocks. According to BS 1377: Part 2:1990:9.2/9.3/9.4/9.6/9.7 it is to determine how many percentages of silt and clay in the soil and to produce a “Grading Curve”.

Test Procedure:

i. Firstly, the oven dried laterite soil will be crushed and then weigh approximately about 500g.
ii. After that, the sieves stack were prepared and arranged from larger opening at the top until the pan placed at the bottom. The sieve stacks size used in this test are from 3.500mm opening until 0.063mm opening and lastly the pan.
iii. All the sieve stacks also need to be cleaned and weigh separately. Then the soil sample was poured from the top and places the cover.
iv. After that, the sieve stacks were place at the sieve shaker and switch on for 10 minute.
v. Finally when the sieve shaker stopped, the mass of each sieve stack including the retained soil is weighing on a balance and recorded

- ***Atterberg Limit Test***

Generally, fine grained soil can exist in several states either liquid, plastic, semi-solid or solid which depends on the amount of water in the soil system. This test is carried out to get the basic index information of soil for estimating the strength and settlement characteristic such as Plasticity Index, liquid limit and plastic limit. Reference standard use for this test is BS1377: Part 2:1990 and BS1377: Part 2:1990:5.3.

3.3.3 Production of CLC

Production of cement laterized cube itself consist of three phase which are mixing process, compressing the mixture and curing the samples. All these three phases will be explained under this section. Since there are four groups of samples to be prepared, the proportion of the mixtures are as follow:

- ***Mix Proportion***

:

Table 3.1: List of mix proportion for samples sets.

Sample	**Mix**	**Type**	**Grain Size**	**Curing 1**	**Curing 2**	**Total**
1	1:2:6	Control	1.18 mm 600 micro 150 micro	6 6 6	6 6 6	36
2	1:2:6	1 mol	1.18 mm 600 micro 150 micro	6 6 6	6 6 6	36
3	1:2:6	2 mol	1.18 mm 600 micro 150 micro	6 6 6	6 6 6	36
4	1:2:6	3 mol	1.18 mm 600 micro 150 micro	6 6 6	6 6 6	36
Total						144

- ***Mixing Process***

The most important process in the production of the cement laterized cube is the mixing process of the materials. This is because a proper mixing technique is needed to produce a good quality cubes.

The procedure of preparing the cube for;

1. All the materials need to be prepared first.
2. Determine the mix ratio for the materials such as 1:2:6
3. Weigh the materials based on the mix ratio (cement : soil : sand).
4. Dry mix the prepared mixture of the cement, soil and sand
5. To stabilize cube with cement and alkali, add the alkaline solution with the required concentration into the mixture.
6. The mixture will be compressed into a 100*100 *100 mm cube using a custom made cube compressor.
7. Then the mixture will be cured and tested until it reached the age of 28 days.

Figure 3.6: Mixing the sample

Figure 3.7: Casting the cube

3.3.4 Curing

- ***Curing Process***

  Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. Curing has a strength influence on the properties of hardened concrete such durability and strength. After the production of the cubes, curing process will take place for 28 days before further test such as compressive strength test. The cubes will undergo curing by left under the sun for a period of 28 days.

- **Curing Method 1 (Air Curing)**
  - The casted cube will be exposed to surrounding air under the shade for 28 days.
  - The cubes will be sprayed with water for the first seven days at morning and evening.

- **Curing Method 2 (Dry in Oven)**
  - The casted cube will be wrapped airtight with plastic wrapper and then put into the oven for 24 hours with temperature of 80°C.
  - After 24 hours of oven dried, the cube will be exposed to surrounding air under the shade for the remaining 27 days.

Figure 3.8: Air curing method

Figure 3.9: Oven dry method

3.3.5 Compressive Strength Test

Compressive strength test was carried out to determine the load bearing capacity of cubes. The weight of each cube will be recorded before they are placed on the compression machine. The top and bottom line lie horizontally on a flat metal plate to prevent sheaving of blocks. The cubes then crushed and corresponding failure load were recorded. The crushing force was divided by the sectional area of the block to achieve the compressive strength. For this research, the CLC sample will be tested at the age of 14 days of curing and 24 days of curing. 3 cubes will be tested for each sets and the average compressive strength will be analyzed for discussion and conclusion.

$f = F/A_c$ [MPa]

Where:

f = compression strength (MPa)
F = ultimate crushing force (N)
A_c = sectional area (mm^2)

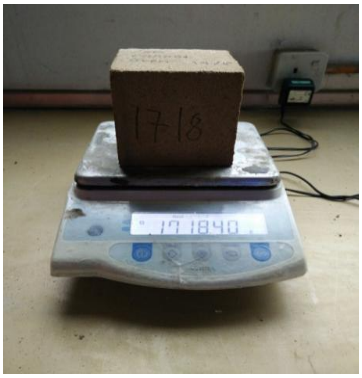

Figure 3.10: Weighing sample

Figure 3.11: Compressive strength test

3.4 LIST OF INSTRUMENT

Figure 3.12: Compression test machine

Figure 3.13: Cube compressor

Figure 3.14: Sieve machine

Figure 3.15: Oven

Figure 3.16: Jaw crusher machine

CHAPTER 4

RESULT AND DISUSSION

4.1 INTRODUCTION

This chapter will present all the collected results and data of laboratory testing from this research. The data will be analyzed and presented in form of tabular and graphical form to show the relationship between the tested parameter.

Generally, this research is mainly focus on the compressive strength of the samples. The series of result were obtained from the compressive strength test which varies according to different soil grains size, curing method and concentration of additives. Besides that, sieve analysis and atterberg limit test was carried out to determine the laterite soil properties.

4.2 SIEVE ANALYSIS

Stated by Houbend, 1994 the silt content must be in the range of 10% - 25 % for fine aggregate to produces the interlocking block. From the analysis, silt content for this laterite soil is 22.72% which indicates that this soil is suitable to be used in the production of CLC.

Table 4.1: Sieve analysis of laterite soil

Sieve	Opening (mm)	W. Initial (g)	W. with Soil (g)	W. Soil (g)	W (%)	∑ W(%)	% Finer (%)
	3.35	540.70	540.72	0.02	0.00	0.00	100.00
	1.18	514.96	518.11	3.15	0.63	0.64	99.36
	0.60	491.57	542.46	50.89	10.24	10.87	89.13
	0.30	431.43	520.54	89.11	17.92	28.80	71.20
	0.15	428.73	527.72	98.99	19.91	48.71	51.29
	0.06	393.21	535.23	142.02	28.57	77.28	22.72
pan	0.01	366.29	479.25	112.96	22.72	100.00	0.00
		3166.89	3664.03	497.14			

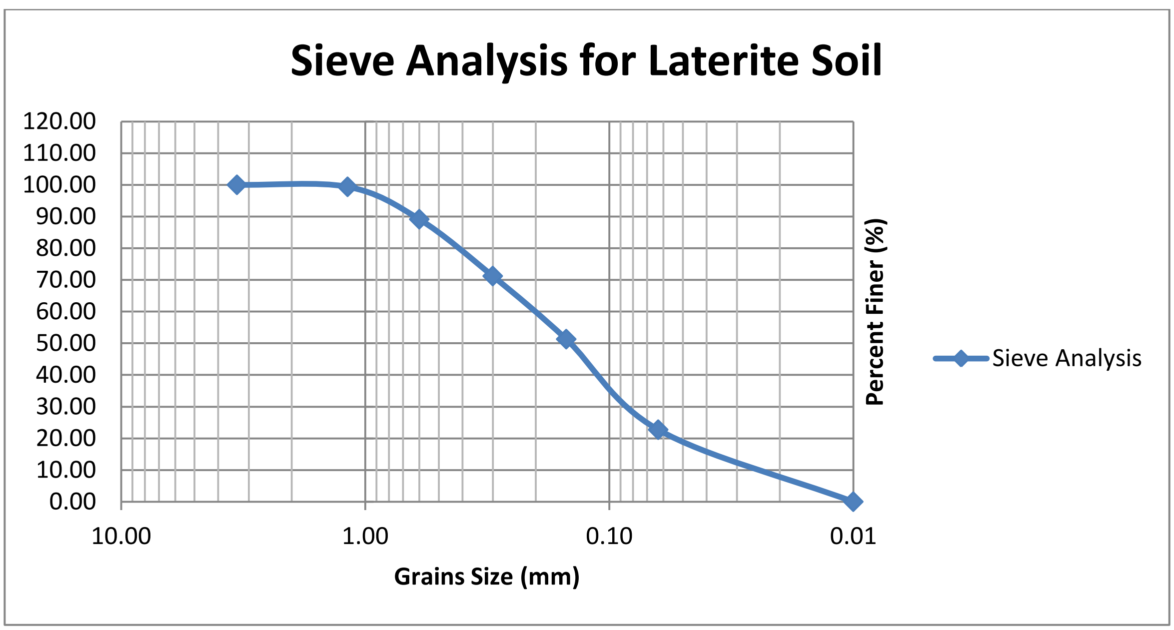

Figure 4.1: Grading curve for sieve analysis of laterite soil

4.3 ATTERBERG LIMIT TEST

Table 4.2: Liquid limit test for laterite soil.

Liquid Limit (BS 1377)						
Test number	1		2		3	
Cone penetration (mm)	18.1	17.4	21.4	22.1	28	26.7
Average penetration (mm)	17.8		21.8		27.4	
Container no.	19C	48C	25C	88C	80C	94C
Container weight (g)	9.68	10.83	10.23	10.33	10.76	10.67
Wet soil + container (g)	19.76	20.91	20.57	20.66	21.32	20.96
Wet soil, Ww (g)	10.08	10.08	10.34	10.33	10.56	10.29
Dry soil + container (g)	16.68	17.81	17.22	17.30	17.74	17.46
Dry soil, Wd (g)	7.00	6.98	6.99	6.97	6.98	6.79
Moisture loss, Ww-Wd (g)	3.08	3.10	3.35	3.36	3.58	3.50
Moisture content (%)	44.00	44.41	47.93	48.21	51.29	51.55
AVERAGE MOISTURE CONTENT (%)	44.2		48.1		51.4	

Table 4.3: Plastic limit test for laterite soil.

Plastic Limit (BS 1377)			
Container no.	29C	15C	3C
Container weight (g)	10.48	10.20	10.50
Wet soil + container (g)	16.15	15.81	18.25
Wet soil, Ww (g)	5.67	5.61	7.75
Dry soil + container (g)	15.14	14.87	16.87
Dry soil, Wd (g)	4.66	4.67	6.37
Moisture loss, Ww-Wd (g)	1.01	0.94	1.38
Moisture content (%)	21.67	20.13	21.66
AVERAGE MOISTURE CONTENT (%)	21.2		

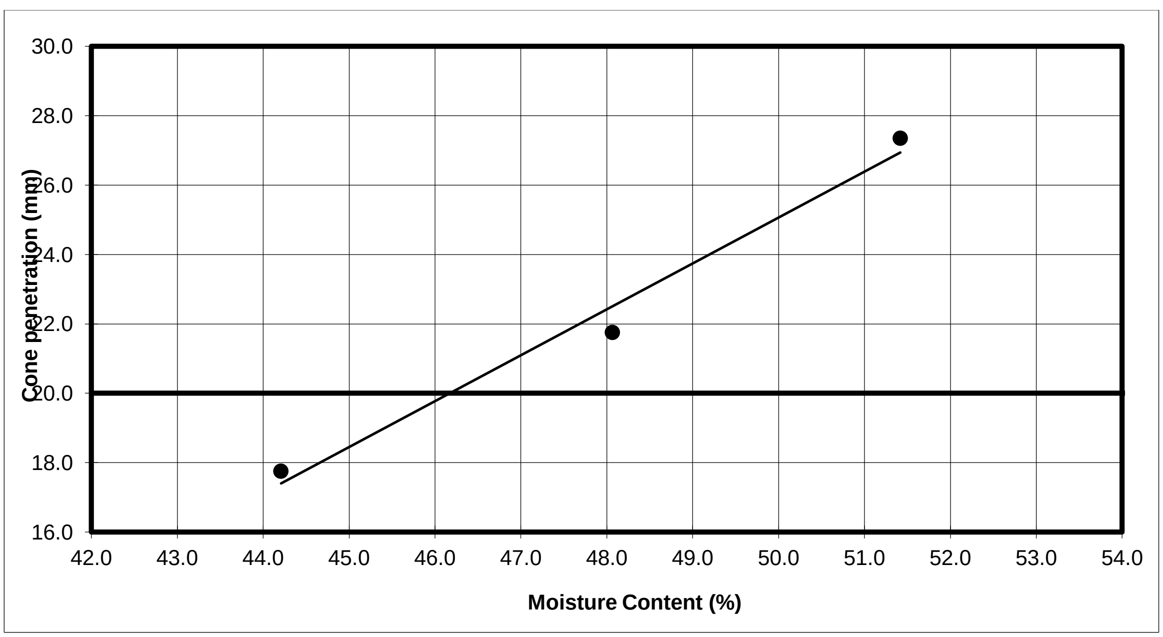

Figure 4.2: Gradient of correlation coefficient.

The objective of the Atterberg limits test is to obtain basic index information about the soil used to estimate the crude indication of their engineering properties such as strength, settlement characteristics, permeability, and compressibility. It is the primary form of classification for cohesive soils. The consistency of the soil, or the Atterberg limits, which determines at what phase the soil is classified based on the water content. It can range from (dry) solid to semi-solid to plastic to liquid (wet). The index information about the soil which are Plastic Index, Plastic Limit and Liquid Limit have been obtained.

Based on the results obtained, the liquid limit for this soil sample is about 46 % and the plastic limit is 21%. This means that the soil exhibits liquid properties at 46% moisture content and plastic properties at 21%. The liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. It means that 46% is the boundary between plastic and viscous fluid states. While for the plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. It means that 21% is the boundary between non-plastic and plastic states.

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.

PI and their meanings:

- 0 – Nonplastic
- (1-5)- Slightly plastic
- (5-10) - Low plasticity
- (10-20)- Medium plasticity
- (20-40)- High plasticity
- >40 Very high plasticity

Based on the result, the soil is said to be high plasticity with the value of 25%. For the soil with medium plasticity, the thread is easy to roll and little time is needed to reach the plastic limit. The thread cannot be re-rolled after the plastic limit is reached. The mass crumbles when it is drier than the plastic limit.

Cohesive soils are characterized by very small particle sizes where surface chemical effects predominate. They are both "sticky" and "plastic". Organic soils are typically spongy, crumbly, and compressible. They are undesirable for supporting structures. There are two ways to classify non cohesive soil that is by using the American Association of State Highway and Transportation Officials (AASHTO) or according to United Soil classification system. Towards the AASHTO system the grain size and plasticity of the test sample can be determined.

4.4 COMPRESSIVE STRENGTH TEST

Compressive strength test was carried out on cube samples consist of different soil grains size, additives concentration and type curing method. Basically, there are 8 sets of cube sample that were tested. The collected result and data of compressive strength were from 14 days and 28 days of curing cube samples. The data can be classified based on the curing method and the collected result is as follow:

4.4.1 Curing 1 (Air curing)

Table 4.4: Average compressive strength for 14 days air curing sample

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)		
		1.18 mm	**600 mic**	**150 mic**
Control		2.402	3.359	2.565
1 mol		3.405	3.984	2.366
2 mol		2.929	2.292	2.126
3 mol		2.204	2.125	1.614

Table 4.5: Average compressive strength for 28 days air curing sample

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)		
		1.18 mm	600 mic	150 mic
Control		2.889	3.602	2.843
1 mol		4.364	3.363	3.201
2 mol		3.430	3.007	2.694
3 mol		2.633	2.486	1.994

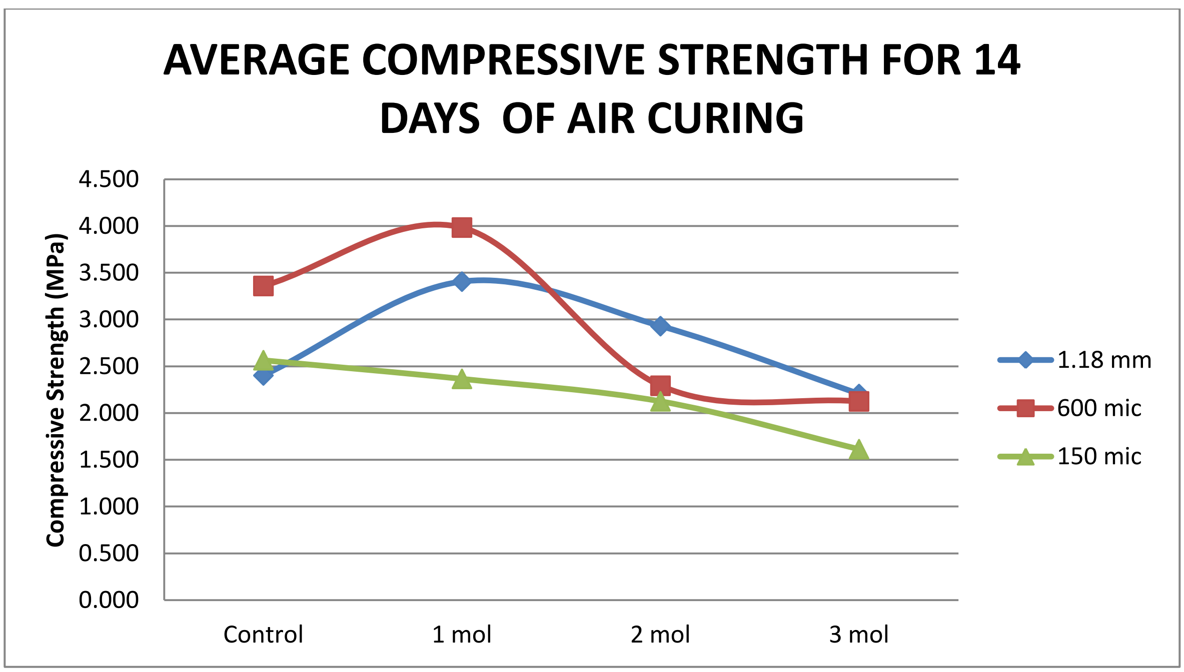

Figure 4.3: Average compressive strength for 14 days of air curing

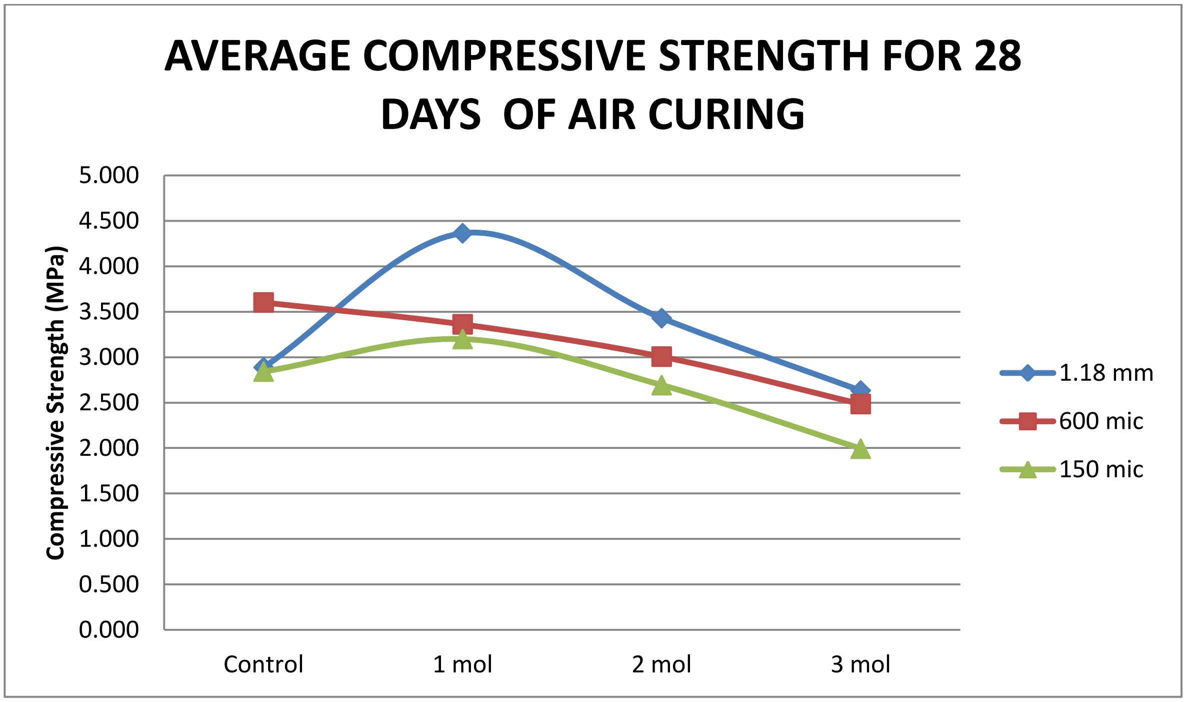

Figure 4.4: Average compressive strength for 28 days of air curing

The plotted result from the 14 days of curing shows a relationship between the soil grains size and the concentration of alkaline solution. The average compressive strength shows an increment for both 1.18 mm and 600 micro sizes of the 1 mol cube sample. The strength starts to decrease when higher concentrations of NaOH were added. However, for 150 micro sizes the strength drops significantly even when added with 1 mol of NaOH.

The plotted result from 28 days shows the same pattern for 1.18 mm and 150 micro grains size respectively with much higher cumulative strength due to longer period of curing. However, the pattern for 600 micro sizes is not as expected where the strength drops significantly with presence of NaOH. This may due to differences in density of cube tested. Denser cube provide higher compressive strength.

The increase in strength when added with alkaline solution has been proven from a research by Mansor, A.R. (2014), the strength of interlocking block increase when added with 1 mol and 2 mol of NaOH. There were small differences in strength between the two samples and the strength may decrease if further addition of higher concentration NaOH.

A research by Lasisi, F. and Ogujinde A.M. (1984), stated that the finer the soil grains size the higher the compressive strength. The finest size that they have tested is for 0.425mm-0.850mm. The pattern can be seen from the plot where the increase in strength for a control type 600 micro has higher strength than control type 1.18 mm. However the strength is smaller for 150 micro sizes. This finding shows a certain grains sizes that are suitable for producing a cement laterized cube. Besides that, a further research can be done to investigate the effect causing the cube sample from 150 micro grains size strength to decrease.

The highest recorded strength was from samples cubes of 1mol of 1.18 mm grains size where the average compressive strength is 4.364 MPa at the age of 28 days of curing. For a control sample, 600 micro achieved the highest strength of 3.602 MPa at 28 days of curing.

4.4.2 Curing 2 (Oven dries)

Table 4.6: Average compressive strength for 14 days oven dry curing

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)		
		1.18 mm	**600 mic**	**150 mic**
Control		3.015	3.224	1.765
1 mol		3.447	2.309	1.991
2 mol		2.911	2.326	2.295
3 mol		2.260	2.278	1.594

Table 4.7: Average compressive strength for 28 days oven dry curing

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)		
		1.18 mm	**600 mic**	**150 mic**
Control		3.393	3.745	2.278
1 mol		4.035	2.619	2.453
2 mol		3.331	2.484	2.860
3 mol		2.228	2.601	2.030

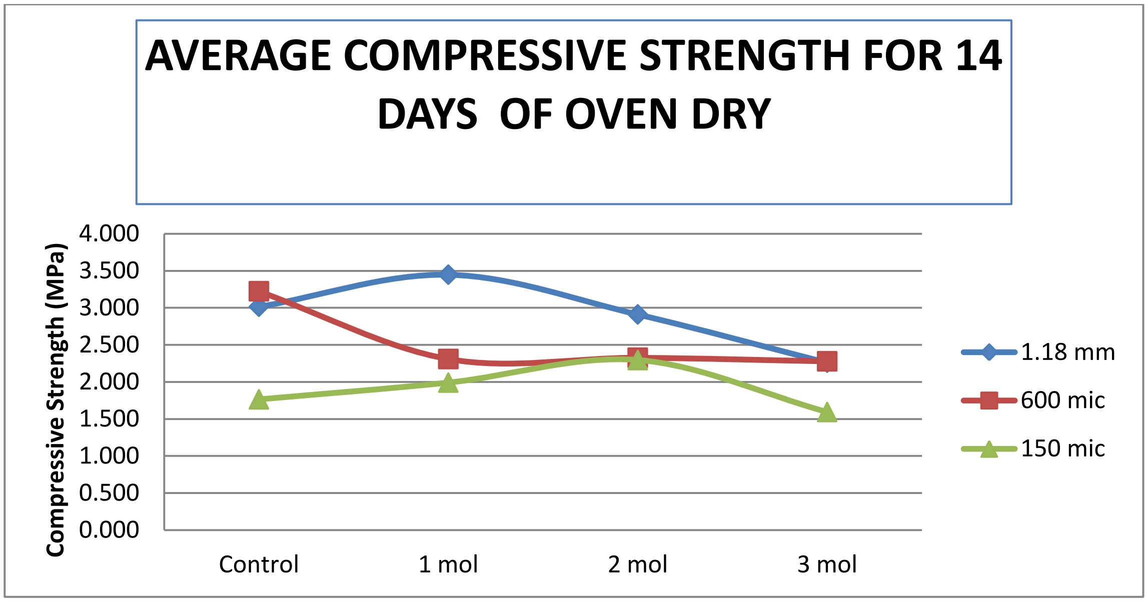

Figure 4.5: Average compressive strength for 14 days oven dry curing

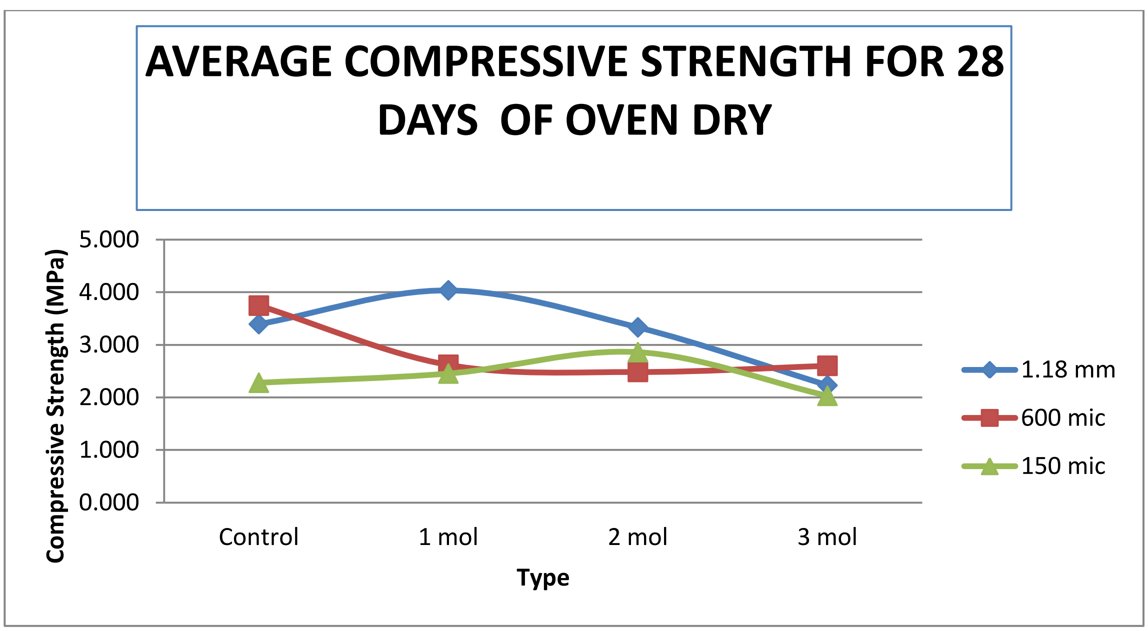

Figure 4.6: Average compressive strength for 28 days oven dry curing

Based on the plotted result of 14 days and 28 days compressive strength, the same pattern can be obtained where an increasing strength at 1 mol of NaOH for 1.18 mm grain size samples. The strength decrease when higher concentrations of additives were added. Besides that, the pattern of compressive strength for 600 micro shows a dropped in strength and form an equivalent compressive strength for all tested cube sample with addition of NaOH. 150 micro cube samples show an increase in strength with addition of NaOH especially for 1 mol and 2 mol sample. The strength starts to decrease for 3mol sample.

The highest recorded average compressive strength for samples which undergo curing oven dry method was 4.035 MPa for sample 1.18mm with 1 mol additives. For control type, the 600 micro has the highest average compressive strength with 3.748 MPa which have proven the statement by Fola Lasisi et.al (1984) where finer soil produces higher compressive strength. However, 150 micro samples produce a cube with average strength below 2.50 MPa.

Based on the collected result, the result may differ due to some precautions which are not taken seriously. Besides that, further research on soil properties should be carried out due to different soil content may affect the performance of cement laterized cube.

4.4.3 Comparison between Curing Method

Table 4.8: Comparison in strength between curing method for 14 days

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)					
		1.18 mm		600 mic		150 mic	
		Air	Oven	Air	Oven	Air	Oven
Control		2.402	3.015	3.359	3.224	2.565	1.765
1 mol		3.405	3.447	3.984	2.309	2.366	1.991
2 mol		2.929	2.911	2.292	2.326	2.126	2.295
3 mol		2.204	2.260	2.125	2.278	1.614	1.594

Table 4.9: Comparison in strength between curing method for 28 days

TYPE	GRAINS SIZE	Average Compressive Strength (MPa)					
		1.18 mm		600 mic		150 mic	
		Air	Oven	Air	Oven	Air	Oven
Control		2.889	3.393	3.602	3.745	2.843	2.278
1 mol		4.364	4.035	3.363	2.619	3.201	2.453
2 mol		3.430	3.331	3.007	2.484	2.694	2.860
3 mol		2.633	2.228	2.486	2.601	1.994	2.030

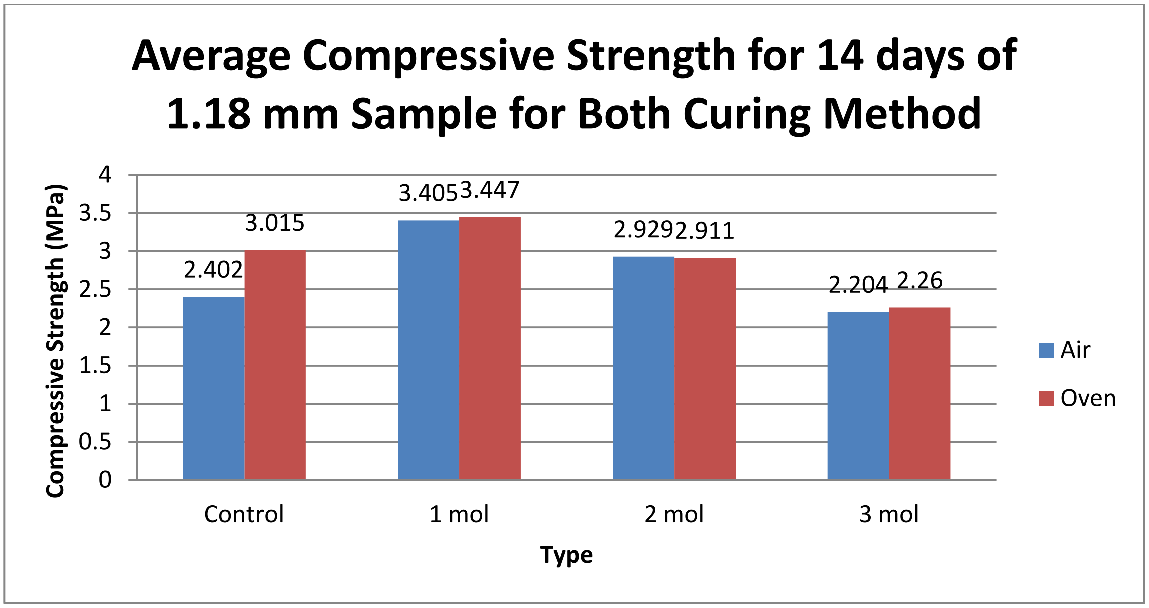

Figure 4.7: Comparison in strength for 1.18mm samples at age of 14 days

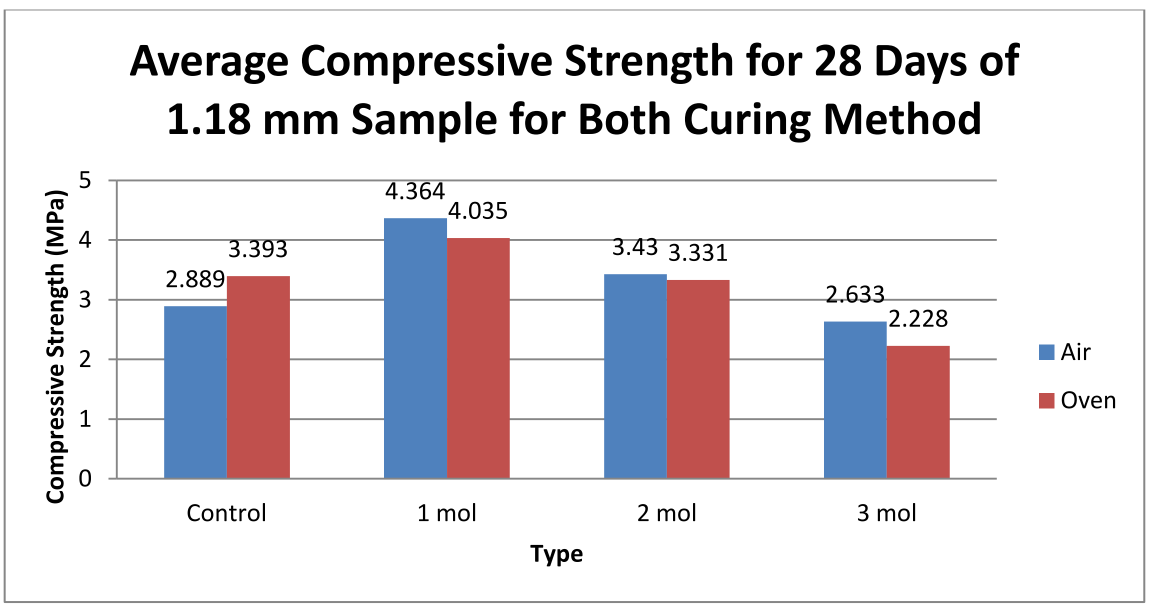

Figure 4.8: Comparison in strength for 1.18mm samples at age of 28 days

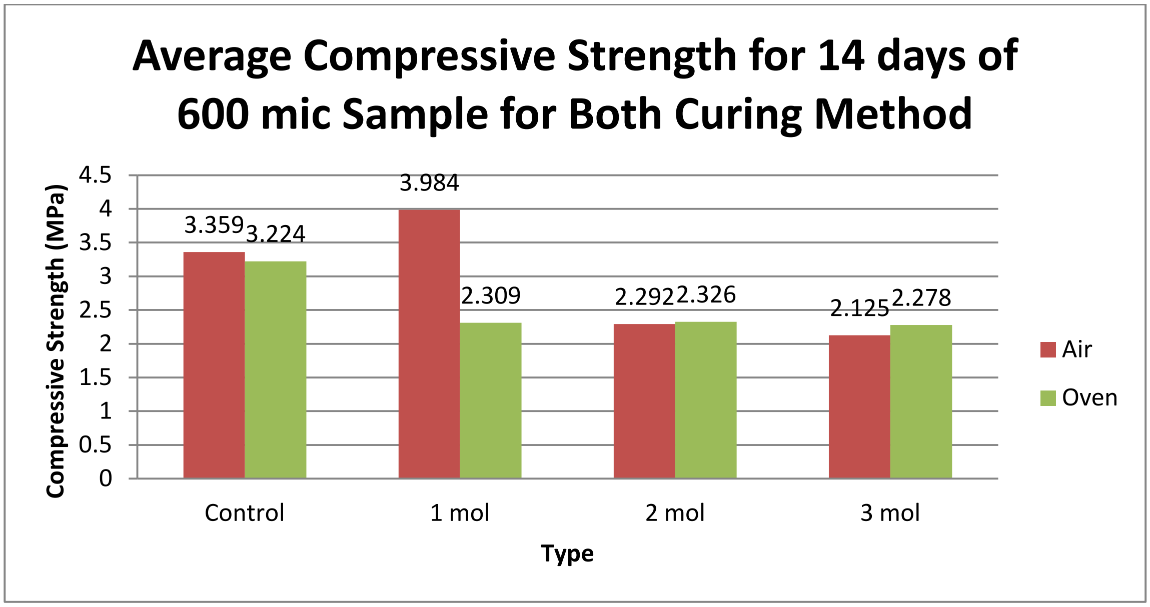

Figure 4.9: Comparison in strength for 600 micro samples at age of 14 days

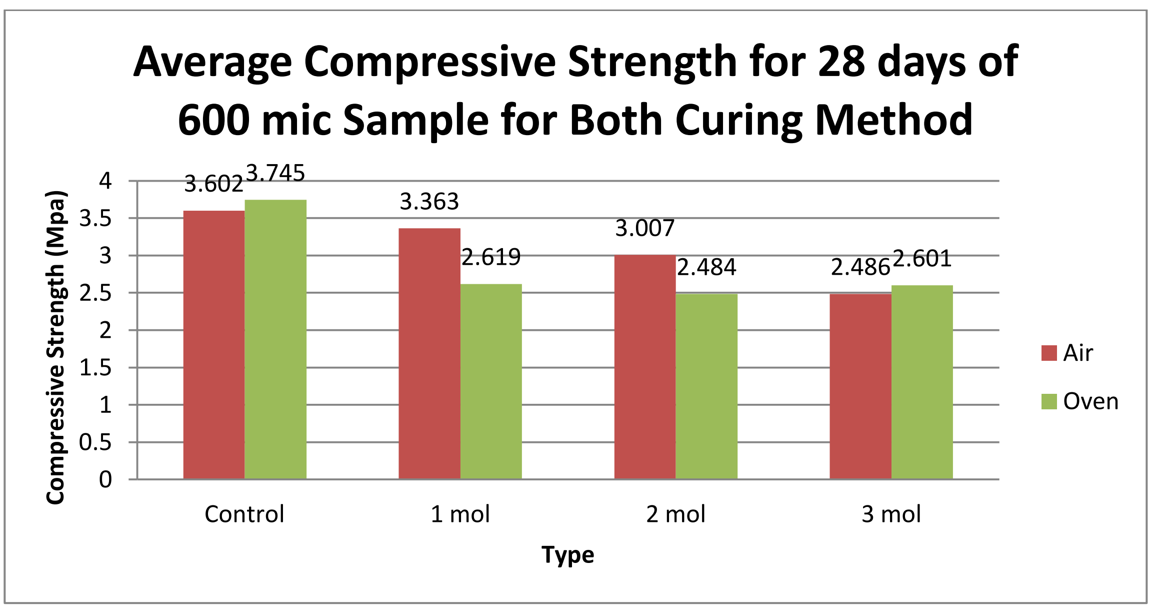

Figure 4.10: Comparison in strength for 600 micro samples at age of 28 days

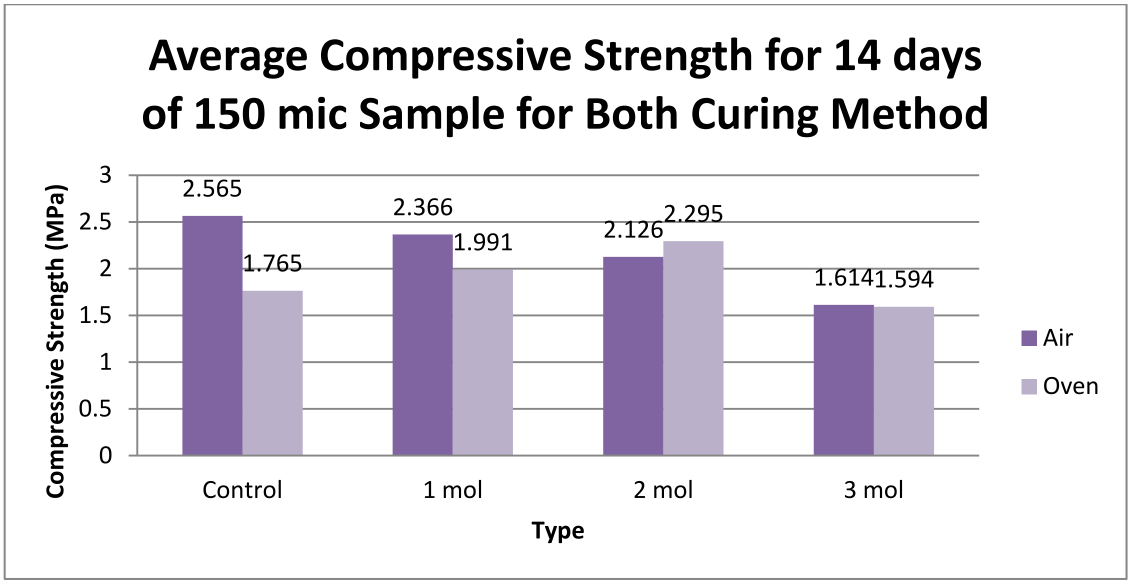

Figure 4.11: Comparison in strength for 150 micro samples at age of 14 days

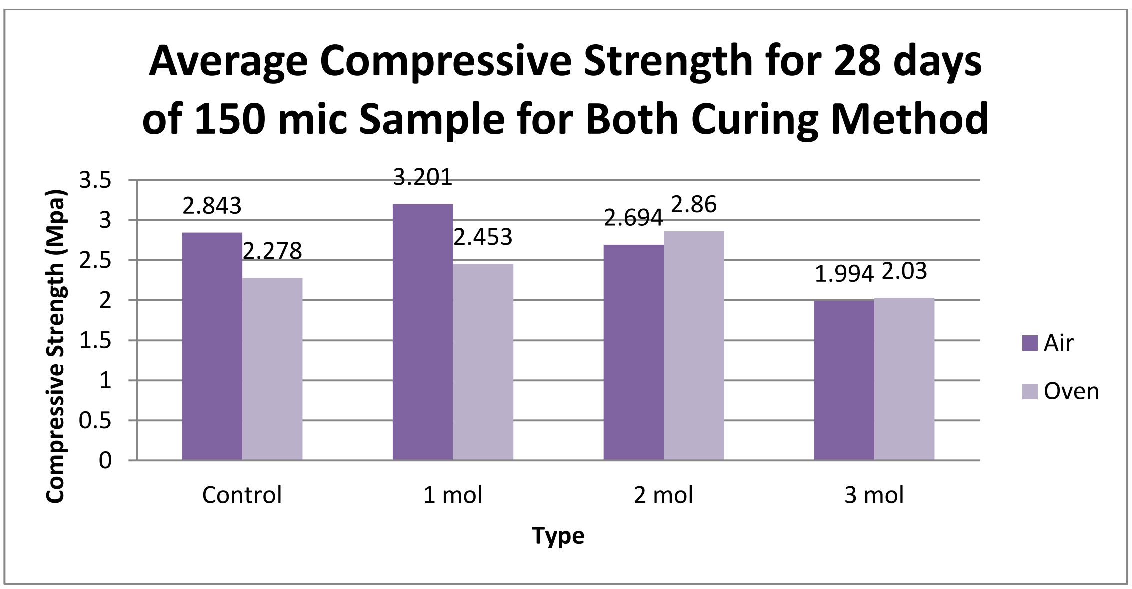

Figure 4.12: Comparison in strength for 150 micro samples at age of 28 days

The plotted results are based on the collected result from all cubes sample for 14 days and 28 days of the two studied curing method. Both curing method produce sample cubes with a same pattern of average compressive strength.

14 days of curing showing that, the compressive strength of cubes that undergo oven dry curing is slightly higher compared to sample that were air cured even with increasing concentration of NaOH. However, at the age of 28 days, the air curing method produce higher strength cement laterized cube sample compared to the oven dried sample even with NaOH presence. Thus, it indicates that oven dry method develops early strength for CLC, but produce lesser strength cubes for 28 days of curing. This result are the same as performed by Pangdaeng, et al.(2014), where they made comparison between vapour proof membrane curing, water curing and temperature curing. Vapour proof membrane, and water curing method resulted in additional OPC hydration and led to higher compressive strength while the temperature curing resulted in a high early compressive strength development. While for air curing method, it develops stronger CLC at longer periods of curing.

For oven dry method, rapid moisture lost is one of the factors that may affect the strength of CLC at 28 days of curing. As stated before, moisture is needed for cement to undergo hydration process which will provide better stabilization for the CLC. Besides that, the alkaline solution needs longer periods for the reactions with clay can fully reacted. Thus it is recommended to properly wrap the cubes before putting into oven to avoid lots of moisture loss.

As a conclusion, air curing is a better method to be implemented compare to the oven dry method because higher strength of cement laterized is needed for practically used as construction materials.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In this chapter, all the finding from the analysis of the obtained result will be concluded. The conclusion will be made based on the objectives of this research which determine either the objectives were successfully achieved or not. Besides that, included in this chapter is the recommendation as a solution to overcome the problems or error during this research was conducted.

5.2 CONCLUSION

The conclusions for this research are based on the discussion and analysis from the collected result. All the relationships that were discovered are closely related to the objectives for this research. The conclusion can be stated as follow:

- ***Objective 1***

The effect of concentration of additives, NaOH can be seen clearly where it increase the strength of CLC at a certain concentration. For this soil sample and mix ratio of 1:2:6, 1 mol of Sodium Hydroxide is recommended. Higher concentration will decrease the compressive strength of sample CLC. The highest strength achieved by sample 1.18mm with 1 mol NaOH concentration that is 4.364 MPa.

- ***Objective 2***

The relationship between grains sizes and concentration of NaOH shows that 1.18 mm produces the highest compressive strength for a concentration of 1 mol that is 4.364 MPa. Finer soil grain size CLC samples will have lower strength when added with NaOH. Compressive strength in term of soil grains with a control sample shows that 600 micro have the highest strength for both curing method. For air curing and oven dry, the strength are 3.602 MPa and 3.745 MPa respectively.150 micro soil grain sizes are not suitable for production of CLC where it produce an average of lower strength samples.

- ***Objectives 3***

Comparison between air curing method and oven dry method can be made where air curing is better than Oven dry method. Air curing produces higher strength of cubes at older age compare to oven dry samples. Besides, it is easier to be implemented in the construction industry without involving any other expensive equipment such as the oven.

From the overview of this research, additives can be used to increase the mechanical properties of material such as alkaline solution for laterite soil. However, an optimum amount must be clarified for the material to achieve the required strength. For example, different soil grains size may need different amount of additives. Besides that, curing method has proven to affect the compressive strength of cement laterized cube, there are many potential curing technique that can be applied but the best curing method for production of cement laterized samples are not discovered yet.

Last but not least, the required standard by Public Work Department for a load bearing wall cannot be achieved. The highest average compressive strength that can be produce by the samples for this research is 4.364 MPa where the required strength is 5.2 MPa. Hence, with a little more improvisations and more details precaution will help to improve this research to achieve the required strength.

5.3 RECOMMENDATIONS

This section will discuss on the recommendations, precaution, and improvisation that worth to be implemented for this research so a better and precise result can be obtained.

i. From this research, the range of additives concentration that increases the CLC strength is in between 1mol of NaOH. Thus, further research can be made by testing the CLC with different concentration that between the ranges to clarified the best amount of additives required for producing maximum strength of CLC.

ii. For oven dry method, the CLC must be wrapped air tight to prevent moisture lost during 24 hours of oven dry. Moisture content is important for the chemical reaction to take place.

iii. Longer period of curing is needed. For example, 2 months periods due to slow reaction of alkaline solution with soil. This will develop higher compressive strength of cement laterized cubes where a complete reaction can be achieved.

iv. The weight of samples must be in the same range to avoid different densities of CLC produced. Densities of compressed cube will affect the compressive strength thus giving inaccurate strength distribution for sample sets.

v. Better curing method should be carried out to obtain the best method which can be implemented in the construction industry and also cost effective.

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