EFFECT OF CEMENT – AGGREGATE RATIO WITH AN ALKALINE ADDITION (NaOH) ON THE MECHANICAL PROPERTIES OF COMPRESSED STABILISED EARTH CUBES

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Thesis submitted in partial fulfilment of the
requirements for the award of the degree of
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Special thanks…

To my beloved parents, family and fellow friends

And

To all my lectures…

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ABSTRACT

Compressed stabilized earth block (CSEB) is one of the new materials utilized as a part of Industrialized Building System (IBS). The usage of CSEB in development industry can be new construction material which is more efficient that can save overall construction period and cost. Nowadays, CSEB are one of the first choices as building materials that being used in the construction. There are so many factors that need to be considered in making stronger compressed stabilised earth cubes especially in term of its strength and durability that to be applied in building construction. The presence of an alkaline solution, optimum mix proportion (cement, soil and sand) and curing method will affect the cubes strength. The purposes for this research are to determine the compressive strength, abrasion and water absorption of the cubes by using different proportion ratios of aggregates added to the cement and also to determine the effect of alkaline to the compressive strength of the cubes. Three sets of cube which are constant in cement-aggregates ratio, 1:8 but different in soil-sand ratio (1:2:6, 1:3:5 and 1:4:4) were carried out. Each set will include an alkaline solution in different concentration which are 1, 2 and 3molarity. The only curing method used is air curing for 28 days. Cubes mechanical properties can be determine by compression test, abrasion test and water absorption test. The highest compressive strength result achieved for control is in 1:4:4 mix proportion with a value of 4.599MPa for 28 days curing age and for the presence of an alkaline solution the highest strength is in 1:4:4 mix proportion with 1mol of concentration, 4.555MPa. All cubes strength did not achieved 5.2MPa at 28 days aged of curing to satisfy the minimum permissible average compressive strength for the cubes. Water absorption for 1:3:5 cubes mix proportion shows lowest percentage compare to the others. The cubes also have their own durability and would be able withstand in harsh environment since the average percentage losses are very small which is less than 1.5%.

ABSTRAK

Kestabilan Mampatan blok (CSEB) merupakan salah satu bahan baru yang digunakan sebagai sebahagian daripada sistem pembinaan industri (IBS). Penggunaan CSEB dalam industri boleh menjadi bahan pembinaan yang baru yang lebih efisyen yang boleh menjimatkan kos dan tempoh keseluruhan pembinaan. Terdapat banyak faktor yang perlu dipertimbang dalam membuat kiub yang lebih kukuh terutamanya dari segi kekuatan dan ketahanan kiub yang digunakan dalam pembinaan bangunan. Kehadiran larutan alkali, nisbah campuran yang optimum (simen, tanah dan pasir) dan kaedah pengawetan akan memberi kesan kepada kekuatan kiub. Kajian ini dilaksanakan adalah untuk menentukan kekuatan, lelasan dan penyerapan air kiub dengan menggunakan perkadaran nisbah yang berbeza bagi tanah dan pasir yang ditambah kepada simen dan juga untuk menentukan kesan alkali untuk kekuatan mampatan kiub. Tiga set kiub dalam nisbah simen agregat yang sama iaitu 1:8 tetapi berbeza dalam nisbah tanah-pasir (1:2:6, 1:3:5 dan 1:4:4) telah dijalankan. Setiap set akan diuji dengan larutan alkali dalam kepekatan yang berbeza iaitu 1, 2 dan 3molariti. Satu-satunya kaedah pengawetan yang digunakan adalah pengawetan udara selama 28 hari. Sifat mekanik bongkah boleh ditentukan dengan ujian mampatan, ujian lelasan dan ujian penyerapan air. Hasil kekuatan tertinggi mampatan dicapai untuk kawalan adalah dalam nisbah 1:4:4 yang bernilai 4.599MPa selama 28 hari pengawetan dan bagi kehadiran larutan alkali kekuatan yang paling tinggi adalah dalam nisbah 1:4:4 dengan 1mol kepekatan alkali, 4.555MPa. Semua kiub tidak mencapai kekuatan 5.2MPa pada 28 hari pengawetan yang perlu dicapai oleh kiub. Penyerapan air untuk 1:3:5 nisbah campuran kiub menunjukkan peratusan terendah berbanding dengan yang lain. Kiub juga mempunyai ketahanan mereka sendiri dan akan dapat bertahan dalam persekitaran yang keras apabila ia menunjukkan purata peratusan yang sangat kecil iaitu kurang daripada 1.5%.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The provision of housing is a test confronted by all nations around the globe, particularly in developing nation like Malaysia. With the increment of development materials expenses as for example, cement, steel and timber; builders are not always have a desire to construct a house on a tight plan. Several possible solutions has been investigated to reach the goal as to fulfil client demand by using minimal effort building material and cost but still can produce affordable and good quality of housing.

Compressed Stabilised Earth Block (CSEB) is one of the new development materials utilizing pre-assembled parts that can interlock to each other and it's improvise from ordinary steps that do not require mortar in bricklaying work. The

quantity of cement that reacts as stabilised agent and the laterite soil are needed as to build quality of laterite CSEB. The common sense utilization of cubes method in development will minimise the total cost and time spend as there will be no mortar include in bricklaying work. Furthermore, it does not need talented and experienced worker (Nasly et al, 2009). The utilization of laterite CSEB is a perfect solution due to decreasing the materials usage and development cost (Adeyeye, 2012).

From the previous study that made by Ahmad Rashdan bin Mansor in 2014, two types of curing method were conducted which are left in sun for set 1 and left in shade for set 2. Three sets of block were prepared with the ratio used are different between each other, 1:2:6, 1:1:6, 1:0.5:6 (cement, laterite soil, sand) with the addition of alkaline solution of 1 molarity and 2 molarity of 1:2:6 mixture. Besides that, the laterite soils were obtained from nearby site location at University Malaysia Pahang, Kuantan.

At all stage of 7days, 14days and 28days of ages, curing set 1which is left in sun was stronger than curing set 2. The maximum compressive strength that was recorded for ratio curing set 1 at 28 days was 3.96Mpa. Furthermore, the ratio of 1:1:6 was stronger than ratio 1:0.5:6 and 1:2:6 at all stage of ages ratio. The highest compressive strength was in ratio 1:1:6 at 28 days of age recorded was 5.63Mpa. Moreover, the highest compressive strength is in 2 molarity alkaline solutions on 28 days which is 5.4Mpa but slightly higher than 2 molarity alkaline solutions, 5.06MPa.

From the previous study that made by Habsullah Ali b Abd Rahim and Muhamad Zulkarnain b Zainal in 2014, the highest compressive strength of interlocking blocks were achieved 7.01MPa in 7 days of aged of curing when it was dried in sun.

This study will explore more on physical and mechanical properties of the cubes by using different ratio of aggregates with a constant amount of cement with the presence of an alkaline solution (NaOH).

1.2 Problem Statement

Cement and clay substances in cubes had a potential in determining the compressive strength, however the ideal ratio between cement-aggregates is not decided yet for minimum permissible average compressive strength for the cubes which is 5.2MPa according to an American Standard Testing Machine (ASTM) C-129 at the 28 days aged of curing. Optimum mixed proportions will give high quality with a maximum strength of a cube.

The standard compression strength that needs to achieve by the cubes is 5.2 N/mm2 for load bearing wall. Based on previous research, the optimum mix proportion had been obtained which is 1:2:6 and the strength of cubes will increase if the concentration of an alkaline solution increases. The expected result will be the cubes by using laterite soil with the present of alkaline can achieved the minimum permissible average compressive strength for the cubes is 5.2MPa at 28 days aged of curing.

1.3 Objective of Study

The main objective for this research is to determine the mechanical properties of cubes in the presence of an alkaline solution, Sodium hydroxide (NaOH) 1, 2 and 3molarity. Other sub objectives that may follow this research are:

i. To determine the compressive strength, abrasion and water absorption of cubes.
ii. To determine optimum mix proportion of cement ratio between laterite soil and sand.
iii. To determine the effect of alkaline solution to cubes in different soil-sand ratio with a constant amount of cement.

1.4 Scope of Study

The scopes of study are focus on:

i. Testing the properties of soil with mineralogy test, hydrometer test, Atterberg limit test and sieve analysis.
ii. Testing the properties of cubes with compression test, abrasion and water absorption.
iii. Testing the cubes strength with the presence of an alkaline solution (1,2 and 3 molarity)
iv. Produce the cubes using same cement-aggregates ratios (1:8) but varies in laterite soil to sand ratio.

1.5 Significance of Study

This research is to determine the cubes optimum mix design by improving its mechanical properties in the different concentration of an alkaline solution. Cubes mechanical properties include its compressive strength, durability and water absorption. This research will study the effect of an alkaline solution towards the cubes strength, durability, water absorption and the advantages by using an alkaline solution in the making of cubes. In the end of this research, the cubes optimum mix proportion and the effect of an alkaline solution to the cubes will be known.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In general, some of laterites soils have a chemical reaction when it mixed with an alkaline solution by depending on the amount of clay content thus producing hard and durable building materials such as stabilized earth blocks. The laterite soils have a tendency to harden in the presence of on air moisture content, which is the reason why blocks have traditionally been widely used in India and it’s allowed to harden and then used for masonry wall construction.

2.2 LATERITE SOIL

The regular meaning of induration is a state in which the consistency of the medium is not influenced by humidity. Laterites very good material to structure yet can be diminished to some structural elements such as the indurated elements that form coherent skeleton and cement pre-existing materials. Furthermore, the level of laterite soil hardness ranges is basically from items that are unconsolidated to the hardest blocks which can be broken by using a hammer. The laterite soil hardness increase as the iron substance increase; minimum hydrated will give greater laterites value (Maignien, 1966).

Laterites are varying in colour, yet there are normally come in brightly colour. The shades are most as often as possible experienced are pink, orange, red and brown. Laterites owe their colour to iron oxides in different conditions of hydration. The physical properties of lateritic soil depend on mineralogical composition and molecule size distribution of the soil. One of the primary focal points of lateritic material is that it doesn't promptly swell with water. This makes it good for pressing material especially when it is not too sandy (Maignien, 1966).

2.3 BENEFITS AND LATERITIC MATERIAL IMPLEMENTATION

Lateritic material helps in decreasing quantity of cement utilized as a part of worldwide building construction. The decreasing in cement utilization through the utilization of environmental friendly building materials such as CSEB is a perfect approach to secure our surroundings through the lessening of energy consumption and CO2 emanations. In addition, the decision by using laterite materials is majorly because of financial factors. Based on Figure 2.1 below, there are some examples on how the laterite materials are being used around the world (Patrick, 2011).

Figure 2.1: Implementation of compressed earth block (Lemougna, 2011)

2.4 ALKALINE ACTIVATION

Alkaline cements are new binders, as an option to traditional Portland cements, acquired through the alkaline activation of varies industrial by-products. These new building materials are describe by its extraordinary mechanical performance, low energy cost and low pollutant gas emissions (CO2, SO2 etc.) produces during the manufacturing process of ordinary Portland cement (OPC). Furthermore, the presence of alkaline solution in the cement mixture can produce earlier and higher mechanical strengths (they can reach 100MPa at 28 days). Besides that, it’s also have lower hydration heat and stronger resistance to chemical attack. The only disadvantage that can be described is its high shrinkage rate with formation of micro cracking (Wang et al., 1994).

The alkaline activation of materials is a substance reaction and transformation that gives a quick change of some particular structures, partial or totally amorphous and/or meta-stables, well-compacted and cementitious composites. Most of the environmental impact of the alkaline activation technique remains in the production of the alkaline activator compounds, namely sodium hydroxide and sodium silicate (Provis, 2009). In general, the alkaline activation was indicating to gives incredible results with respect to the changes in mechanical properties of CEBs manufactured. In other word, it can give a lot of advantages due to environmental impact and cost.

Geopolymers that had been conducted with a 14 M solution of NaOH gave a higher resistance to compression test than the samples conducted with a 8 M solution of NaOH, without comparing the curing temperature and age (Hardjito & Rangan, 2005). Moreover, the NaOH concentration solution plays an important factor in the strength of alkali activated fly ash-based geopolymers.

It has been observed that through chemical polymerisation which is mineral polymerization method, minerals such as clay could be hardened and changed into helpful construction materials (Ingles, 1970). All these mineral polymers are produced at minimum temperature by utilising minimal energy input. In this process, the aluminosilicate kaolinite responds with alkali at low temperatures and polycondenses into hydroxysodalite, which is a stable and hard material. Thus, mineral polymers and alkali-activated poly-aluminosilicates have been gradually gaining the consideration of the world as they are getting to be potential progressive materials (Patfoort & Wastiels, 1989). Several factors that can influence the overall compressive strength which are:

a) Variation of Sodium hydroxide

In increasing the amount of Sodium hydroxide (NaOH) will increase the total amount of compressive strength of all cylinder specimens with 50mm height and 25 diameter:

S1: dried cylinder specimens

S2: immersed cylinder specimens

S3: cycled wet cylinder specimens

S4: dried cycled cylinder specimens

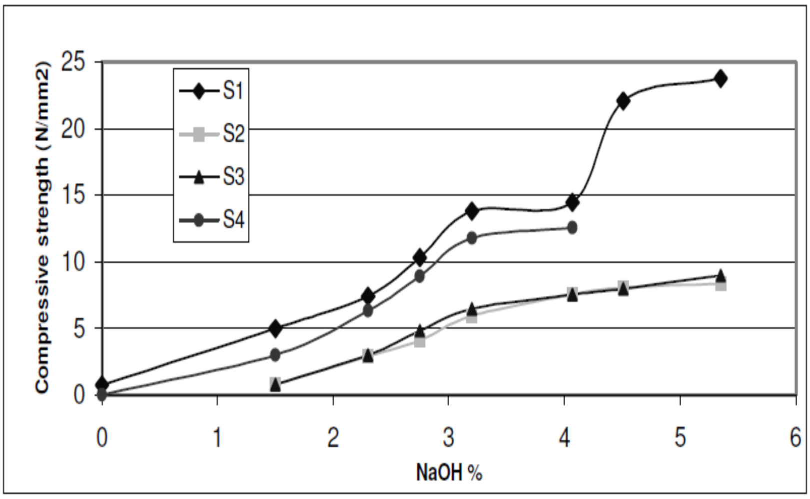

Figure 2.2: Compressive strength as a function of percentage NaOH (Alshaaer, 2000).

b) Variation of water content

The specimen compressive strength can be increase when the water content is closer to plasticity limit of the clay (Alshaaer, 2000).

c) Soil Aggregates

The decreasing in size of the clay aggregates will increase the compressive strength. Basically, crushing soil sample into very small aggregates (less than 106 µm) has been demonstrated successful in order to achieve a solid construction material and provide larger surface reaction between the the soil and the NaOH solution. This reaction produces stronger network polymer, which ties the grains of the material together (Alshaaer, 2000).

d) Additional treatment to improve the compression strength

The cylinder specimen that being cured in 80 C, and afterward were immersed in concentrated NaOH solution (± 5 M) will give a better compressive strength result compared to the normal treatment. Figure 2.3 shows the relation between duration of heating and specimen strength.

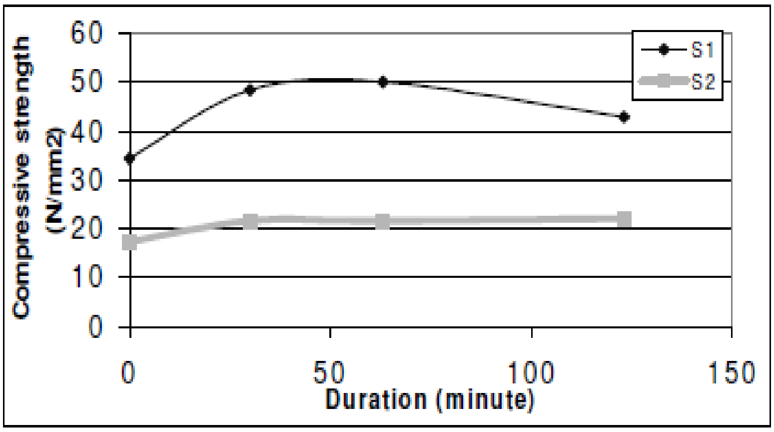

Figure 2.3: Variation of compressive strength with heating duration (Alshaaer, 2000).

Moreover, by referring the figure 2.4, heating the NaOH solution containing the specimens at 80 C around 50 minutes will change the NaOH density and shows a large increment in compressive strength with good stability under dry and wet conditions. Optimizing the heating time is essential in improving the quality and stability of the material.

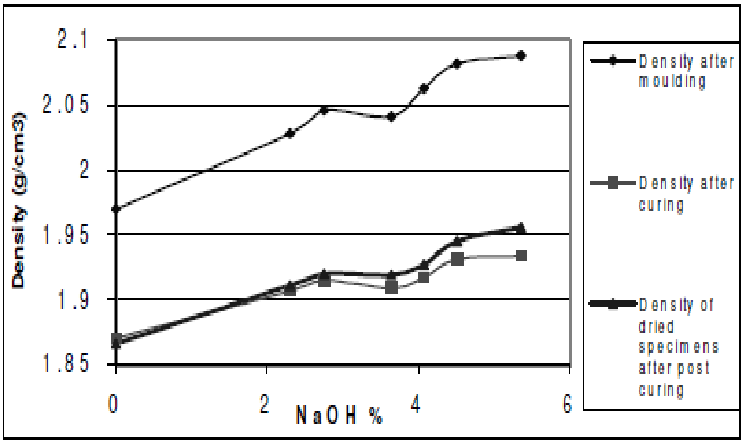

Figure 2.4: Variation of density with percentage NaOH (Alshaaer, 2000).

The sand/clay ratio should be optimized, as the mechanical and physical properties of the material depend generally on this proportion. In addition to that, use small amount of NaOH solution to avoid alkali/salt residual in the material and for financial reasons. Moreover, the density of alkali solution will be increase with increasing the amount of NaOH content or by using water close to the plasticity limit of the clay. In term of compressive strength, it will be decrease if the amount/percentage of NaOH in the specimen increases up above the optimum value because of the increasing the NaOH residual in the structure of the mineral polymers. The remaining NaOH could change to salts by absorption CO2 from the air, thus decreasing the strength and stability of the material (Alshaaer, 2000).

2.5 COMPRESSIVE STRENGTH

The reason for performing the compressive strength test is to determine the load-bearing limits of the cubes. The block compressive strength relies on upon different factors such as materials utilized, moisture content, curing period and curing method.

From previous research that had been done (Rashdan, 2014), two types of curing method were conducted which are left in sun for set 1 and left in shade for set 2. Three sets of block were prepared with the ratio used are different between each other, 1:2:6, 1:1:6, 1:0.5:6 (cement, laterite soil, sand) with the addition of alkaline solution of 1 molarity and 2 molarity of 1:2:6 mixture. At all stage of 7days, 14days and 28days of ages, curing set 1which is left in sun was stronger than curing set 2. The maximum compressive strength that was recorded for ratio curing set 1 at 28 days was 3.96Mpa. Furthermore, the ratio of 1:1:6 was stronger than ratio 1:0.5:6 and 1:2:6 at all stage of ages ratio. The highest compressive strength was in ratio 1:1:6 at 28 days of age recorded was 5.63Mpa. Moreover, the highest compressive strength is in 2 molarity alkaline solutions on 28 days which is 5.4MPa but slightly higher than 2 molarity alkaline solutions, 5.06MPa. The highest compressive strength of interlocking blocks were achieved 7.01MPa in 7 days of aged of curing when it was dried in sun (Zulkarnain, 2014).

The average compressive strength for the compressed stabilised earth cubes which is 3.5MPa according to an American Standard Testing Machine (ASTM) C-129 at the 28 days aged of compressive strength. 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.

2.6 DISCUSSION

From the analysis in the previous studies regarding to this research, the optimum mix proportion to produce the cube will be 1:2:6 mix proportion while the reaction between the NaOH concentrations with the differences cement-aggregates ratio of cubes must be discovered. To be remembered, the increasing of laterite soil in a constant amount of cement can reduce the strength of cubes. The 1:2:6 mix proportion will be used as a part in compressive strength analysis in the presence of an alkaline solution in different concentrations. For the curing method, this research will undergo air curing for 28 days.

The presence of alkaline solution can increase the strength of CSEB. On top of that, the study on the strength of CSEB in increasing concentration of alkaline solution shows an increment in compressive strength value (Rashdan, 2014). Moreover, the higher the amount of cement used in the concrete mixture will give a greater strength to the cubes.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

Each research needs a lot of attention on the research methods. This part will be discuss about the steps involve in this research in detail. In other words, this research was conducted based on methodology part. The methodology is so important to ensure the research will be study correctly. A constant mix proportion 1:8 cement-aggregates ratio but varies in laterite soil-sand ratios in the presence of an alkaline solution will be used to check either it can gives an impact to the results.

The laterite soil that gets from Kerteh, Terengganu will be testing first before its will be used as a part of cube. The cubes were undergoing air cured and water was sprinkled to cubes twice per day (morning and evening) for 7 days. The total batches in this research are 144 batches. These batches contain laterite soil, fine sand and concrete as stabilizer with proportion of 1:2:6, 1:3:5 and 1:4:4 in the presence of different concentration of an alkaline solution. For this research, there are 2 sorts of test that had been made, that is for the laterite soil itself and for the cubes. To determine the properties of the laterite soil, it will undergo various type of test. As for example, Mineralogy Test, Atterberg limit test and sieve analysis. Compression test, water absorption test, and abrasion test will be conducted after the cubes have been cured for 28 days. The objectives of the tests are as below:

- Mineralogy - Sample of soil tested on Central Lab to get mineral content and pH value of the laterite soil.
- Atterberg Limit - Basic index information about soil to estimate strength and settlement characteristic as Plasticity Index, Plastic Limit, Liquid Limit and Shrinkage Limit.
- Sieve Analysis - To obtain finer percent of laterite soil from 5mm to pan.
- Water Absorption - Determine moisture absorption percentage.
- Abrasion - Determine durability of the laterite cubes.
- Compression - Determine the strength of the cubes.

3.2 MATERIALS PREPARATION AND TESTING

This section will mainly focus on the preparation of raw materials needed to produce the CSEB cubes. These raw materials include Ordinary Portland Cement (OPC), Fresh Laterite Soil, River Sand and Sodium hydroxide (NaOH) as an alkaline solution. The total amounts of the material are:

- Laterite soil - 86.40 Kg
- Mine sand - 144.0 Kg
- Portland Cement - 28.80 Kg

3.2.1 Ordinary Portland Cement (OPC)

There are so many types of Portland cement available in the market. In this study, Ordinary Portland Cement is decided to be utilized as a part of creating the cubes. OPC is being widely used and become popular in construction field.

Figure 3.1: 'Orang Kuat' OPC

3.2.2 Laterite Soil

The laterite soils were obtained from Kerteh, Terengganu and will be tested before its being use in cubes. By using laterite soil, it becomes an alternative material in cubes production that usually used sand and cement only.

Figure 3.2: Laterite soils

3.2.3 Sand

River sand has been decided to be utilized as a part of this study as the natural fine aggregate and before that, it must be sieve through 1.18mm. Essentially, mine sand is the main choice to be used however it is uneasy to acquire it.

Figure 3.3: River sand

3.2.4 Alkaline solution admixture

Alkaline was the admixture in the cubes. The alkaline solution that had been used was sodium hydroxide, NaOH with different concentration which are 1, 2 and 3 mol. Each molarity will be applied to each group of cubes which represent the differences laterite soil-sand content ratio.

3.2.5 Water

The water is additionally required in the mixing procedure. Specified water content used as a part of the mix proportion is depending on laterite soil plastic limit.

3.2.6 Mineralogy Test

Before the new soil is use to produce the cubes, it will undergo the Mineralogy test to determine the specific type of soil and mineral substance in the soil. The fresh soil will be send to UMP Centre Lab for Mineralogy testing.

3.2.7 Atterberg Limit

Fine grained soil can exist in any several states (liquid, plastic, semi-solid or solid) depends on the amount of water in the soil system. Atterberg limit test is carried out to get the basic index information of soil to estimate the strength and settlement characteristic such as Plasticity Index, Plastic limit and liquid limit. Reference standard use for this test is BS1377: Part 2:1990 and BS1377: Part 2:1990:5.3.

3.2.8 Sieve Analysis

The objective of this analysis is to produce a “Grading Curve” for fine aggregate according to BS 1377: Part 2:1990:9.2/9.3/9.4/9.6/9.7. The procedure of sieve analysis is according to the BS 882. It is to determine how many percentages of silt and clay in the soil. Only gravel and sand particle from soil will be used to produce the cubes as the silt and clay give a low compressive strength.

Test Procedure:

i. Crush the soil using Jaw Crusher machine and sieved through 1.18mm sieve for laterite soil.
ii. For river sand, after sieved through 1.18mm sieve

3.2.9 Crushing and Sieving

Crushing and sieving procedure will be done on fresh laterite soil. The fresh laterite soil will be air-dried for a couple days and afterward it will be crushed by using Jaw Crusher machine. Just after the soil crushed using the machine, then it will be sieve by using sieve machine to get a finer laterite soil (1.18mm).

3.3 CURING SETS

There is only one type of curing process which is air dry. The set will undergo compressive strength test after 28 days curing aged. A constant 1:8, cement-aggregates ratio will be used.

3.3.1 Curing Process

The completed produce cubes will be subjected to curing process. The cubes will be place on the table provided and will be sprinkle with water twice per day which is first in the morning and then in the evening for 7 days. 3 nos samples will be subjected to this type of curing process.

3.3.2 Mix Proportion

The constant ratio 1:2:6 of cement-laterite-sand for the curing set will be used as a control mix proportion and for the alkaline addition; a constant amount of cement with different aggregates ratios will be used.

Table 3.1: Mix proportion and the number of block include in each test

Sample	**type**	**Cement: aggregates**	**Compression test**	**Water absorption test**	**Abrasion test**	**Total**
1	Control	1:2:6 1:3:5 1:4:4	18	9	9	36
2	1 mol alkaline	1:2:6 1:3:5 1:4:4	18	9	9	36
3	2 mol alkaline	1:2:6 1:3:5 1:4:4	18	9	9	36
4	3 mol alkaline	1:2:6 1:3:5 1:4:4	18	9	9	36
GRAND TOTAL						**144**

For one batch, eg 1:2:6;

Compression test : 6 (14 days curing) + 6 (28 days curing)

Water absorption : 3 (28 days curing)

Abrasion : 3 (28 days curing)

3.4 MIXING PROCESS

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

3.4.1 Mixing Procedure

i. The materials required are first being prepared and weighed accordingly.
ii. The soil and sand will be first poured in the concrete mixing tray and properly blended together and then followed by pouring the cement.
iii. After the materials are mix well together, water/alkaline solution (according to the laterite soil plastic limit) will be added gradually by using a watering pot.
iv. Weighted the mixture 1.8kg for each cube as a preparation for casting.
v. The mixture poured on the iron mould cube in size 100 mm x 100 mm x 100 mm and pressure was slowly applied.
vi. Pull out the cube after 10 seconds cube was compressed and placed the cube on top of wooden plate.
vii. For other specimen, repeat the step from i to vi.

Figure 3.4: Cubes mixing and production

3.5 COMPRESSION STRENGTH TEST

The objective of this test is to prescribe the compressive strength of the cube samples. The compression strength test will be carried out on the 14 and 28 days age of the cubes. This test results will know whether the cubes are satisfy the minimum requirement strength to be used as a wall structure. In a concrete compression test, samples are prepared in 100 mm concrete cube. Reference standard: BS 1881: Part 116:1983.

3.5.1 Testing Procedure

i. The cubes must be dry before testing.
ii. Three concrete specimens were used for testing
iii. The cubes will be weighted and the surface area of the cubes will be measured.
iv. The cubes will be placed between two steel plates and will be placed in the compression strength testing machine.
v. Start the compression machine with the load applied continuously with nominal increasing rate. When the load applied begins to decreases, remove the sample. The maximum load is then recorded.
vi. The process was repeated for other cubes.
vii. The ultimate compressive strength for each cube samples will be calculated and analysed.

Figure 3.5: Compression test machine

3.6 WATER ABSORPTION

This test was performed by randomly selecting three cubes from each group of samples at specified age. Record the weight of cubes on balance and immerse the cubes completely in water for 24 hours by referring Figure 3.5 and after remove the cubes, record the weight again, The percentages of the water absorbed by the cubes were calculated and the average results for each group of samples are estimates as follows:

$$Wa = \frac{Ws - Wd}{Wd} \; x \; 100\%$$

Where:

Wa = Percentage of water absorption

Wd = Weight of dry cubes

Ws = Weight of immersed cubes

Figure 3.6: Cubes immersed in water

3.7 ABRASION TEST

This test was performed to focus on the durability of the cubes against the extreme environmental roughness on construction site. This test was done by selecting select three cubes from each group of samples and weighing them on a balance. After the weights were recorded, the cubes were place on a smooth surface and afterward wire-brushed to and fro on all surfaces for 50 occasions. After brushing the cubes, their weights were record once again and the amount of materials abraded was calculated.

Figure 3.7: Cubes brushed on to all surfaces

CHAPTER 4

RESULT AND DISCUSSION

4.1 GENERAL

This part will examine about the outcome that were obtain from the laboratory testing that had been conducted before. All the information will be recorded and examined in table and graphical structure to relate the information to one another between the tested parameter. In the discussion part, the factors/errors that impacted the testing results will be discussed about.

From this research, several cubes data are acquired from the lab testing which are the compressive strength, water absorption and abrasion as mechanical properties of the cubes. Various result were obtained in each mix proportion and give different graph shape that will be used to define the optimum mix ratio that gives the highest value of compressive strength. The material properties like Atterberg limit, sieve and direct shear also additionally displayed in this area.

4.2 SIEVE ANALYSIS

Based on the table below, it shows all the data and particle size distribution chart for laterite soil that being used in this research. The laterite soil was taken from Kerteh, Terengganu.

Table 4.1: Result for 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	100.00		

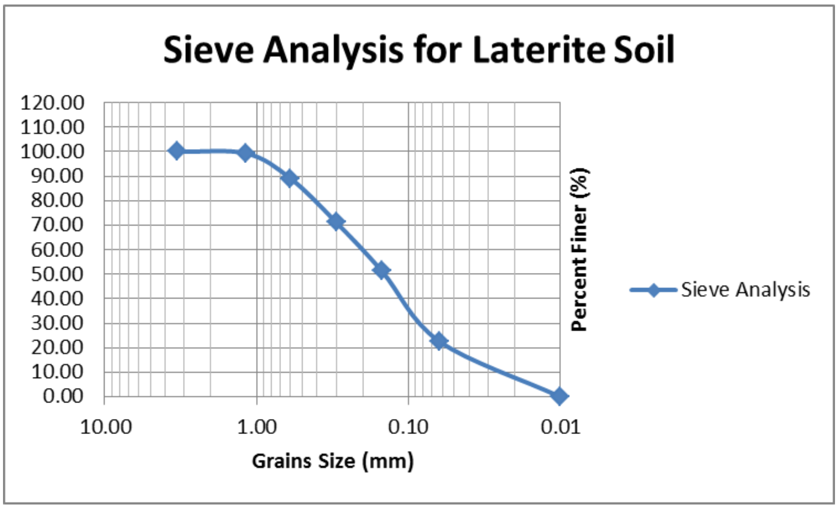

Figure 4.1: Size distribution of laterite soil particles

Based on laterite soil sieve analysis, the result shows that the laterite soil has contain 30% of silt content.

4.3 ATTENBERG LIMIT TEST

The table below shows the liquid limit and plastic limit data to obtain moisture contain of the laterite soil. The laterite soil was taken from Kerteh, Terengganu.

Table 4.2: Result for liquid limit of 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: Result for plastic limit of 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		

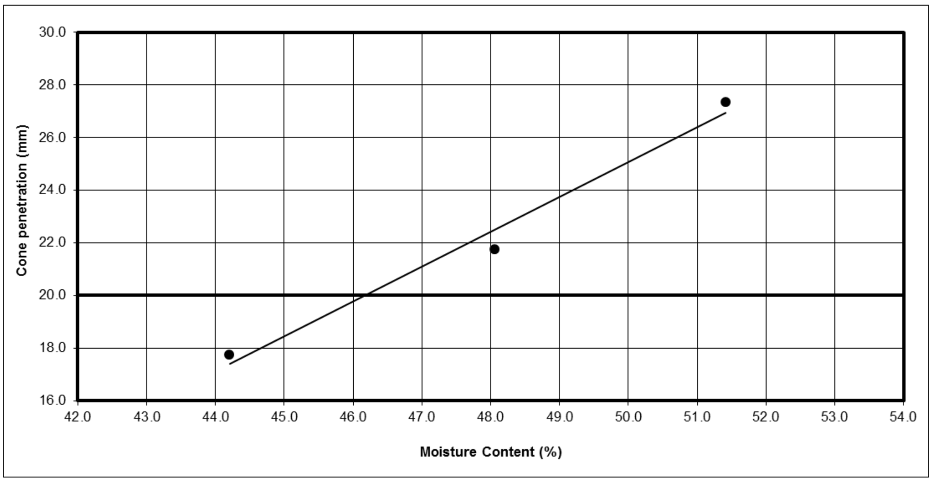

Figure 4.2: Moisture content of laterite soil

From this Attenberg limit test, the laterite soil contain 47.83% of an average moisture content for liquid limit and 21.2% of an average moisture content for plastic limit and from the figure above, it shows 0.99 gradient of correlation coefficient.

4.4 COMPRESSIVE STRENGTH

The compressive strength test had been carried out from various soil-sand ratio with a constant amount of cement with an increasing alkaline solution concentration at age of 14 and 28 days. Each mix proportion consist of 4 sets/type which are control, 1mol, 2mol and 3mol. Three samples in each set are tested to obtain an average value of compressive strength

4.4.1 Different Ratio Trial

From the previous research (Rashdan, 2014), the optimum mix proportion was obtained which is 1:2:6. By referring the objective that stated earlier, this research was conducted to determine optimum mix proportion of cement ratio with laterite soil and sand for stronger cubes, thus three sets of cubes with varies aggregates ration but constant amount of cement had been prepared and ready for a compressive strength test. The ratios were 1:2:6, 1:3:5 and 1:4:4 (cement, laterite soil, sand) with no presence of an alkaline solution.

Table 4.4: Average compressive strength result in absence NaOH

Mix	**1:2:6**			**1:3:5**			**1:4:4**		
compressive strength	Weight (g)	kN	MPa	Weight (g)	kN	MPa	Weight (g)	kN	MPa
14 days compressed Strength	1.729	15.911	1.591	1.771	39.063	3.906	1.771	43.047	4.305
28 days compressed Strength	1.751	20.363	2.036	1.756	40.559	4.056	1.878	45.997	4.599

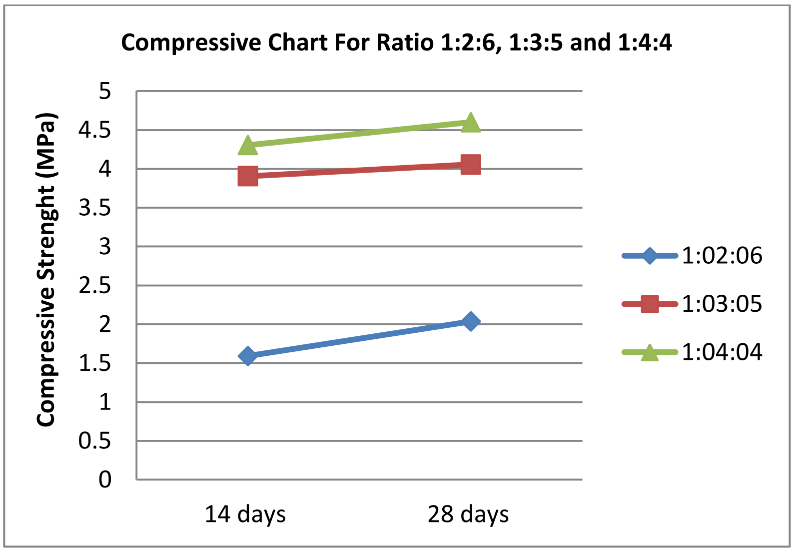

Figure 4.3: Compressive strength chart in absence NaOH

The compressive strength tests were conducted to the control specimen when it was reached the age of 14 and 28 days. By referring Table 4.1 and Figure 4.1, the 1:4:4 mix proportion give the highest average compressive strength value of 4.599MPa while the 1:2:6 mix proportion give the least average compressive strength value of 2.036MPa on 28 days curing aged. The outcomes also demonstrate positive increments of an average compressive strength value from 14 to 28 days aged of curing but this mix proportion still not achieved the minimum requirement set by JKR for external walls (5.2MPa).

4.4.2 Alkaline solution sets

In the objective of this research was to determine the effect alkalinity of 1, 2 and 3 molarity of an alkaline solution had been chosen for the admixture to cubes. The effect of alkaline solution will bring extra strength to the compressive strength.

Table 4.5: Average compressive strength result in presence NaOH

	1:2:6				1:3:5				1:4:4			
type	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol
14 days compressed Strength	1.591	1.561	2.318	1.506	3.906	3.378	3.409	3.094	4.305	4.589	3.094	3.415
28 days compressed Strength	2.036	2.089	3.522	2.011	4.056	4.223	3.751	4.330	4.599	4.555	3.594	3.829

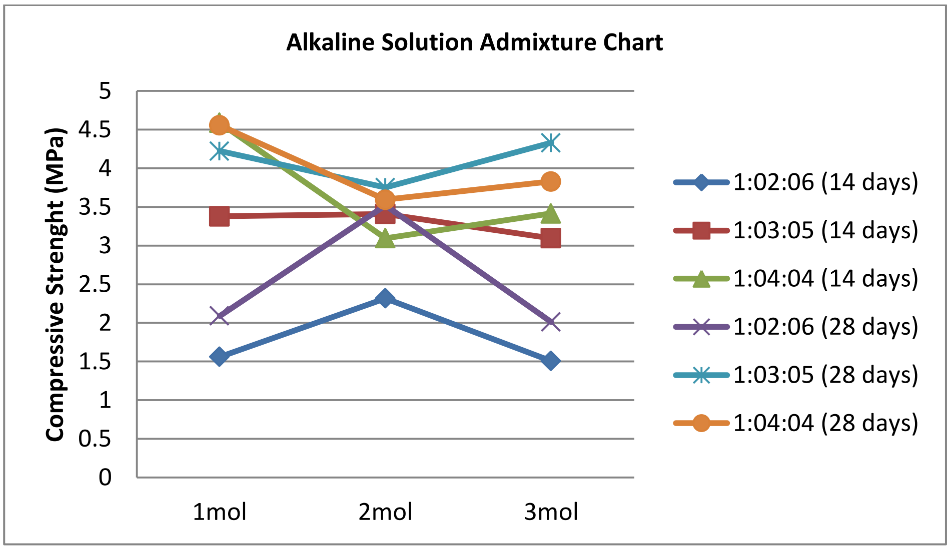

Figure 4.4: Compressive strength chart in presence NaOH

The compressive strength tests were conducted from 1mol concentration until 3mol concentration when the cubes were reached the age of 14 and 28 days. Based on Table 4.2 and Figure 4.2, the 1:4:4 mix proportion with 1mol concentration at the 28 days aged of curing gives the highest average compressive strength value of 4.555MPa while the 1:2:6 mix proportion give the least average compressive strength value of 2.036MPa on 28 days curing aged. By referring the graph above, the result pattern of the cubes strength are not consistent with an increasing alkaline concentration. All mix proportions still not achieved the minimum requirement set by JKR for external walls (5.2 MPa).

4.5 WATER ABSORPTION

The objective of water absorption test was to focus on determining the percentage of water that being absorb by the cubes. Select three cubes at 28 days aged of curing for each type of the specified mix proportions. Record the weight of cubes on a balance. Submerge the cubes totally in water for 24 hours and record the weight of the cubes again.

Table 4.6: Water absorption result for 1:2:6, control

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:2:6	Control	1775	2042	267	15.04	16.49
		1763	2032	269	15.26	
		1639	1953	314	19.16	

Table 4.7: Water absorption result for 1:2:6, 1mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:2:6	1mol	1698	1987	289	17.00	17.31
		1711	1995	284	16.60	
		1641	1942	301	18.34	

Table 4.8: Water absorption result for 1:2:6, 2mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:2:6	2mol	1832	2067	235	12.83	12.76
		1873	2094	221	11.80	
		1780	2023	243	13.65	

Table 4.9: Water absorption result for 1:2:6, 3mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:2:6	3mol	1713	1972	259	15.12	14.93
		1757	2014	257	14.63	
		1717	1975	258	15.03	

Table 4.10: Water absorption result for 1:3:5, control

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:3:5	Control	1774	2027	253	14.26	13.69
		1802	2040	238	13.21	
		1781	2023	242	13.59	

Table 4.11: Water absorption result for 1:3:5, 1mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:3:5	1mol	1789	2010	221	12.35	12.73
		1770	1996	226	12.79	
		1779	2011	232	13.04	

Table 4.12: Water absorption result for 1:3:5, 2mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:3:5	2mol	1882	2075	193	10.26	10.60
		1778	1987	209	11.75	
		1925	2113	188	9.77	

Table 4.13: Water absorption result for 1:3:5, 3mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:3:5	3mol	1799	1997	198	11.00	10.57
		1874	2066	192	10.25	
		1817	2007	190	10.46	

Table 4.14: Water absorption result for 1:4:4, control

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:4:4	Control	1881	2117	236	12.55	13.66
		1937	2166	229	11.82	
		1704	1987	283	16.61	

Table 4.15: Water absorption result for 1:4:4, 1mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:4:4	1mol	1888	2100	212	11.23	12.92
		1922	2125	203	10.56	
		1641	1918	277	16.88	

Table 4.16: Water absorption result for 1:4:4, 2mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:4:4	2mol	1785	2005	220	12.32	11.96
		1840	2054	214	11.63	
		1802	2017	215	11.93	

Table 4.17: Water absorption result for 1:4:4, 3mol

Mix proportion	type	Dry Weight (g)	Immersed Weight (g)	Weight increased (g)	Water absorption (%)	Average percentage (%)
1:4:4	3mol	1835	2034	199	10.84	10.75
		1844	2045	201	10.90	
		1866	2062	196	10.50	

Table 4.18: Water absorption result for all mix proportions

	1:2:6				1:3:5				1:4:4			
type	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol
Water absorption (%)	16.49	17.31	12.76	14.93	13.69	12.73	10.60	10.57	13.66	12.92	11.96	10.75

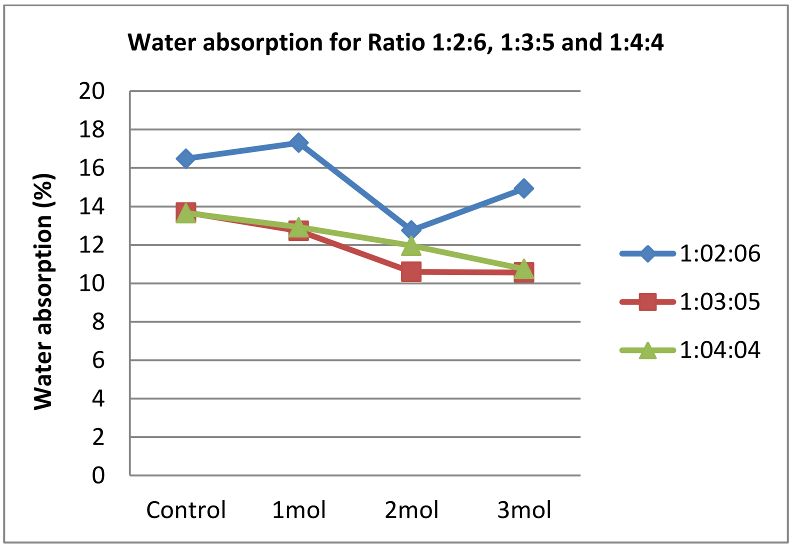

Figure 4.5: Water absorption chart for all mix proportions

The water absorption tests were conducted from the control until 3mol specimens when there were reached the age of 28 days. All mix proportions (1:2:6, 1:3:5 and 1:4:4) have an average percentage water absorption value of 10% - 18% which are satisfy for water absorption test. The 1:2:6 mix proportion give the highest average percentage of water absorption while the 1:3:5 mix proportion give the least average percentage of water absorption. Cubes are not waterproof but low water absorption gives the cubes much better in strength and durability.

4.6 ABRASION TEST

The objective of abrasion was to focus on determining the durability of cubes. Select three cubes at 28 days aged of curing for each type of the specified mix proportions. Record the weight of cubes on a balance. Apply a wire-brushed to all cubes surfaces about 50 times and record the weight of cubes again to measure the amount of particle abraded.

Table 4.19: Material abraded for 1:2:6, control

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:2:6	Control	1788	1770	18	1.02	1.39
		1720	1695	25	1.47	
		1745	1716	29	1.69	

Table 4.20: Material abraded for 1:2:6, 1mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:2:6	1mol	1663	1645	18	1.09	0.96
		1736	1725	11	0.64	
		1666	1647	19	1.15	

Table 4.21: Material abraded for 1:2:6, 2mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:2:6	2mol	1853	1827	26	1.42	1.49
		1818	1790	28	1.56	
		1827	1800	27	1.50	

Table 4.22: Material abraded for 1:2:6, 3mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:2:6	3mol	1779	1764	15	0.85	1.44
		1719	1686	33	1.96	
		1748	1722	26	1.51	

Table 4.23: Material abraded for 1:3:5, control

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:3:5	Control	1811	1808	3	0.17	0.19
		1742	1738	4	0.23	
		1792	1789	3	0.17	

Table 4.24: Material abraded for 1:3:5, 1mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:3:5	1mol	1796	1789	7	0.39	0.37
		1779	1774	5	0.28	
		1801	1793	8	0.45	

Table 4.25: Material abraded for 1:3:5, 2mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:3:5	2mol	1819	1816	3	0.17	0.16
		1921	1919	2	0.10	
		1821	1817	4	0.22	

Table 4.26: Material abraded for 1:3:5, 3mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:3:5	3mol	1852	1849	3	0.16	0.18
		1898	1895	3	0.16	
		1826	1822	4	0.22	

Table 4.27: Material abraded for 1:4:4, control

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:4:4	Control	1859	1848	11	0.60	0.51
		1599	1587	12	0.76	
		1835	1832	3	0.16	

Table 4.28: Material abraded for 1:4:4, 1mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:4:4	1mol	1932	1929	3	0.16	0.16
		1955	1952	3	0.15	
		1927	1924	3	0.16	

Table 4.29: Material abraded for 1:4:4, 2mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:4:4	2mol	1835	1830	5	0.27	0.20
		1828	1825	3	0.16	
		1852	1849	3	0.16	

Table 4.30: Material abraded for 1:4:4, 3mol

Mix proportion	type	Weight before test (g)	Weight after test (g)	Weight abraded (g)	Percentage abraded (%)	Average percentage (%)
1:4:4	3mol	1949	1945	4	0.21	0.18
		1835	1832	3	0.16	
		1909	1906	3	0.16	

Table 4.31: Material abraded for all mix proportions

type	1:2:6				1:3:5				1:4:4			
	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol	Control	1mol	2mol	3mol
Percentage abraded (%)	1.39	0.96	1.49	1.44	0.19	0.37	0.16	0.18	0.51	0.16	0.20	0.18

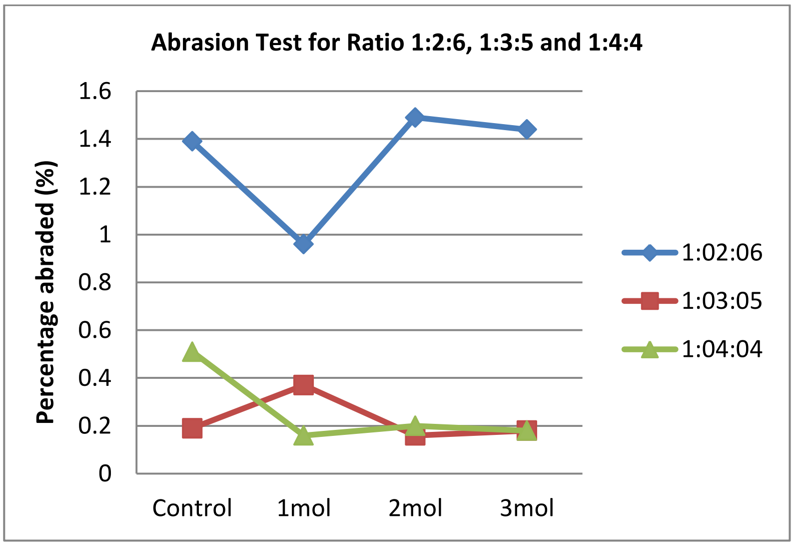

Figure 4.6: Material abraded chart for all mix proportions

The abrasion tests were conducted from the control until 3mol specimens when there were reached the age of 28 days. All mix proportions (1:2:6, 1:3:5 and 1:4:4) have their own durability and would be able withstand in harsh environment since the average percentage losses are very small which is less than 1.5%. The 1:2:6 mix proportion give the highest average percentage of particle abraded value compare to the other two mix proportions.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 GENERAL

In this section, there are two parts which are conclusions and suggestions. This section will be focus on to the main objective either it had been achieved or not after analysing all the results obtained from the compressive strength, water absorption and abrasion test and make some suggestions throughout this research.

5.2 CONCLUSION

The optimum mixed design for a stronger cube which has the maximum compressive strength for the absence of an alkaline solution (control) is 1:4:4 mix proportion which gives a value of 4.599MPa after 28 days of curing. All mix proportions demonstrate positive increments of an average compressive strength value from 14 to 28 days aged of curing but still not achieved the minimum requirement set by JKR for external walls (5.2MPa).

3 sets of cube in each mix proportion with different in alkaline concentration (1, 2 and 3molarity) had been done. The ratios were 1:2:6, 1:3:5 and 1:4:4. The impact of an alkaline solution will gives an extra strength to the cubes in term of compressive strength. It is proven by comparing the control cubes in 1:3:5 and 1:4:4 mix proportions. The highest compressive strength was in ratio 1:4:4 with 1mol concentration of an alkaline solution, 4.555MPa after 28 days of curing but still not achieved the minimum requirement set by JKR for external walls.

Water absorption for each mix proportion with different in alkaline concentration are satisfactory since there were achieved an average percentage water absorption value of 10% - 18% which are satisfy for water absorption test. Abrasion test proved that all the cubes mix proportions have their own durability and would be able withstand in harsh environment since the average percentage losses are very small which is less than 1.5%.

5.3 RECOMMENDATION

From the results and analysis, discussion, and observation done during this research, there are a few recommendations have been figured out to obtain more accurate data for this project:

i. Ensure that when measure weight of a cube which is 1.8kg; use the laboratory weight balance to get more accurate value.

ii. Use a higher percentage of soil in 1:8 cement-aggregate ratios to give more reaction between alkaline solution and soil to take place.

iii. Reduce the size of laterite soil to 600 µm and 150 µm to increase the total surface area that exposed to an alkaline solution reaction.

iv. Ensure that the type of Ordinary Portland Cement is same in all production of cubes because it does affect the cubes strength.

v. Increase the period of curing aged up to 60 days (2months) to provide a complete reaction between the soil and alkaline solution.

vi. Record the weight of cubes at the first day of curing and 28 days to measure the moisture content loss of a cube.

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