ECOLOGICAL BRICK EPITHETICAL FROM COW CHIPS

MUHAMMAD AFIQ BIN SAMSIR

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Signature : …………………………….

Supervisor : Imran Syakir Bin Mohamad

Date : …………………………….

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MUHAMMAD AFIQ BIN SAMSIR

This thesis is fulfillment of the requirement for the award of Bachelor Degree in Mechanical Engineering (Thermal-Fluid)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : ……………………………………..

Author : MUHAMMAD AFIQ BIN SAMSIR

Date : ……………………………………..

For my beloved Mother, Father and Wife.

ACKNOWLEDGMENT

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Special thanks to my parents and my wife has a lot of support and advices to completing this report. Unforgettable, special thanks to Uncle Lan owner of Cow Farm for his kind, knowledge and assistance me to find row materials for my project. Jimah Energy Ventures Sdn. Bhd. that supply fly ash class c to my project. Last but not least, I would like to dedicate my appreciation to my course mates and friends especially Hakimi, Tayalan and Yau who are direct or direct or indirectly helping me to accomplish this study.

ABSTRACT

Clay soil brick causes some problem such as having costing in making, cause pollution and corruption to the symmetry of earth surface. It is due to the clay soil mining from mesa. This research is focus on development of ecological brick as alternative wall materials for building structure and non-toxic reinforced brick from abundant local material that not degraded the environment. This research contained 80 % of waste material, clay soil and cement will replace by cow chips and fly ash. The aim of the research is to determine the optimum composition of ecological brick by two methods. First method is compression technique which only use cow chips as raw material. Second method are divided into two parts, (a) drying in room temperature for 28 days and (b) drying in furnace for 6 hours at 160 °C. In this technique, we combine the aggregate which is cow chips and fly ash. The lightweight brick specification that must be fulfilled is 5 % to 20 % for porosity, while the density is from 700 kg/m^3 to 1800 kg/m^3 and compression strength is 4.5 MPa to 35 MPa. Result for first method, sample CC7 were 7 Bar of compression ratio, 13.94 % porosity and 954.8432 kg/m^3 of density. The more compression ratio were used, the more strong bonding were produced in brick structure which then produce less porosity and higher density. Result for second method (a) sample A4 were 13.94 % porosity and 954.8432 kg/m^3 of density and (b) sample B4 were 15.35 % porosity and 724.4785 kg/m^3 of density. The more percentage of cow chips used will produce high porosity and less density which the bonding reduce in strength. Samples that used high percentage of cow chips can used as insulation material because of high porosity. The shape of graphs from compression test show that ductile material withstand large extension before the specimen ruptures. The specimen is yielding before fail and shows warning sign. These means, it is absorbing much larger quantities of energy before failure. Therefore, ductile material is natural choice for brick. Sample CC7, A4 and B4 also had fulfilled the requirement of compressive load or strength for brick which are 4.756 kN, 4.562 kN and 5.325 kN respectively.

ABSTRAK

Bata yang diperbuat daripada tanah liat akan menyebabkan beberapa masalah seperti kos pembuatan yang tinggi, pencemaran ekosistem dan alam sekitar hasil daripada kegiatan perlombongan tanah liat. Kajian ini berfokus kepada pembangunan bata ekologi sebagai bahan binaan untuk struktur bangunan. Ianya dihasilkan daripada bahan semula jadi serta tanpa kandungan bahan toksik. Bata ini menggunakan bahan buangan seperti tinja lembu untuk menggantikan tahan liat manakala simen digantikan dengan *'Fly Ash'*. Sebanyak 80 % kandungan bahan buangan akan digunakan. Kajian ini bertujuan untuk menentukan komposisi optimum dalam pembuatan bata ekologi. Terdapat dua kaedah yang dilaksanakan, yang pertama adalah teknik mampatan yang hanya menggunakan tinja lembu sebagai bahan utama. Kaedah kedua melalui proses pengeringan yang terbahagi kepada dua bahagian, (a) dikeringkan pada suhu bilik selama 28 hari dan (b) pengeringan didalam relau selama 6 jam dengan suhu 160 °C. Kaedah kedua ini mengunakan tinja lembu yang akan dijadikan agregat bersama *'Fly Ash'*. Dalam kajian ini, sampel CC7, A4 dan B4 telah dipilih berdasarkan spesifikasi piawai bata ringan, melibatkan parameter keliangan, ketumpatan dan kekuatan mampatan masing-masing adalah 5 % hingga 20 %, 700 kg/m^3 hingga 1800 kg/m^3 dan 4.5 MPa hingga 35 MPa. Sampel CC7, mempunyai 13.94 % keliangan, 954,8432 kg/m^3 ketumpatan dan 7 bar nisbah mampatan. Manakala sampel A4 mempunyai 13.94 % keliangan, 954,8432 kg/m^3 ketumpatan dan sampel B4 mempunyai 15.35 % keliangan dan 724,4785 kg/m^3 ketumpatan. Sampel CC7 , A4 dan B4 juga telah memenuhi piawaian beban mampatan atau kekuatan untuk bata yang masing-masing 4,756 kN, 4,562 kN dan 5,325 kN.

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LIST OF ABBREVIATIONS

ASTM	=	American Society for Testing and Materials
CAOH	=	Calcium hydroxide
CaO	=	Calcium Oxide
$CaCO_3$	=	Calcium Carbonate
CO_2	=	Carbon Dioxide
$CaSO_4{\cdot}2H_2O$	=	Calcium Sulphate Dihydrate
CMOS	=	Complementary Metal-Oxide-Semiconductor
CCD	=	Change Couled Device
IEEE	=	Institude of Electrical and Electronics Engineers
P	=	Phosphorus
N	=	Nitrogen
K	=	Potassium

LIST OF APPENDIX

CHAPTER I

INTRODUCTION

1.0 BACKGROUND

The initial blocks were produced out of the mud of riverbanks and heated in the sun, as long prior as 10,000 B.C. Cleaved straw and grass were added to avoid distortion and breaking. Around 4,000 B.C., block makers started preparing uniform shapes and terminating them in kilns. Terminating brought about the mud particles to bond synthetically, thus enhancing block toughness (Chamberlain, 2003).

Cow Chips is also an optional ingredient in the manufacture of brick housing depending on the availability of materials at hand. It have strong antibacterial properties. It works as a good disinfectant by keeping away insects (Gaskin, 1914). It is an excellent insulator which is as it keeps house cool in summers and warm in winters. It use as construction material for houses encourages utilization of natural resources and minimize wastage.

This product will be conducted by produce a sustainable and non-toxic reinforced bricks from abundant local material which is Cow Chip. This project will use cow chips as an aggregate, and fly ash, lime, gypsum and adhesive as the binder to produce a brick. This product will modified the abundant local material in the manufacture of an ecological brick, to produce brick material better than the existing brick. Modification of this product still refers to the standards design requirement in American Society for Testing and Material. Several testing will be done to determine the physical, mechanical and thermal properties of a brick.

1.1 PROBLEM STATEMENT

As we know, brick making is higher energy consumption, top soil degradation and pollution activity. Kindles are cinder block kilns and around 300 grams of wood fired spent in this procedure block (Krishnaiah, 2010). In doing this. It can exhaustion of trees, air contamination, expanding the centralization of carbon dioxide in the climate add to an unnatural weather change.

Nowadays in Malaysia the usage of clay soil will occur disrupted ecosystem. In order to use abundant local material which is cow chips to replace clay soil, it because the usage of cow chips in Malaysia industry is very limited. It only use into agriculture fertilizer and biomass of about 20 % (Sharifuddin, 2010), the remains it just turn into soil.

Based on the problem statement above, this research to develop a manufacturing technology of brick, i chose cow chips as aggregate. Cow chips will replace clay soil, otherwise it can improve the current brick and doing it will reduce the waste, increase value of waste, reduce brick price, reduce CO_2 emission and save our earth to get better life.

1.2 OBJECTIVE

The purposes of the research are to produce a sustainable and non-toxic reinforced brick from abundant local material which is cow chips which improve the brick's properties.

1.3 RESEARCH SCOPE

The scope for this final project is limited to the problem of fabrication and characterization of sustainable and non-toxic reinforced brick from abundant local material which is cow chips which improve the brick's properties as follows;

i. To develop an ecological brick from cow chips.
ii. Material that being use is cow chips as an aggregate and using fly ash, gypsum, lime and adhesive as the binder.
iii. To analysis on the mechanical and physical properties of cow chips brick with various compositions that include compressive strength, density and porosity testing.
iv. Analysis on thermal properties only includes thermal conductivity.

CHAPTER II

LITERATURE REVIEW

2.0 INTRODUCTION

This research is focus on development of ecological brick as alternative wall materials for building structure and non-toxic reinforced brick from abundant local material. Ecological brick are built with material that not degrade the environment, cow chips will replace clay soil and change cement with fly ash. It contained 80 % of waste material. The research to determine the optimum composition of the manufacturing of ecological brick with two method. First method is compression technique only use cow chips as raw material. Second method are divided into two parts, drying in room temperature for 28 days and drying in furnace for 6 hours at temperature 160 °C, this technique we combine the aggregate which is cow chips and fly ash.

2.1 BRICK

Bricks are all the more normally utilized within the development of structures than any viable material aside from wood. Brick and terracotta structural engineering is prevailing inside its field and an extraordinary industry has advanced and put resources into the assembling of numerous diverse sorts of blocks of all shapes and colors. With up to date apparatus, earth moving gear, effective electric engines and advanced tunnel furnaces, making bricks has ended up significantly more gainful and productive (Heritage, 2013). Bricks might be created out of mixture of materials the most widely recognized being earth additionally calcium silicate and cement. With earth blocks being the more mainstream, they are currently made utilizing three methods delicate mud, dry press and expelled. Likewise throughout 2007 the new 'fly ash' block was made utilizing the by items from coal power plant (Bhanumathidas, 2003).

Great quality blocks have a major advantage over stone as they are dependable, climate safe and can endure acids, contamination and fire. Bricks might be made to any determination in color, measure and shape which makes bricks simpler to raise with than stone (Heritage, 2013). Brickwork is additionally much shabbier than cut stone work. However there are a few bricks which are more permeable and consequently more helpless to moistness when laid open to water.

2.2 COW CHIPS

Cow Chips is feces plus urine, it is approximately 88 % water and its density is approximately 960 kg/m^3 (Evans, 1993). Figure 2.1 shown the day by day admission and yield of a normal 450 kg cow. Bolster utilization is normally 2.5 % to 3.0 % of figure weight hinging upon the sort of eating regimen. For a 450 kg cow, this is around the range of 12 kg of nourish admission for every day. As weight increase is 1 kg to 1.6 kg for every day, the leftover should leave the creature, incompletely as excrement which is the fusion of feces and urine and mostly by means of belching as gas. Cows additionally drink extensive amounts of water with the day by day volume hinging upon figure weight, diet and climatic conditions. Some of this water is lost to the climate by means of breath; nonetheless, an impressive extent is voided as a major aspect of the compost. Ordinarily, excrement is 85 % to 90 % water. The everyday compost processing of a 450 kg cow is around the range of 27 kg for every day, which is in the cowshed of 5 to 6 % of figure weight. Of the 27 kg, in the vicinity of 24 kg is water and 3 kg is strong material in dry matter (Government, 2013).

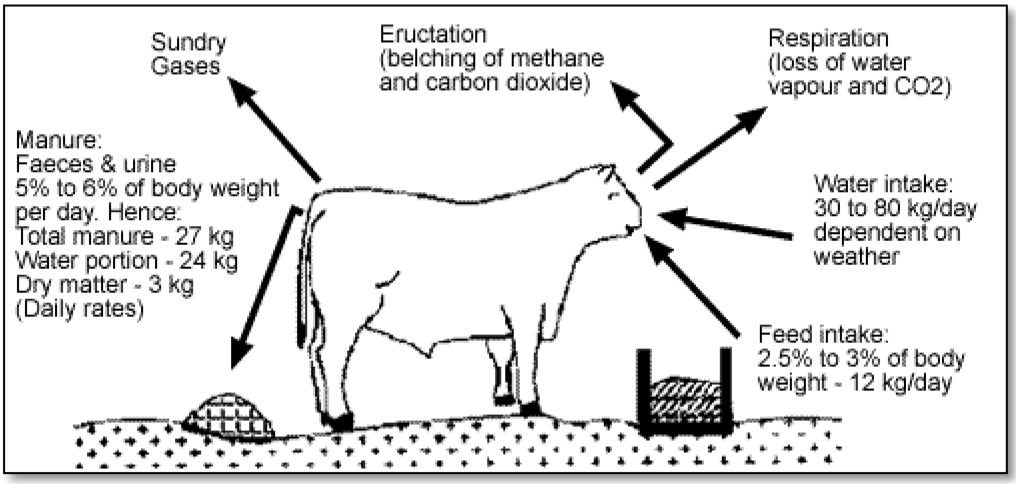

Figure 2.1: Cow weight 450 kg produce manure 27kg per day.

(Source: Government, 2013)

Table 2.1: Daily manure production for Cow Chips.

Animal size (kg)	**Manure production (kg/day)**	**Total solids (kg/day)**	**Volatile solids (kg/day)**	**BOD* (kg/day)**	**Nutrient content (kg/day)**		
					N	**P**	**K**
220	13.2	1.54	1.32	0.35	0.075	0.024	0.052
300	18.0	2.08	1.06	0.48	0.104	0.034	0.076
450	27.0	3.10	2.70	0.72	0.153	0.050	0.108
600	36.0	4.18	3.56	0.96	0.206	0.068	0.149

* BOD = Biological Oxygen Demand

* N = Nitrogen

* P = Phosphorus

* K = Potassium

Table 2.1 shows the day by day excrement processing and its attributes for a reach of cow sizes. The real measure discharged can differ by in the vicinity of 25 % either side of these midpoints because of distinctions in eating regiment, animal health, accessibility of water and weather. From daily cow manure, each cow can produce dung around 36 kg per day, 252 kg per week and 1080 kg per months of cow chips. This waste does not have good value in Malaysia market. It also an optional ingredient in the manufacture of brick housing depending on the availability in rural area (Lowrance, 2012).

2.3 FLY ASH

Fly Ash debris is transformed by coal fired power plants throughout the combustion of coal. Fly powder comprises principally of inorganic lustrous particles shaped from the mineral matter in the coal. Throughout combustion, these minerals are warmed to a liquid state and synthetically consolidated and hardened while suspended in the fumes gas. They are then gathered by electrostatic precipitators or sack houses (Bhanumathidas, 2003)

According to ASTM Class C fly ash debris is ordinarily generated from lignite or subbituminous coal that meets the appropriate necessities. This class of fly ash powder, notwithstanding having pozzolanic lands, likewise has a few cementations lands (Uysal, 2012). Figure 2.2 shown the Class C fly ash.

Figure 2.2: Fly Ash (Class C)

(Source: Uysal, 2012)

Fly ash remains is an amazingly fine powder comprising of round particles not exactly 50 microns in size (Uysal, 2012). It is one of the development business' most ordinarily utilized Pozzolans. Pozzolans are siliceous or siliceous/alumino materials controlling the capability to structure cementitious mixes when blended with lime which is calcium hydroxide or CaOH (Romagnoli, 2013) and water.

In a properly proportioned mix, fly ash can improve many of the properties of concrete (LAFARGE, 2013), the advantage is there in the mix can improved workability and consolidation, increased flexural and compressive strengths improved pump ability, reduced drying shrinkage, reduced bleeding and segregation, decreased permeability, increased resistance to ASR and sulfate attack, improved economics and the last is can reduced water requirements.

2.4 LIMESTONE

Limestone is a type of sedimentary stone that very common all over the Mediterranean and Europe. Figure 2.3 shown the limestone, it is made out of the shells of zillions of little tiny sea snails and creatures like that. All these stuff lived in the sea about billions of years ago. After they died, they fell to the bottom of the sea and rotted. However the shell did not rot and just stayed there. This is because it was made of calcium just like teeth (Carr, 2012)

Pressure then squashed them all together into rock. The pressures were come from the other shell, water and sand that being washed over the shells. Because of change of sea with time which is many years later, people could quarry it where they were left on the land. Limestone can turn into travertine or marble when gets more squashed.

Figure 2.3: Limestone
(Source: Romagnoli, 2013)

Lime that used to make out cement can also be obtained from limestone by burn it in lime kilns. In the middle ages, people burned most of the statues of ancient Greece and Rome to turn them into lime. Calcium Oxide (CaO), is a white crystalline solid with a melting point of 2572 °C (Romagnoli, 2013). It is manufactured by heating limestone, coral, sea shells, or chalk, which are mainly $CaCO_3$, to drive off carbon dioxide.

$$CaCO_3(s) \xrightarrow{500-600℃} CaO(s) + CO_2\,(g) \qquad \text{Eq. (2.1)}$$

This reaction is reversible; calcium oxide will react with carbon dioxide to form calcium carbonate. The reaction is driven to the right by flushing carbon dioxide from the mixture as it is released. Lime as degree of flexibility. Exhibits certain degree of water proofing properties. Prevents subsoil dampness. Exhibits volumetric stability. Resists weathering effects and is very durable.

2.5 GYPSUM

Pure gypsum is a white to transparent mineral, however at some point simpurities color it grey, brown, or pink. Its substance name is calcium sulphate dihydrate, and its chemical formula is $CaSO_4•2H_2O$ (Song, 2012). The point when gypsum is heated, it loses around the range of 75 % of its water and comes to be hemihydrate gypsum ($CaSO_4•½H_2O$), which is delicate and might be effectively ground to a powder called hemihydrate gypsum plaster or plaster Paris. Figure 2.4 is shown that gypsum crystals found in the mine before the process to form a powder.

Figure 2.4: Gypsum Crystal

(Source: Song, 2012)

Gypsum has been known for a long time and is one of the eldest building materials on the planet. The most punctual utilization of gypsum yet uncovered was in Anatolia around 6000 B.C. Later, in around the range of 3700 B.C., gypsum was utilized on the interior parts of the incredible pyramids in Egypt (Olson, 2001).

In a properly proportioned mix, gypsum can improve many of the properties of brick, which is the advantage is fire resistant, reduce or control sound and have an environmental benefits.

2.6 WATER

Water is a chemical substance with the chemical formula H_2O. Its molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exist on earth with solid state, ice and gaseous state, water vapor or steam.

Water is a tasteless, odorless liquid at standard temperature and pressure. The color of water and ice is, intrinsically, a very slight blue hue, although water appears colorless in small quantities. Ice also appears colorless and water vapor is essentially visible as a gas.

The purpose of water used in brick construction is to start the hardening process of the brick. The hardening process happens through hydration of the fly ash. The second function is to make the mix workable enough to satisfy the requirements of the job. Too much quantity of water will cause loss of strength by upsetting the water and fly ash ratio. Besides that, “water gain” can be produced on the surface, a condition which leaves a surface layer of weak material called laitance (Mechanics, 2008).

In addition, an excessive amount of water will affect the tightness of the brick. The water that used in mixing must be clean and free from oils, alkalis, acids, and organic materials. Water for drinking is the most recommended to be used. This is because it is usually satisfied for use in mixing brick. For the unreinforced brick, seawater may be used.

2.7 ADDITIVE

Additives or admixtures are used to change the composition of brick or to accelerate or delay its hardening. The three types commonly used are air entraining agents, retarders, and accelerators. If the end result can be reached more economically by altering the mix proportions, the use of additives are not recommended (Mechanics, 2008).

Additive are used in this research is methylcellulose or methyl cellulose, is a chemical aggregate which is drawn from the cellulose of vegetables whereby in this research it act as additives. Methylcellulose assists command some vital properties of a formulation such as rheology, dispersion, and water demand and water retention. Methylcellulose addition improves the tensile properties, but degrades the compressive properties and the thermal stability. The larger is the methylcellulose content, the greater is each effect (Fu, 1996). It has multiple functional benefits, including high consistency and workability with decreased stickiness, high standing strength and high yield.

Additive is a material that used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during mixing (Practice, 2001). Air-entraining agents are liquids derived from natural wood resins, animal fats, vegetable fats, or various wetting agents such as alkali salts and water soluble soaps. It was used to develop a system of microscopic air bubbles in concrete, mortar, or cement paste during mixing.

Admixture retarding is an admixture that causes a decrease in the rate of hydration of the hydraulic brick and lengthens the time of setting. Besides that, an admixture accelerating is an admixture that causes an increase in the rate of hydration of the hydraulic cement, and thus shortens the time of setting also increases the rate of strength development or both (Practice, 2001).

2.8 PREVIOUS FINDING

2.8.1. Lightweight brick from cow chips.

EcoFaebrick, advanced by student from Prasetiya Mulya Business School, are produced out of Cow Chips with soil concentrates and are cured utilizing biogas, reducing the carbon dioxide emitted throughout the accepted procedure of utilizing wood-fire heat. The effect is a building material that is 20% lighter than clay bricks and has 20% greater compressive load. Since they make utilization of a replenish able waste item, EcoFaebrick are likewise less exorbitant than earth blocks. EcoFaebricks are made in organization with nearby neighborhoods, furnishing work chances and serving to safeguard rural land crushed by clay quarrying. Assembles in India, Kenya, and Mexico have communicated investment in the engineering development (Chazali, 2008).

2.8.2. Raw material proportion.

This research refer the fly ash brick proportion for second method. Proportioning of raw material in an important aspect for making of desired quality of brick. It will depend on the quality of the raw material and compressive strength and water quality of brick required. The following mix proportion can be adopted for manufacture of Fly Ash Brick.

Table 2.2: Proportion of brick composition (Gupita, 2002).

Raw material	**Composition (%), proportion sludge lime brick**	**Composition (%), proportion hydrated lime brick**	**Composition (%), proportion cement brick**
Fly Ash	55 - 60	60 - 65	50 - 60
Sand	20 - 25	18 - 27	32 - 40
Lime	15 - 20	8 - 12	-
Gypsum	5	5	-
Cement	-	-	8 - 10

Table 2.2 shown Proportion of brick composite. In this research second proportion was selected due to hydrated lime. Hydrated lime will react with cow chip to be anti-smelly and bacteria. Composition was rearrange is shown in Table 2.3. Percentages of additive was added into composition because additive will help fly ash to bond with cow chips.

Table 2.3: Composition proportion for ecological brick.

Fly Ash (%)	**Cow Chips (%)**	**Lime (%)**	**Gypsum (%)**	**Additives (%)**	**Water (%)**
80	0				
70	10				
60	20				
50	30				
40	40	10	5	5	40
30	50				
20	60				
10	70				
0	80				

2.8.3. Criteria of selection.

Referring to (Manjit, 2012) lightweight brick shown data in Table 2.4 with consider porosity, density, compression strength and maximum load. Four criteria will cover the physical and mechanical properties. The most important we consider is compress strength, due this data this brick need to reach or exceed the minimum limit.

Table 2.4: Criteria of lightweight brick (Source : Manjit, 2012).

Criteria	**Range**
Porosity (%)	5 to 20
Density (kg/m^3)	700 to 1800
Compression Strength (MPa)	1.5 to 35
Maximum load (kN)	4.5 to 35

CHAPTER III

METHODOLOGY

3.0 INTRODUCTION

The research was a laboratory scale research to determine the optimum composition of the manufacturing of ecological brick with two method. First method is compression technique only use cow chips as raw material. Second method are divided into two parts, drying in room temperature for 28 days and drying in furnace, for this technique we combine the aggregate which is cow chips and fly ash. The preparations of specimens are using various percentage compositions on cow chips and fly ash

3.1 MATERIALS

The materials used in manufacturing of ecological brick in this research are cow chips, fly ash, lime, gypsum, additive and water. Raw materials available in the livestock and chemical stores.

3.2 FLOWCHART PROCESS

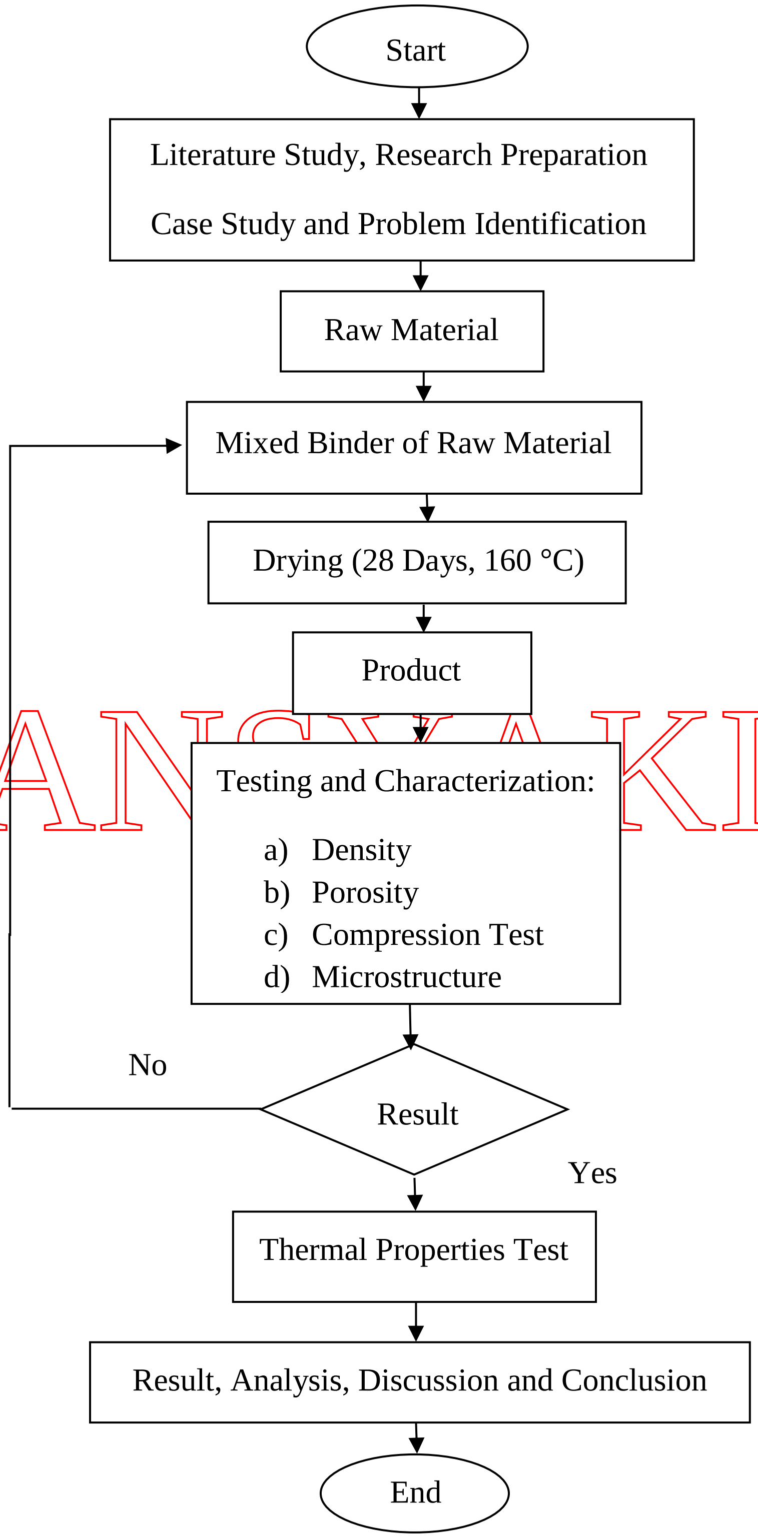

Figure 3.1: Flow Chart of Project

Figure 3.1 shown the final year research process. In this project, start with literature study, research preparation case study and problem identification. After that we gather all raw materials. Start the making brick with the standard of procedure. Than we need go through the drying process to become product. Product will undergoes the testing. If get the best and fulfill brick specification the thermal properties test will run. Final gathers all data from experiment for result, analysis, discussion and conclusion.

3.3 COMPOSITION OF RAW MATERIAL

Table 3.1 shows the variations in term of percentages of raw material which is cow chips, we used to get the optimum compression ratio of the manufacture of ecological brick. Table 3.2 shown there are fourteen sample codes with various compression ratio. Table 3.3 shows the variations in term of percentages of raw material we used to get the optimum compositions of the manufacture of ecological brick. Second method are divided into two parts and have two sample code to show it. There are eighteen sample codes with various percentages of raw materials. All specimens were tested by using the American Society of Testing of Material (ASTM). Then the best sample result had undergoes the thermal properties test and obtained the thermal conductivity value. The best sample was chosen based on criteria such as (Manjit, 2012):

i. Porosity: 5 to 20 (%)
ii. Density: 700 to 1800 (kg/m^3)
iii. Compression Strength: 1.5 to 35 (MPa)
iv. Maximum Load: 4.5 to 35 (kN)

Table 3.1: Ecological Brick Composition for first method (Compression technique).

Material	**Quantity (%)**
Cow Chips	80
Calcium Oxide	10
Gypsum	5
Cellulose	5
Water	20 not include in 100% of material

Table 3.2: Sample code with compression ratio.

Sample Code	**Compression ratio (Bar)**
CC1	1
CC2	2
CC3	3
CC4	4
CC5	5
CC6	6
CC7	7
CC8	8
CC9	9
CC10	10
CC11	11
CC12	12
CC13	13
CC14	14

Table 3.3: Ecological Brick Composition for second method (drying in room temperature for 28 days and drying in furnace)

<table>
<tr><th>Sample Code 28 Days</th><th>Sample Code Furnace</th><th>Fly Ash (%)</th><th>Cow Chips (%)</th><th>Lime (%)</th><th>Gypsum (%)</th><th>Additives (%)</th><th>Water (%)</th></tr>
<tr><td>A0</td><td>B0</td><td>80</td><td>0</td><td rowspan="9">10</td><td rowspan="9">5</td><td rowspan="9">5</td><td rowspan="9">40</td></tr>
<tr><td>A1</td><td>B1</td><td>70</td><td>10</td></tr>
<tr><td>A2</td><td>B2</td><td>60</td><td>20</td></tr>
<tr><td>A3</td><td>B3</td><td>50</td><td>30</td></tr>
<tr><td>A4</td><td>B4</td><td>40</td><td>40</td></tr>
<tr><td>A5</td><td>B5</td><td>30</td><td>50</td></tr>
<tr><td>A6</td><td>B6</td><td>20</td><td>60</td></tr>
<tr><td>A7</td><td>B7</td><td>10</td><td>70</td></tr>
<tr><td>A8</td><td>B8</td><td>0</td><td>80</td></tr>
</table>

3.4 MATERIAL PREPARATION

From Table 3.1 and Table 3.3, all material are measure by using weighing scale, for 100 % or material are converted to 1 kg ratio. All material without water are mixed up and stir in one container. Next, pour the water into container and the mixture was stirred again until homogeneity.

First method are compression technique, the mixture was drying in furnace for 6 hours at temperature 160 °C. After dried, the mixture was crushed to dust, pour into cylinder mold and do the compression to make sample brick.

Second method for the first part, drying in room temperature for 28 days. The mixture was poured into mold and leave all sample in materials science lab. The second part mixture was poured into mold and we move all sample into furnace, the temperature was set up from room temperature around 29 °C and increase to 160 °C it take 5 hour. After reach 160 °C temperature maintain for 2 hours, then switch off the furnace, all sample cooling in furnace until reach room temperature to avoid extreme temperature drop and crack.

3.5 TESTING STANDARD

Specimens had undergone physical and mechanical properties testing after reach certain temperature that consist of ASTM C67-02c Sampling and Testing Brick, ASTM C109 Test Compressive Strength, ASTM C373-88 Test Density and Porosity and ASTM D4643 – 08 Water Content. Besides that, the ASTM E210 - 63(2010) Microstructure Analysis was done those specimens by using Optical Microscope. In addition, the best result which was the highest valued of load and compressive strength that they can stand had undergone ASTM C1470-00 Thermal properties Test to determine the value of thermal conductivity, refer Appendix B.

CHAPTER IV

RESULT

4.0 INTRODUCTION

The research was a laboratory scale research to determine the optimum composition of the manufacturing of ecological brick with two method. First method is compression technique only use cow chips as raw material. Second method are divided into two parts, drying in room temperature for 28 days and drying in furnace, for this technique we combine the aggregate which is cow chips and fly ash. Then the best sample result had undergoes the thermal properties test and obtained the thermal conductivity value.

4.1 DATA FOR PHYSICAL AND MECHANICAL PROPERTIES

All specimens were tested by using the American Society of Testing of Material (ASTM). The best sample was chosen based on brick, using waste materials in building materials criteria such as (Manjit, 2012):

i. Porosity: 5 to 20 (%)
ii. Density: 700 to 1800 (kg/m^3)
iii. Compression Strength: 1.5 to 35 (MPa)
iv. Maximum Load: 4.5 to 35 (kN)

Table 4.1: All data for physical and mechanical properties first method (Compression technique).

Sample Code	Compression Ratio (Bar)	% Porosity	Density (kg/m^3)	Maximum Load (kN)
CC1	1	29.09	752.4717	0.7690
CC2	2	22.12	764.1300	1.2360
CC3	3	20.61	799.4298	1.3400
CC4	4	19.70	837.4973	2.7560
CC5	5	17.58	877.2467	3.5560
CC6	6	16.06	916.3070	4.0180
CC7	7	13.94	954.8432	4.7560
CC8	8	12.73	1031.8758	5.2430
CC9	9	11.82	1057.6265	6.1230
CC10	10	11.21	1125.2885	7.5610
CC11	11	9.39	1194.3307	9.0120
CC12	12	7.27	1263.5202	11.2360
CC13	13	5.76	1349.5383	13.3540
CC14	14	3.33	1429.1421	15.5690

Table 4.1 shown all data for physical and mechanical properties which can be refer at Appendix C. The compression ratio that fulfill brick criteria shown starting from sample CC7 until CC14, from eight sample that success we select the minimum compression ratio is 7 bar which is sample CC7, because we can reduce the cost of making brick when using minimum power consumption. Percentages of porosity is 13.94 followed with density is 954.8432 kg/m^3 and compression strength is 4.56 MPa. All criteria is satisfied.

Table 4.2: All data for physical and mechanical properties second method (Drying in room temperature for 28 days).

Sample Code	Fly Ash (%)	Cow chips (%)	% Porosity	Density (kg/m^3)	Compression Strength (MPa)	Maximum Load (kN)
A0	80	0	1.58	1113.9430	5.8840	8.5620
A1	70	10	3.17	1041.8796	5.3940	7.9580
A2	60	20	8.35	953.2008	4.9030	6.6520
A3	50	30	10.18	870.3132	2.9420	5.5620
A4	40	40	11.74	788.2494	1.9610	4.5620
A5	30	50	13.19	729.1806	1.4710	3.5160
A6	20	60	17.47	619.3506	0.9850	2.3650
A7	10	70	24.32	533.6494	0.5690	1.2350
A8	0	80	36.64	401.2567	0.2350	0.9650

All data before taking average reading need refer to Appendix D for Table 4.2 and refer Appendix E for Table 4.3, it shown all data for physical and mechanical properties. The composition that fulfill brick criteria shown starting from sample A0 until A4 and B0 until B4, from five sample that success we select the maximum usage of cow chips is sample A4 and B4, if more waste is used, have high chance to save our environment. Sample A4 have given 40 % of cow chips and 40 % fly ash, the percentages of porosity is 11.74, density is 788.2494 kg/m^3 followed with compression strength is 4.5620 MPa and maximum load is 1.9610 kN. Sample B4 have given 40 % of cow chips and 40 % fly ash, the percentages of porosity is 15.35, density is 724.4785 kg/m^3 followed with compression strength is 5.3250 MPa and maximum load is 3.9230 kN. All criteria is satisfied.

Table 4.3: All data for physical and mechanical properties second method (Drying in furnace).

Sample Code	Fly Ash (%)	Cow chips (%)	% Porosity	Density (kg/m^3)	Compression Strength (MPa)	Maximum Load (kN)
B0	80	0	5.35	1052.4566	7.8450	15.2630
B1	70	10	8.56	974.7436	6.8640	12.5630
B2	60	20	12.58	880.0914	5.8840	10.2560
B3	50	30	13.35	820.3694	4.9030	8.3650
B4	40	40	15.35	724.4785	3.9230	5.3250
B5	30	50	16.40	665.1588	2.9420	4.3250
B6	20	60	16.99	593.4732	2.4550	3.2610
B7	10	70	17.38	464.7022	0.9810	1.6540
B8	0	80	18.40	372.0312	0.6940	0.9850

4.2 THERMAL CONDUCTIVITY

Purpose of this testing is to determine the thermal conductivity value of one sample code that has the best result among 3 technique. Overall sample CC7, A4 and B4 is the best sample code that have been fulfilled the brick requirement. The less density value means the brick more light in weight. For the porosity testing, the more porosity value means the brick more suitable for insulation and more pore. Lastly is compressive strength, the higher value of compressive strength, it shows the stronger the brick and can accept more load applied. The value of thermal conductivity was determine by apparatus named KD2 Pro thermal properties analyzer. It sensor has been used are TR-1, it is designed primarily for soil, concrete, rock, and other granular or solid materials. The relatively large diameter and typically longer heating time of the TR-1 sensor minimize errors from contact resistance in granular samples or solid samples with pilot holes. TR-1 sensor conform to the specifications for the Lab Probe called out by the IEEE 442-03. Guide for Soil Thermal Resistivity Measurements.

Figure 4.1: Sample undergoes the thermal conductivity test.

Figure 4.1 shown sample with the TR-1 sensor, in solid materials where a pilot hole has been drilled and contact resistance can be significant, using thermal grease and extending the read time to the maximum allowed 10 minutes will produce the most accurate results. Table 4.4 shown the best sample result including thermal conductivity. The thermal conductivity result for CC7, A4 and B4 are 0.087 W/m.K, 0.070 W/m.K and 0.067 W/m.K respectively.

Table 4.4: Best result for all specification.

Sample Code	**% Porosity**	**Density (kg/m^3)**	**Maximum Load (kN)**	**Compression Strength (MPa)**	**Thermal Conductivity (W/m.K)**
CC7	13.94	954.8432	4.7560	4.5600	0.087
A4	8.35	953.2008	4.5620	1.9610	0.070
B4	13.35	820.3694	5.3250	3.9230	0.067

CHAPTER V

DISCUSSION

5.1 PHYSICAL PROPERTIES (DENSITY AND POROSITY)

Figure 5.1 shows the comparison and relationship between the density and porosity with compression ratio for first method. When the compression ratio increased, the density value also increased, while the porosity value become decrease. Compression ratio is directly proportional to density, compression ratio is inversely proportional to porosity and density is inversely proportional to porosity. 7 Bar of compression ratio sample which is 13.94 % porosity and 954.8432 kg/m^3 of density was fulfilled the brick specification. These show that the compression ratio were influence the bonding between all materials in brick. The more compression ratio were used, the more strong bonding were produced in brick structure which then produce less porosity and higher density.

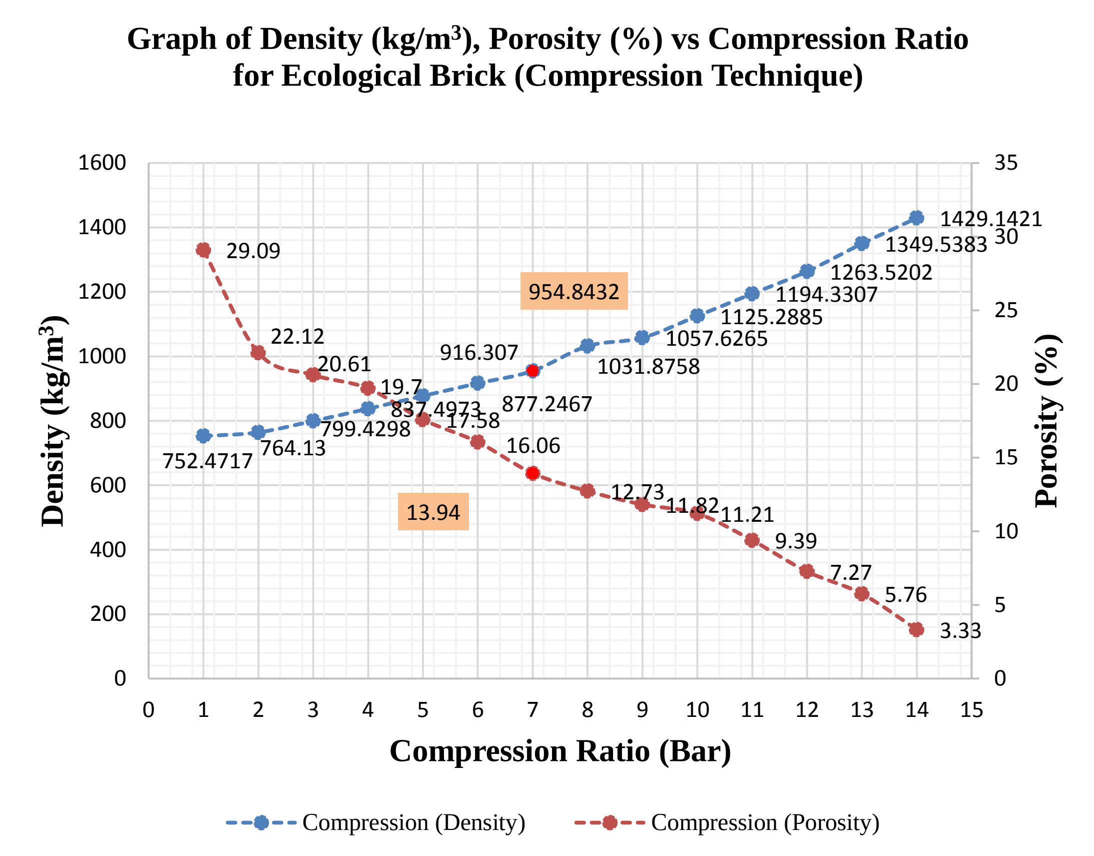

Figure 5.1: Comparison of density, porosity versus compression ratio of first method.

Figure 5.2 and Figure 5.3 shows the comparison and relationship between the density and porosity with percentage of cow chips for second method which is dry in room temperature for 28 days and dry in furnace. When the percentage of cow chips increased, the porosity value also increased, while the density value become decreased. Percentage of cow chips is directly proportional to porosity, percentage of cow chips is inversely proportional to density and density is inversely proportional to porosity. For figure 5.2, the comparative results are shown by the dry method at room temperature. It shows 40 % of cow chips sample A4 which is 11.74 % porosity and 788.2494 kg/m^3 of density was fulfilled the brick specification. For figure 5.3 shown comparison result by dry in furnace. It shows 40 % of cow chips sample B4 which is 15.35 % porosity and 724.4785 kg/m^3 of density was fulfilled the brick specification. This figure also show the percentage of cow chips were influence the bonding between all materials in brick. The more percentage of cow chips were used, produce high porosity and less density then the bonding became weak. For the samples that used high percentage of cow chips can used as insulation material because of high porosity.

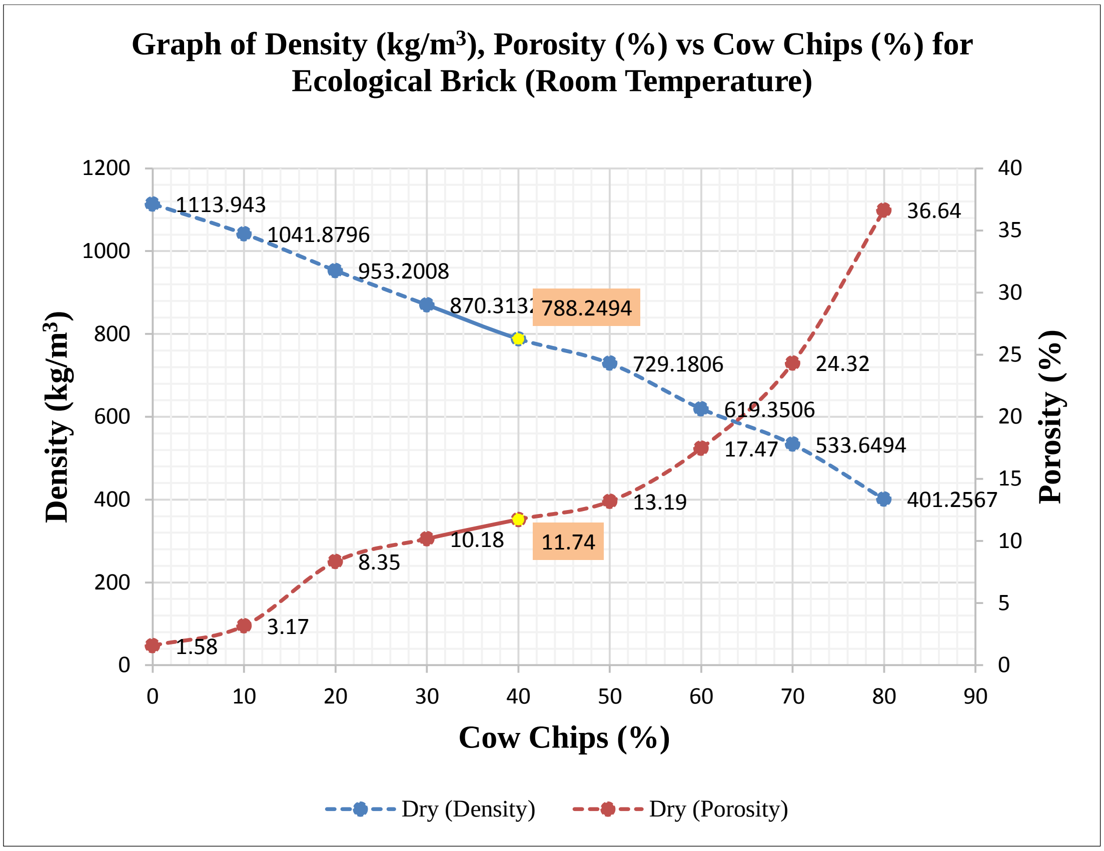

Figure 5.2: Comparison of density, porosity versus cow chips (room temperature).

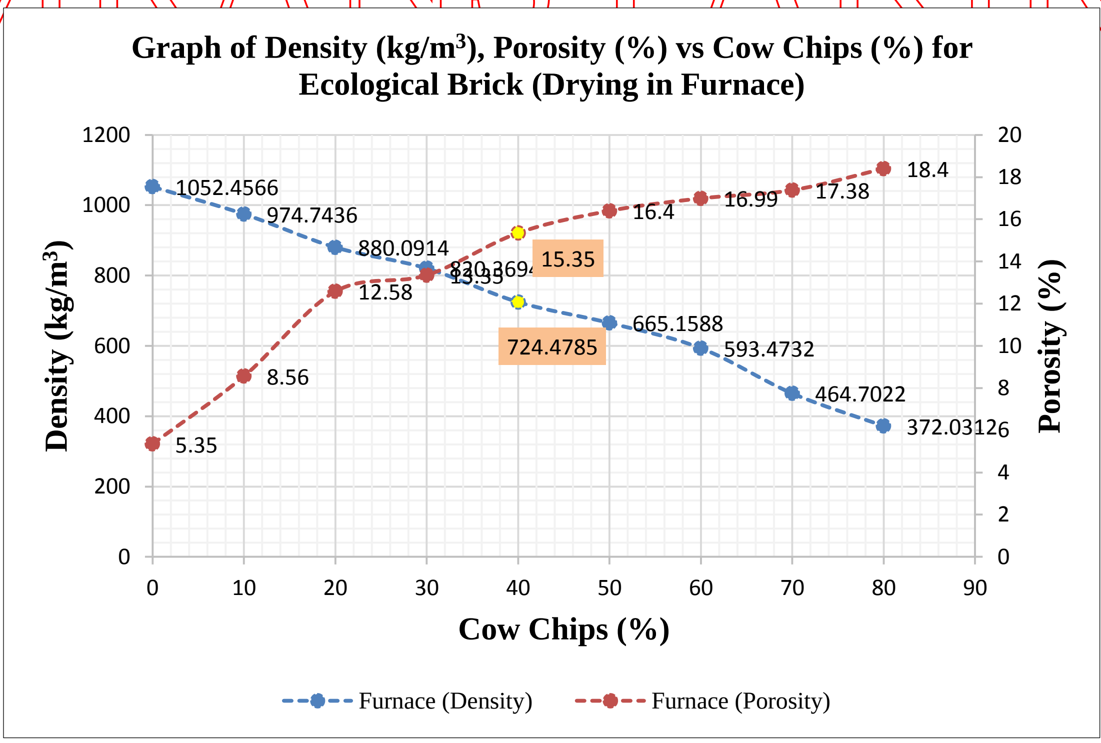

Figure 5.3: Comparison of density, porosity versus cow chips (drying in furnace).

5.2 MECHANICAL PROPERTIES (COMPRESSIVE TESTING)

Figure 5.4, Figure 5.5 and Figure 5.6 shown the compression load, kN versus compression extension, mm graph. From the results, it show that all the samples behavior are ductile characteristic. The shape of graphs show that ductile material withstand large extension before the specimen ruptures. They are yielding before fail and shows warning sign. These means, it is absorbing much larger quantities of energy before failure. Therefore, ductile material is natural choice for brick. Sample CC7, A4 and B4 were fulfilled the requirement of compressive load or strength for brick which are 4.756 kN, 4.562 kN and 5.325 kN respectively.

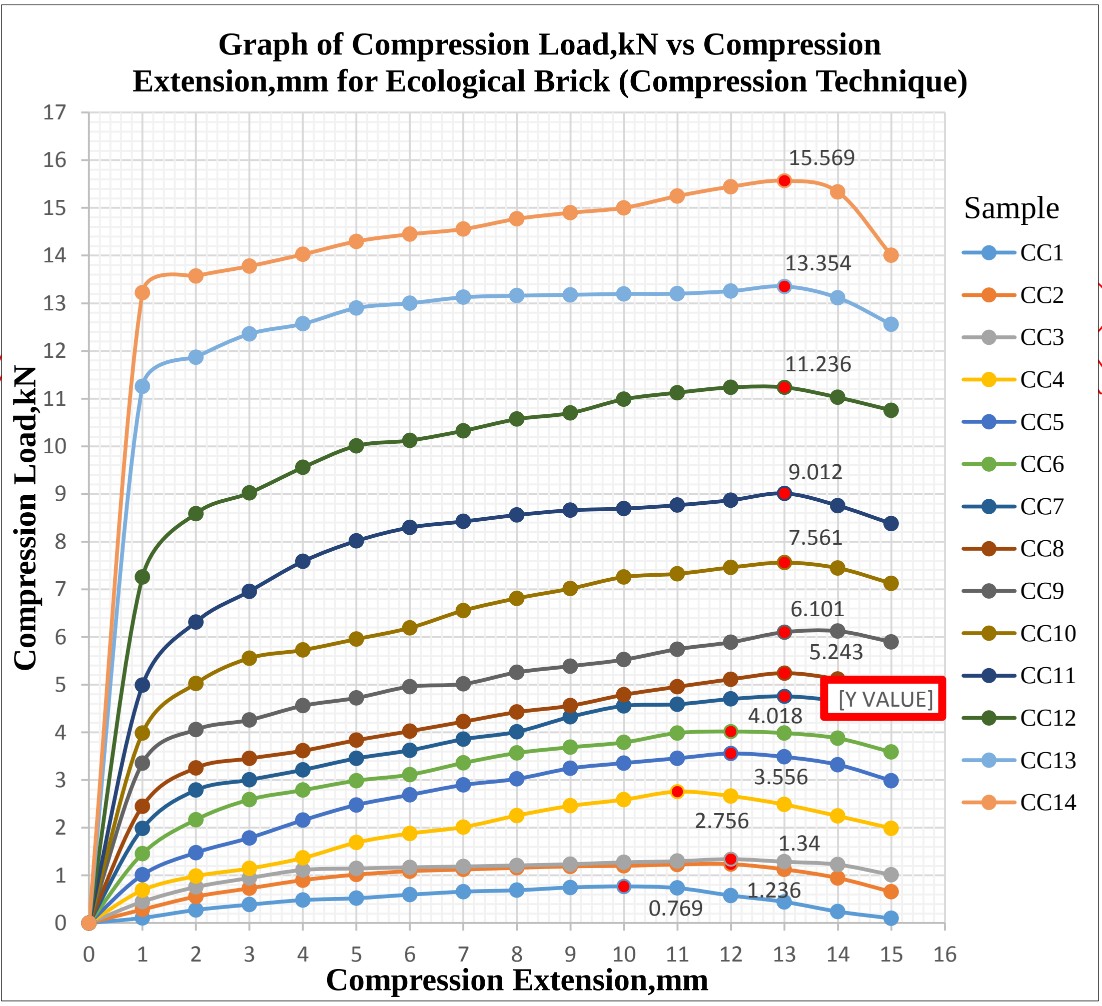

Figure 5.4: Graph compression load, kN vs Compression Extension, mm.

Figure 5.4 shown the compression load, kN versus compression extension, mm graph. Minimum compression load are 4.5 kN, From sample CC7 until CC14 all exceeded the minimum point of the brick requirement. The more compression ratio were used, the stronger bonding were produced in brick structure. Sample CC7 with 4.756 kN was selected because we can reduce the cost of making brick when using minimum power consumption. In order to maximize the usage of cow chips, sample CC14 with compression 14 Bar was selected. The cow chips contained is much more compared with other, because to make brick with same size the usage of cow chips is difference due to compression ratio. In this research, sample CC1 until CC6 it consider failed, because the compression load not reach the minimum requirement of brick. This method will improve the compressive load by doing heat treatment at 800 ºC of temperature in furnace, then the sample become true ceramic. By using this method, the properties of brick will change from ductile to brittle.

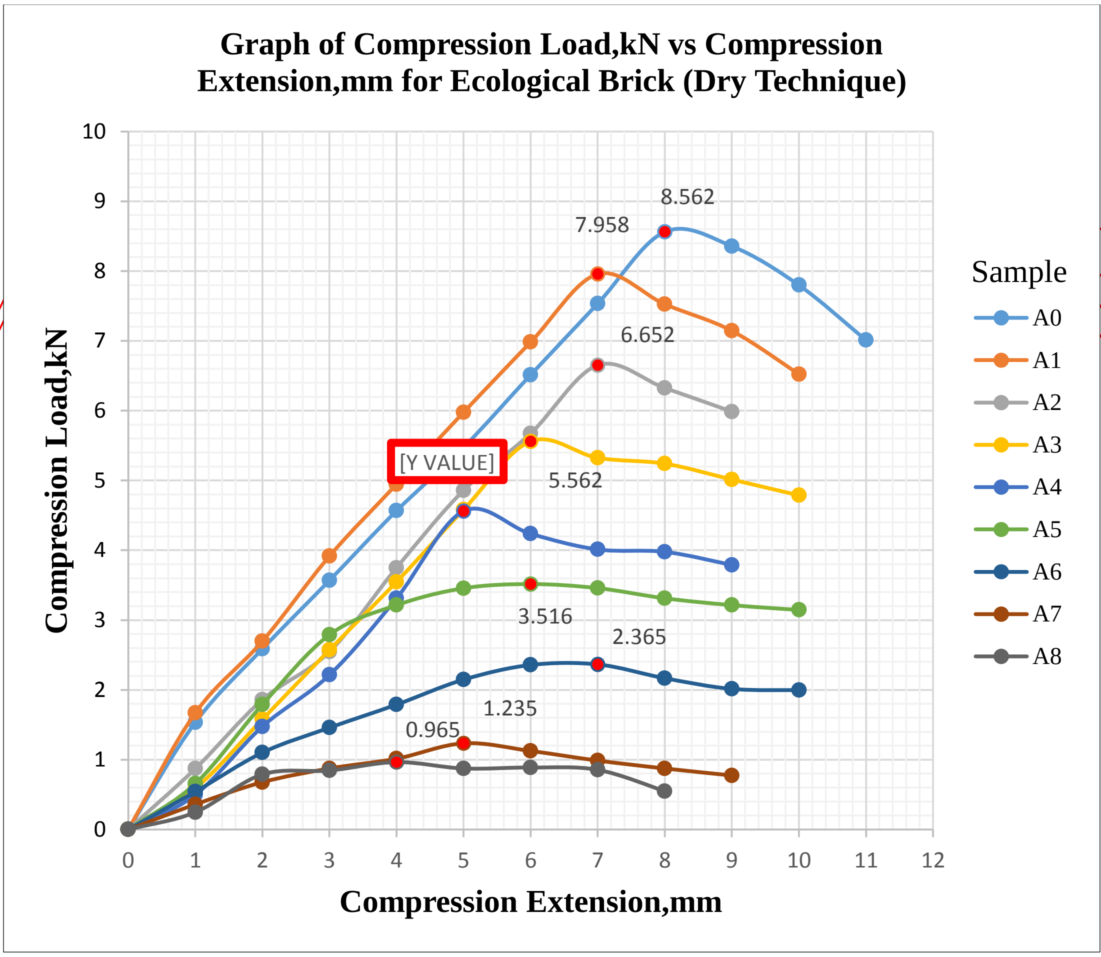

Figure 5.5: Graph compression load, kN vs Compression Extension, mm.

Figure 5.5 and Figure 5.6 shown the compression load, kN versus compression extension, mm graph. The minimum compression load are 4.5 kN.

Based on these graphs, from sample A4 to A0 and sample B4 to B0, the compression reading are exceeded the minimum requirement of brick. For sample A4 and B4 are 4.562 kN and 5.325 kN contained 40 % of cow chips and 40 % of fly ash. This figure also show the percentage of cow chips were influence the bonding between all materials in brick. The compression load of sample B4 was higher than sample A4 because during curing in furnace, sample are undergoes the semi ceramic state. The quantity of cow chips and binder which is fly ash need to use in same ratio to make sure the bonding is enough to fulfill a brick requirement.

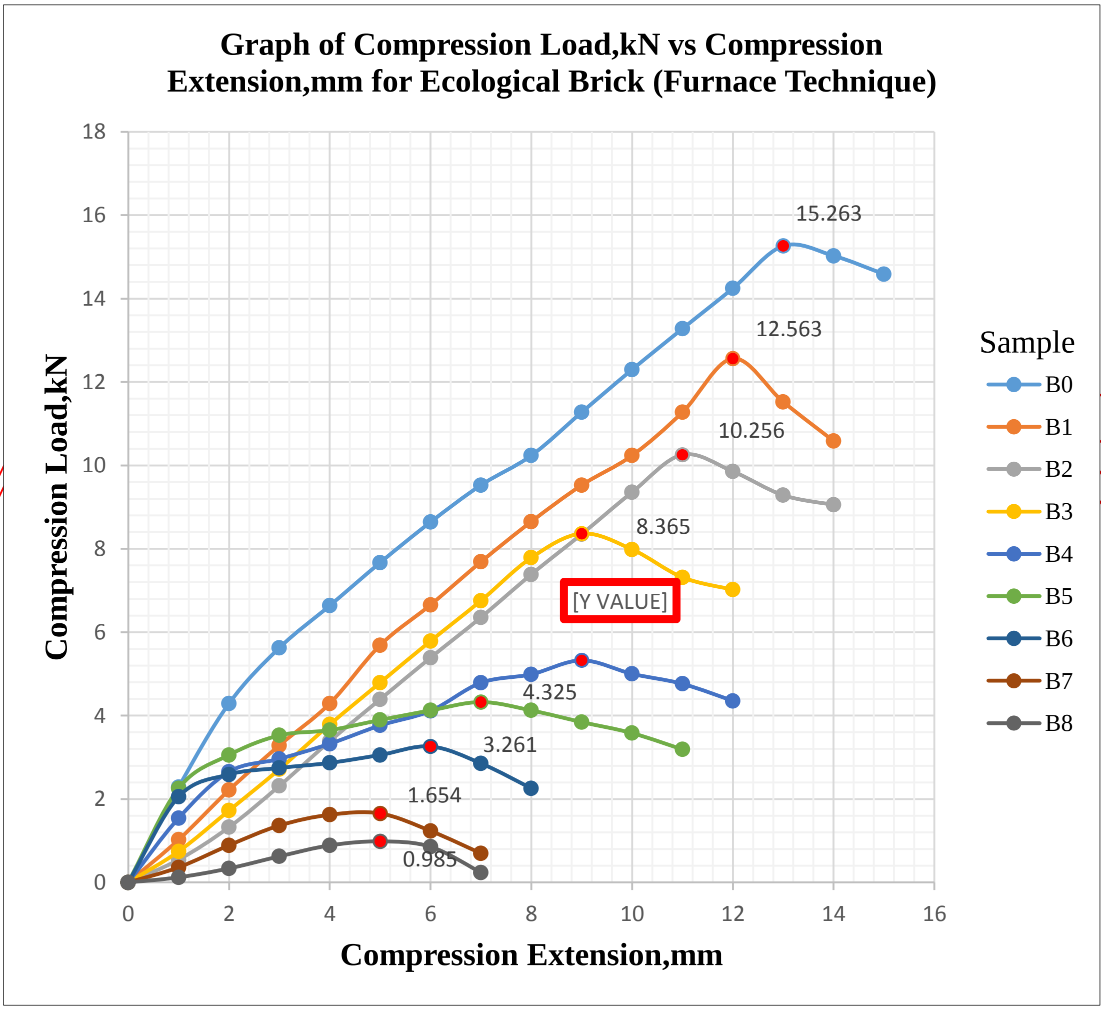

Figure 5.6: Graph compression load, kN vs Compression Extension, mm.

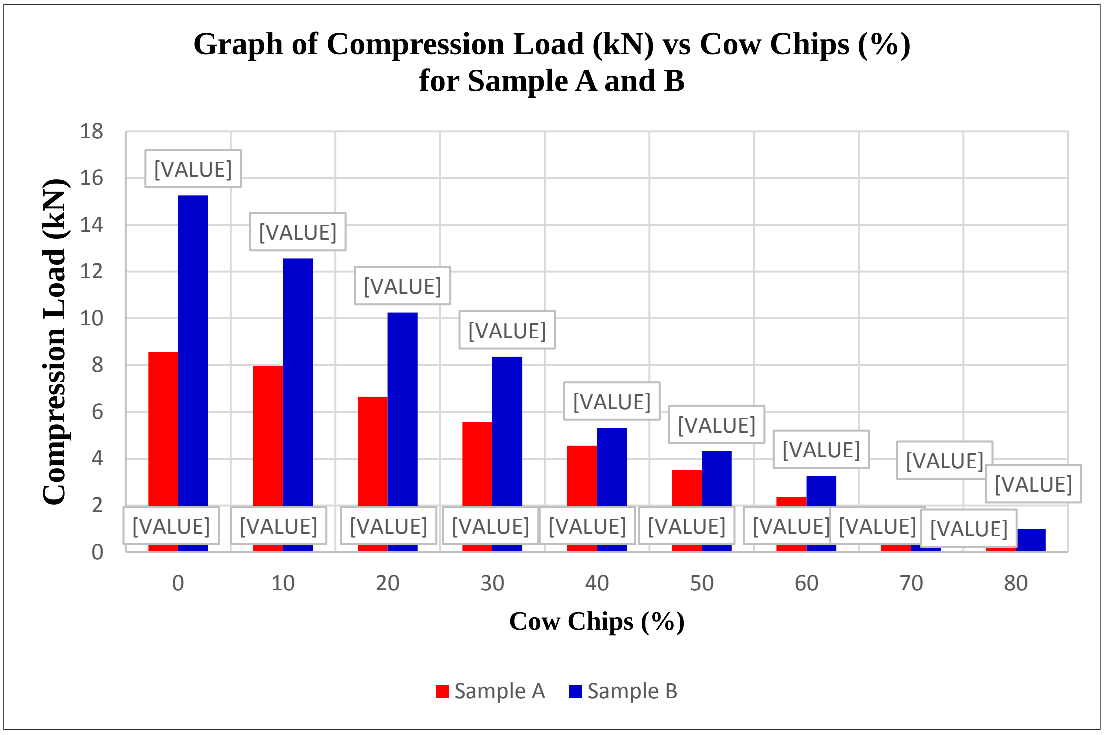

Figure 5.7: Graph compression load, kN vs Compression Extension, mm.

Figure 5.7 shown data of compression load versus cow chips with two sample, Sample B have higher value of load compared with sample A. Sample B was drying in furnace, during drying sample was undergoes the heat treatment but not reach the true ceramic. This sample only reach semi ceramic stage, because the temperature only 160 ºC. This sample will give better compression load if drying in furnace with 800 ºC for 6 hours, it will become true ceramic but the properties of material will change from ductile to brittle. Sample from heat treatment will increase the compression load, percentages of cow chips will increase the usage. 40 % of cow chip was selected in this research, because the minimum of maximum load is 4.5 kN. Sample A4 and B4 shows 4.562 kN and 5.325 kN was selected due the maximum percentages of waste which cow chips. Sample have 50 %, 60 %, 70 % and 80 % of cow chips it consider failed due to compression load is under the minimum requirement.

CHAPTER VI

CONCLUSION

Based on the result and analysis had been done for this research, the product sample created were gave positive and good result which fulfill the standard requirement based on several testing. The testing that has been conducted in this research was consisting of density, porosity, compression, thermal conductivity and microstructure. The aims of this research were achieved. The physical properties such as density and porosity of ecological brick were determined. The porosity standard requirement of lightweight brick is from 5 % to 20 % while the density standard requirement of lightweight brick is from 700 kg/m^3 to 1800 kg/m^3. Table 6.1 are the sample result that fulfill the requirement of lightweight brick.

Table 6.1: The best sample among all methods (Physical properties)

Sample Code	**Method**	**Cow chips (%)**	**Porosity (%)**	**Density (kg/m^3)**
CC7	Compression ratio	80	13.94	954.8432
A4	Room temperature	40	11.74	788.2494
B4	furnace	40	15.35	724.4785

Table 6.1 conclude the most efficient method is using compression ratio technique. Beside that the usage of cow chips is the highest which is 80% that achieved the aim of research to maximum utilize of this local abundant material. Compare to the others method only used 40% of cow chips.

The other one and the most important testing for concrete is compression test. The maximum load and compressive strength standard requirement of lightweight brick are from 1.5 kN to 35 kN and 4.5 MPa to 35 MPa respectively. Table 4.2, Table 4.3 and Table 4.4 are the sample result of this test that fulfill the requirement of lightweight brick.

From Table 4.2, Table 4.3 and Table 4.4, the most efficient method is also compression ratio. By using this method, the compressive strength and maximum load that brick can absorb before rupture are higher compare to others method. Overall, the mechanical properties of lightweight brick were also determined. The microstructure view of lightweight brick also checked. The bonding between the raw materials in the mixture can be seen through microstructure test. In addition, thermal conductivity of brick also had been measured as shown in Table 4.4.

Table 4.4 shown the thermal conductivity measures the capacity of temperature exchange between heat and cold passing through a material mass. Three sample that have been chose are good in thermal conductivity because low than regular brick around 0.6 W/m. This brick will be wall and have the properties insulation (Abu, 2003). In development of building, the cost of insulation will reduce when use ecological brick. The power consumption will reduce, an example house with air conditioner will stay cool with long duration compare using normal brick when air conditioner is switch off.

Last but not least, the result of this research can provide simultaneous impact increased economy value of cow chips. By using the abundant local material which is cow chips instead of clay soil in common brick. This is because the usage of clay soil in brick can harmful the ecosystem. Beside that CO_2 production can be reduced by using compression method compare to furnace method if using of clay soil in brick making process.

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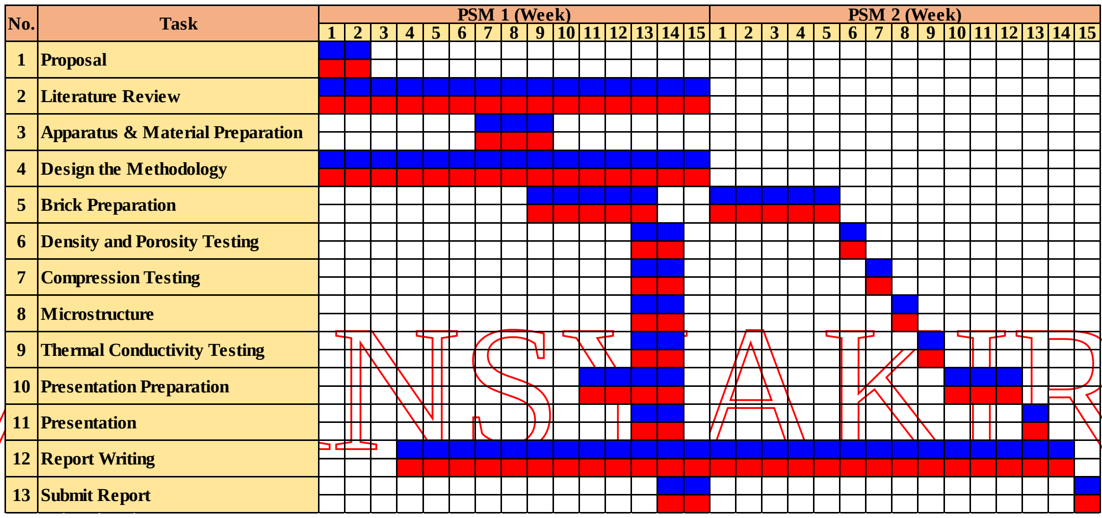
APPENDIX

APPENDIX A (Gantt chart)



APPENDIX B (American Society for Testing and Materials)

i. ASTM C109 Test Compressive Strength

Cube specimens are tested in according with ASTM C109, standard test method for compressive strength of cube brick specimen. A test result is average of at least three or preferably nine standard cured strength specimens made from the same brick sample and tested at the same from the same brick and tasted at the same condition. In most cases strength requirement for maximum strength for brick are at an age of 28 days.

The standard specimen is 2 inches in length, width, height and is capped with suitable material to provide a smooth bearing surface on each end of the specimens. The compressive strength is measure used by breaking cube brick specimen in a Universal Testing Machine is shown in Figure 3.2.

The compressive strength is calculated from the failure load divided by the cross sectional area resisting the load and reported in units of pound-force-per square inches (psi) in US. Customary units of Mega Pascal (MPa) in SI units. For this research, cube shape of brick size is 2 inches in length, width and height will undergo this test.

Figure 3.2: Universal Test Machine

The compressive test machine is connected to the computer as shown in. The data of brick sample such as length, width and height were key in into the Bluehill Software. The result data obtained from the computer are graphical data which is compressive load versus compressive extension. The other data can be obtained is in tabulated data where consist of several result which are maximum load, compressive strength , modulus, energy at local peak maximum, and strain 1 at yield (offset 0.2%).

ii. ASTM C373-88 Test Density and Porosity.

The apparent density and porosity and of the specimens measuring length 2 inches by 2 inches width and 2 inches of height was estimated by the Archimedes method using kerosene (ASTM C308-79). Subsequently their specific gravities were determined by dividing the unit weight of the sample by the unit volume.

Density

$$\text{Density, } \rho = \frac{m}{V} \qquad \text{Eq (3.1)}$$

Where m is the weight dry sample (kg), V is the volume cylinder (m^3), and ρ is density of the concrete sample (kg/m^3).

For the percent of porosity measurement, the weight reading must be taken before dipping it into water for 24 hours. Figure 3.4 shown the process of dipping. After 24 hours in water, samples were removed from immersion and weight reading was taken again.

Porosity

$$\%\ \text{Porosity} = \frac{W_{final} - W_{initial}}{W_{initial}} \times 100\% \qquad \text{Eq (3.2)}$$

Where W_{final} the weight after dipping or weight is wet specimen (g) and $W_{initial}$ is the weight before dipping or weight dry specimen (g)

iii. ASTM D4643 - 08 Determination of Water (Moisture) Content of Soil.

Volumetric water content:

$$\%\text{ water by volume} = \frac{(\text{wet brick weight}) - (\text{dry brcik weight})}{(\text{volume of sample})\ (\text{density of water})} \times 100 \qquad (3.3)$$

Gravimetric water content:

$$\%\text{ water by weight} = \frac{\text{wet soil weight} - \text{dry soil weight}}{\text{dry brick weight}} \times 100 \qquad (3.4)$$

For the percent of water content measurement, the weight reading must be taken before drying it into oven for 6 hours for which are 1500 ˚C. After reach the time, samples were removed from heating and weight reading was taken again. Then compare the value from volumetric water content and gravimetric water content.

iv. ASTM E210 - 63(2010) Optical Microscope

A microscope is in principle nothing else than a simple lens system for magnifying small objects. The first lens, called the objective, has a short focal length (a few mm), and creates an image of the object in the intermediate image plane. This image in turn can be looked at with another lens, the eye piece, which can provide further magnification.

The picture from an optical microscope lens could be caught by typical light delicate Polarizes to create a micrograph. Initially pictures were caught by photographic film yet advanced improvements in CMOS and later charge coupled device (CCD) Polarizes permit the catch of computerized pictures. Absolutely Digital Microscope lens are currently accessible which just utilize a CCD Polarized to inspect an example, and the picture is indicated straightforwardly on a workstation screen without the need for eye pieces.

Figure 3.3: Optical Microscope

v. ASTM C1470-00 Thermal Properties Test

The KD2 Pro Thermal Properties Analyzer shown in Figure 3.6 is used the transient line heat source method to measure thermal conductivity, resistivity, diffusivity, and heat capacity. This apparatus is fully portable field and lab thermal properties analyzer. The data analysis is based on thirty year and plus of research experience on heat and mass transfer in soils and other porous material (Pullman, 2012).

Time and temperature also can be readout from this apparatus. A proprietary algorithm fit time and temperature data with exponential integral function using nonlinear least square method. This full mathematic solution delivers thermal resistivity to within ± 10%. In addition, the KD2 Pro Thermal Properties Analyzer corrects for linear temperature drift.

This method has been conforms to IEEE standard 442-1981 and ASTM Standard D5334-00 by using specimen with dimension 100 mm long and 2.4mm diameter (Pullman, 2012).

Figure 3.4: KD2 Pro Thermal Properties Analyzer

APPENDIX C (Physical and mechanical properties for compression technique)

i. Density Testing

$$\text{Density, } \rho = \frac{m}{V} \qquad \text{Eq (1)}$$

Where m is the weight dry sample (kg), V is the volume cylinder (m3), and ρ is density of the concrete sample (kg/m³).

Sample Code: CC1

Table 1: Dimension and Parameter of Sample Code CC1.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5} m^3$)**	**Density (kg/m^3)**
CC11	0.0483	0.0340	0.0330	4.3853	752.5141
CC12	0.0485	0.0340	0.0330	4.4044	749.2507
CC13	0.0481	0.0340	0.0330	4.3671	755.6502
Average	0.0483	0.0340	0.0330	4.3856	752.4717

Sample Code: CC2

Table 2: Dimension and Parameter of Sample Code CC2.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC21	0.0476	0.0340	0.0330	4.3217	763.5884
CC22	0.0474	0.0340	0.0330	4.3035	766.8177
CC23	0.0477	0.0340	0.0330	4.3308	761.9839
Average	0.0473	0.0340	0.0330	4.3187	764.1300

Sample Code: CC3

Table 3: Dimension and Parameter of Sample Code CC3.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC31	0.0454	0.0340	0.0330	4.1220	800.5822
CC32	0.0457	0.0340	0.0330	4.1492	795.3340
CC33	0.0453	0.0340	0.0330	4.1128	802.3731
Average	0.0455	0.0340	0.0330	4.1280	799.4298

Sample Code: CC4

Table 4: Dimension and Parameter of Sample Code CC4.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC41	0.0434	0.0340	0.0330	3.9404	837.4784
CC42	0.0432	0.0340	0.0330	3.9222	841.3645
CC43	0.0436	0.0340	0.0330	3.9585	833.6491
Average	0.0434	0.0340	0.0330	3.9404	837.4973

Sample Code: CC5

Table 5: Dimension and Parameter of Sample Code CC5.

Specimen	Height (m)	Diameter (m)	Mass (kg)	Volume ($\times 10^{-4}m^3$)	Density (kg/m^3)
CC51	0.0415	0.0340	0.0330	3.7679	875.8194
CC52	0.0412	0.0340	0.0330	3.7406	882.2114
CC53	0.0416	0.0340	0.0330	3.7770	873.7093
Average	0.0414	0.0340	0.0330	3.7618	877.2467

Sample Code: CC6

Table 4.8: Dimension and Parameter of Sample Code CC6.

Specimen	Height (m)	Diameter (m)	Mass (kg)	Volume ($\times 10^{-5}m^3$)	Density (kg/m^3)
CC61	0.0396	0.0340	0.0330	3.5954	917.8395
CC62	0.0398	0.0340	0.0330	3.6135	913.2420
CC63	0.0396	0.0340	0.0330	3.5954	917.8395
Average	0.0369	0.0340	0.0330	3.6014	916.3070

Sample Code: CC7

Table 7: Dimension and Parameter of Sample Code CC7.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC71	0.0383	0.0340	0.0330	3.4773	949.0122
CC72	0.0379	0.0340	0.0330	3.4410	959.0235
CC73	0.0380	0.0340	0.0330	3.4501	956.4940
Average	0.0381	0.0340	0.0330	3.4561	954.8432

Sample Code: CC8

Table 8: Dimension and Parameter of Sample Code CC8.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC81	0.0365	0.0340	0.0330	3.3139	995.8055
CC82	0.0363	0.0340	0.0330	3.2958	1101.2743
CC83	0.0364	0.0340	0.0330	3.3048	998.5476
Average	0.0364	0.0340	0.0330	3.3048	1031.8758

Sample Code: CC9

Table 9: Dimension and Parameter of Sample Code CC9.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}m^3$)**	**Density (kg/m^3)**
CC91	0.0343	0.0340	0.0330	3.1142	1059.6622
CC92	0.0344	0.0340	0.0330	3.1232	1056.6086
CC93	0.0344	0.0340	0.0330	3.1232	1056.6086
Average	0.0344	0.0340	0.0330	3.1202	1057.6265

Sample Code: CC10

Table 10: Dimension and Parameter of Sample Code CC10.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5}m^3$)**	**Density (kg/m^3)**
CC101	0.0324	0.0340	0.0330	2.9417	1121.8003
CC102	0.0323	0.0340	0.0330	2.9326	1125.2813
CC103	0.0322	0.0340	0.0330	2.9235	1128.7840
Average	0.0323	0.0340	0.0330	2.9326	1125.2885

Sample Code: CC11

Table 11: Dimension and Parameter of Sample Code CC11.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5} m^3$)**	**Density (kg/m^3)**
CC111	0.0303	0.0340	0.0330	2.7510	1199.5638
CC112	0.0306	0.0340	0.0330	2.7782	1187.8195
CC113	0.0304	0.0340	0.0330	2.7601	1195.6089
Average	0.0304	0.0340	0.0330	2.7631	1194.3307

Sample Code: CC12

Table 12: Dimension and Parameter of Sample Code CC12.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5} m^3$)**	**Density (kg/m^3)**
CC121	0.0289	0.0340	0.0330	2.6239	1257.6699
CC122	0.0288	0.0340	0.0330	2.6148	1262.0468
CC123	0.0286	0.0340	0.0330	2.5967	1270.8438
Average	0.0288	0.0340	0.0330	2.6118	1263.5202

Sample Code: CC13

Table 13: Dimension and Parameter of Sample Code CC13.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5} m^3$)**	**Density (kg/m^3)**
CC131	0.0271	0.0340	0.0330	2.4605	1341.1908
CC132	0.0269	0.0340	0.0330	2.4423	1351.1853
CC133	0.0268	0.0340	0.0330	2.4332	1356.2387
Average	0.0269	0.0340	0.0330	2.4453	1349.5383

Sample Code: CC14

Table 14: Dimension and Parameter of Sample Code CC14.

Specimen	**Height (m)**	**Diameter (m)**	**Mass (kg)**	**Volume ($\times 10^{-5} m^3$)**	**Density (kg/m^3)**
CC141	0.0256	0.0340	0.0330	2.3243	1419.7823
CC142	0.0254	0.0340	0.0330	2.3061	1430.9874
CC143	0.0253	0.0340	0.0330	2.2970	1436.6565
Average	0.0254	0.0340	0.0330	2.3091	1429.1421

Table 15: Result sample for density.

Sample Code	**Compression ratio (Bar)**	**Density (kg/m^3)**
CC1	1	**752.4717**
CC2	2	**764.1300**
CC3	3	**799.4298**
CC4	4	**837.4973**
CC5	5	**877.2467**
CC6	6	**916.3070**
CC7	7	**954.8432**
CC8	8	**1031.8758**
CC9	9	**1057.6265**
CC10	10	**1125.2885**
CC11	11	**1194.3307**
CC12	12	**1263.5202**
CC13	13	**1349.5383**
CC14	14	**1429.1421**

ii. Porosity Testing

$$\% \text{ Porosity} = \frac{W_{final} - W_{initial}}{W_{initial}} \times 100\% \qquad \text{Eq (2)}$$

Where W_{final} the weight after dipping or weight is wet specimen (g) and $W_{initial}$ is the weight before dipping or weight dry specimen (g)

Table 4.16: Result sample for porosity.

Sample Code	**W_{final} (g)**	**$W_{initial}$ (g)**	**Porosity**	**% Porosity**
CC1	0.0426	0.0330	0.2909	**29.09**
CC2	0.0403	0.0330	0.2212	**22.12**
CC3	0.0396	0.0330	0.2061	**20.61**
CC4	0.0395	0.0330	0.1970	**19.70**
CC5	0.0388	0.0330	0.1758	**17.58**
CC6	0.0383	0.0330	0.1606	**16.06**
CC7	0.0376	0.0330	0.1394	**13.94**
CC8	0.0372	0.0330	0.1273	**12.73**
CC9	0.0369	0.0330	0.1182	**11.82**
CC10	0.0367	0.0330	0.1121	**11.21**
CC11	0.0361	0.0330	0.0939	**9.39**
CC12	0.0354	0.0330	0.0727	**7.27**
CC13	0.0349	0.0330	0.0576	**5.76**
CC14	0.0341	0.0330	0.0333	**3.33**

iii. Compression Testing

Table 17: Data Compressive Test for sample CC1.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC11	0.768	0.70
CC12	0.769	0.71
CC13	0.770	0.69
Average	0.769	0.70

Table 18: Data Compressive Test for sample CC2.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC21	1.236	1.15
CC22	1.234	1.08
CC23	1.239	1.13
Average	1.236	1.12

Table 19: Data Compressive Test for sample CC3.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC31	1.339	1.25
CC32	1.337	1.23
CC33	1.344	1.18
Average	1.340	1.22

Table 20: Data Compressive Test for sample CC4.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC41	2.754	2.35
CC42	2.761	2.33
CC43	2.753	2.34
Average	2.756	2.34

Table 21: Data Compressive Test for sample CC5.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC51	3.558	3.25
CC52	3.555	3.21
CC53	3.555	3.23
Average	3.556	3.23

Table 22: Data Compressive Test for sample CC6.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC61	4.015	3.66
CC62	4.018	3.66
CC63	4.021	3.63
Average	4.018	3.65

Table 23: Data Compressive Test for sample CC7.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC71	4.753	4.55
CC72	4.761	4.60
CC73	4.754	4.53
Average	4.756	4.56

Table 4.24: Data Compressive Test for sample CC8.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC81	5.238	4.95
CC92	5.245	5.02
CC83	5.246	4.95
Average	5.243	4.98

Table 25: Data Compressive Test for sample CC9.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC91	6.125	5.68
CC92	6.121	5.66
CC93	6.123	5.70
Average	6.123	5.68

Table 26: Data Compressive Test for sample CC10.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC101	7.560	6.24
CC102	7.564	6.24
CC103	7.559	6.21
Average	7.561	6.23

Table 27: Data Compressive Test for sample CC11.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC111	9.015	6.80
CC112	9.008	6.82
CC113	9.013	6.75
Average	9.012	6.79

Table 28: Data Compressive Test for sample CC12.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC121	11.233	7.98
CC122	11.240	8.09
CC123	11.235	7.99
Average	11.236	8.02

Table 29: Data Compressive Test for sample CC13.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC131	13.351	8.94
CC132	13.359	8.98
CC133	13.352	8.99
Average	13.354	8.97

Table 30: Data Compressive Test for sample CC14.

Sample Code	Maximum Load (kN)	Compression Strength (MPa)
CC141	15.567	9.55
CC142	15.572	9.60
CC143	15.568	9.53
Average	15.569	9.56

Table 31: Result sample for maximum load and compression strength.

Sample Code	Compression ratio (Bar)	Maximum Load (kN)	Compression Strength (MPa)
CC1	1	0.7690	0.70
CC2	2	1.2360	1.12
CC3	3	1.3400	1.22
CC4	4	2.7560	2.34
CC5	5	3.5560	3.23
CC6	6	4.0180	3.65
CC7	7	4.7560	4.56
CC8	8	5.2430	4.98
CC9	9	6.1230	5.68
CC10	10	7.5610	6.23
CC11	11	9.0120	6.79
CC12	12	11.2360	8.02
CC13	13	13.3540	8.97
CC14	14	15.5690	9.56

APPENDIX D (Physical and mechanical properties for room temperature)

i. Density Testing

$$\text{Density, } \rho = \frac{m}{V} \qquad \text{Eq (1)}$$

Where m is the weight dry sample (kg), V is the volume cylinder (m3), and ρ is density of the concrete sample (kg/m³).

Sample Code: A0

Table 1: Dimension and Parameter of Sample Code A0.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}m^3$)**	**Density (kg/m^3)**
A01	0.0503	0.0508	0.0508	0.1452	1.2981	1118.5579
A02	0.0505	0.0508	0.0508	0.1455	1.3032	1116.4825
A03	0.0508	0.0508	0.0508	0.1451	1.3110	1106.7887
Average	0.0505	0.0508	0.0508	0.1453	1.3041	1113.9430

Sample Code: A1

Table 2: Dimension and Parameter of Sample Code A1.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}m^3$)**	**Density (kg/m^3)**
A11	0.0506	0.0508	0.0508	0.1357	1.3058	1039.2097
A12	0.0503	0.0508	0.0508	0.1355	1.2981	1043.8333
A13	0.0504	0.0508	0.0508	0.1356	1.3006	1042.5957
Average	0.504	0.0508	0.0508	0.1356	1.3015	1041.8796

Sample Code: A2

Table 3: Dimension and Parameter of Sample Code A2.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
A21	0.0503	0.0508	0.0508	0.1245	1.2981	959.0941
A22	0.0509	0.0508	0.0508	0.1248	1.3135	950.1332
A23	0.0506	0.0508	0.0508	0.1241	1.3058	950.3752
Average	0.0506	0.0508	0.0508	0.1245	1.3058	953.2008

Sample Code: A3

Table 4: Dimension and Parameter of Sample Code A3.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
A31	0.0509	0.0508	0.0508	0.1145	1.3135	871.7168
A32	0.0511	0.0508	0.0508	0.1125	1.3187	871.3127
A33	0.0509	0.0508	0.0508	0.1149	1.3135	867.9102
Average	0.0510	0.0508	0.0508	0.1140	1.3152	870.3132

Sample Code: A4

Table 5: Dimension and Parameter of Sample Code A4.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
A41	0.0509	0.0508	0.0508	0.1045	1.3135	795.5843
A42	0.0507	0.0508	0.0508	0.1023	1.3084	781.8710
A43	0.0505	0.0508	0.0508	0.1026	1.3032	787.2928
Average	0.0507	0.0508	0.0508	0.1031	1.3084	788.2494

Sample Code: A5

Table 6: Dimension and Parameter of Sample Code A5.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}$m^3)**	**Density (kg/m^3)**
A51	0.0507	0.0508	0.0508	0.0955	1.3084	729.8991
A52	0.0509	0.0508	0.0508	0.0957	1.3135	728.5877
A53	0.0506	0.0508	0.0508	0.0952	1.3058	729.0550
Average	0.0507	0.0508	0.0508	0.0955	1.3092	729.1806

Sample Code: A6

Table 7: Dimension and Parameter of Sample Code A6.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}$m^3)**	**Density (kg/m^3)**
A61	0.0509	0.0508	0.0508	0.0816	1.3135	621.2410
A62	0.0510	0.0508	0.0508	0.0813	1.3161	617.7342
A63	0.0507	0.0508	0.0508	0.0810	1.3084	619.0767
Average	0.0509	0.0508	0.0508	0.0813	1.3127	619.3506

Sample Code: A7

Table 8: Dimension and Parameter of Sample Code A7.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}$m^3)**	**Density (kg/m^3)**
A71	0.0509	0.0508	0.0508	0.0698	1.3135	531.4046
A72	0.0508	0.0508	0.0508	0.0701	1.3110	534.7063
A73	0.0505	0.0508	0.0508	0.0697	1.3032	534.8373
Average	0.0507	0.0508	0.0508	0.0699	1.3202	533.6494

Sample Code: A8

Table 9: Dimension and Parameter of Sample Code A8.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
A81	0.0509	0.0508	0.0508	0.0523	1.3135	398.1728
A82	0.0507	0.0508	0.0508	0.0529	1.3084	404.3106
A83	0.0506	0.0508	0.0508	0.0524	1.3058	401.2866
Average	0.0507	0.0508	0.0508	0.0524	1.3092	401.2567

Table 10: Result sample for density.

Sample Code	**Fly Ash (%)**	**Cow Chips (%)**	**Density (kg/m^3)**
A0	80	0	1113.9430
A1	70	10	1041.8796
A2	60	20	953.2008
A3	50	30	870.3132
A4	40	40	788.2494
A5	30	50	729.1806
A6	20	60	619.3506
A7	10	70	533.6494
A8	0	80	401.2567

ii. Porosity Testing

$$\% \text{ Porosity} = \frac{W_{final} - W_{initial}}{W_{initial}} \times 100\% \qquad \text{Eq (2)}$$

Where W_{final} the weight after dipping or weight is wet specimen (g) and $W_{initial}$ is the weight before dipping or weight dry specimen (g)

Table 11: Result sample for porosity.

Sample Code	W_{final} (g)	$W_{initial}$ (g)	Porosity	% Porosity
A0	0.1476	0.1453	0.0158	1.58
A1	0.1399	0.1356	0.0317	3.17
A2	0.1355	0.1245	0.0835	8.35
A3	0.1256	0.1140	0.1018	10.18
A4	0.1152	0.1031	0.1174	11.74
A5	0.1081	0.0955	0.1319	13.19
A6	0.0955	0.0813	0.1747	17.47
A7	0.0869	0.0699	0.2432	24.32
A8	0.0716	0.0524	0.3664	36.64

iii. Compression Testing

Table 12: Data Compressive Test for sample A0.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A01	8.562	5.885
A02	8.564	5.884
A03	8.560	5.883
Average	8.562	5.884

Table 13: Data Compressive Test for sample A1.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A11	7.960	5.391
A12	7.959	5.396
A13	7.955	5.395
Average	7.958	5.394

Table 14: Data Compressive Test for sample A2.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A21	6.651	4.899
A22	6.649	4.908
A23	6.656	4.902
Average	6.652	4.903

Table 15: Data Compressive Test for sample A3.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A31	5.558	2.941
A32	5.564	2.943
A33	5.564	2.942
Average	5.562	2.940

Table 16: Data Compressive Test for sample A4.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A41	4.566	1.965
A42	4.559	1.958
A43	4.561	1.960
Average	4.562	1.961

Table 17: Data Compressive Test for sample A5.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
A51	3.152	1.474
A52	3.521	1.471
A53	3.515	1.468
Average	3.516	1.471

Table 17: Data Compressive Test for sample A6.

Sample Code	**Compression Strength (MPa)**	**Maximum Load (kN)**
A61	2.361	0.988
A62	2.363	0.976
A63	2.371	0.991
Average	2.365	0.985

Table 18: Data Compressive Test for sample A7.

Sample Code	**Compression Strength (MPa)**	**Maximum Load (kN)**
A71	1.232	0.565
A72	1.240	0.567
A73	1.233	0.575
Average	1.235	0.569

Table 19: Data Compressive Test for sample A8.

Sample Code	**Compression Strength (MPa)**	**Maximum Load (kN)**
A81	0.963	0.233
A82	0.967	0.236
A83	0.965	0.236
Average	0.965	0.235

Table 20: Result sample for maximum load and compression strength.

Sample Code	**Cow Chips (%)**	**Compression Strength (MPa)**	**Maximum Load (kN)**
A0	0	8.5620	5.8840
A1	10	7.9580	5.3940
A2	20	6.6520	4.9030
A3	30	5.5620	2.9420
A4	40	4.5620	1.9610
A5	50	3.5160	1.4710
A6	60	2.3650	0.9850
A7	70	1.2350	0.5690

APPENDIX E (Physical and mechanical properties for furnace)

i. Density Testing

$$\text{Density, } \rho = \frac{m}{V} \qquad \text{Eq (1)}$$

Where m is the weight dry sample (kg), V is the volume cylinder (m3), and ρ is density of the concrete sample (kg/m³).

Sample Code: B0

Table 1: Dimension and Parameter of Sample Code B0.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}m^3$)**	**Density (kg/m^3)**
B01	0.0509	0.0508	0.0508	0.1385	1.3135	1054.4347
B02	0.0510	0.0508	0.0508	0.1384	1.3161	1051.5918
B03	0.0508	0.0508	0.0508	0.1377	1.3110	1050.3432
Average	0.0509	0.0508	0.0508	0.1382	1.3135	1052.4566

Sample Code: B1

Table 2: Dimension and Parameter of Sample Code B1.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}m^3$)**	**Density (kg/m^3)**
B11	0.0506	0.0508	0.0508	0.1276	1.3058	977.1787
B12	0.0510	0.0508	0.0508	0.1278	1.3161	971.0508
B13	0.0507	0.0508	0.0508	0.1277	1.3084	976.0012
Average	0.0508	0.0508	0.0508	0.1277	1.3101	974.7436

Sample Code: B2

Table 3: Dimension and Parameter of Sample Code B2.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}\mathrm{m}^3$)**	**Density ($\mathrm{kg/m}^3$)**
B21	0.0509	0.0508	0.0508	0.1150	1.3135	875.5234
B22	0.0507	0.0508	0.0508	0.1158	1.3084	885.0504
B23	0.0507	0.0508	0.0508	0.1151	1.3084	879.7004
Average	0.0508	0.0508	0.0508	0.1153	1.3101	880.0914

Sample Code: B3

Table 4: Dimension and Parameter of Sample Code B3.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}\mathrm{m}^3$)**	**Density ($\mathrm{kg/m}^3$)**
B31	0.0508	0.0508	0.0508	0.1077	1.3110	821.5103
B32	0.0510	0.0508	0.0508	0.1082	1.3161	822.1260
B33	0.0511	0.0508	0.0508	0.1078	1.3187	817.4718
Average	0.0510	0.0508	0.0508	0.1079	1.3153	820.3694

Sample Code: B4

Table 5: Dimension and Parameter of Sample Code B4.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}\mathrm{m}^3$)**	**Density ($\mathrm{kg/m}^3$)**
B41	0.0509	0.0508	0.0508	0.0954	1.3135	726.3038
B42	0.0509	0.0508	0.0508	0.0951	1.3135	724.0197
B43	0.0508	0.0508	0.0508	0.0948	1.3110	723.1121
Average	0.0509	0.0508	0.0508	0.0951	1.3127	724.4785

Sample Code: B5

Table 6: Dimension and Parameter of Sample Code B5.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
B51	0.0509	0.0508	0.0508	0.0874	1.3135	665.3978
B52	0.0507	0.0508	0.0508	0.0872	1.3084	666.4629
B53	0.0508	0.0508	0.0508	0.0870	1.3110	663.6156
Average	0.0508	0.0508	0.0508	0.0872	1.3110	665.1588

Sample Code: B6

Table 7: Dimension and Parameter of Sample Code B6.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
B61	0.0509	0.0508	0.0508	0.0783	1.3135	596.1172
B62	0.0507	0.0508	0.0508	0.0774	1.3084	591.5622
B63	0.0506	0.0508	0.0508	0.0774	1.3058	592.7401
Average	0.0507	0.0508	0.0508	0.0777	1.3092	593.4732

Sample Code: B7

Table 8: Dimension and Parameter of Sample Code B7.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4} m^3$)**	**Density (kg/m^3)**
B71	0.0507	0.0508	0.0508	0.0607	1.3084	463.9254
B72	0.0510	0.0508	0.0508	0.0611	1.3161	464.2504
B73	0.0509	0.0508	0.0508	0.0612	1.3135	465.9307
Average	0.0509	0.0508	0.0508	0.0610	1.3127	464.7022

Sample Code: B8

Table 9: Dimension and Parameter of Sample Code B8.

Specimen	**Height (m)**	**Length (m)**	**Width (m)**	**Mass (kg)**	**Volume ($\times 10^{-4}$m^3)**	**Density (kg/m^3)**
B81	0.0508	0.0508	0.0508	0.0486	1.3110	370.7094
B82	0.0510	0.0508	0.0508	0.0488	1.3161	370.7925
B83	0.0510	0.0508	0.0508	0.0493	1.3161	374.5916
Average	0.0509	0.0508	0.0508	0.0489	1.3144	372.0312

Table 10: Result sample for density.

Sample Code	**Fly Ash (%)**	**Cow Chips (%)**	**Density (kg/m^3)**
B0	80	0	1052.4566
B1	70	10	974.7436
B2	60	20	880.0914
B3	50	30	820.3694
B4	40	40	724.4785
B5	30	50	665.1588
B6	20	60	593.4732
B7	10	70	464.7022
B8	0	80	372.0312

ii. Porosity Testing

$$\% \text{ Porosity} = \frac{W_{final} - W_{initial}}{W_{initial}} \times 100\% \qquad \text{Eq (4.4)}$$

Where W_{final} the weight after dipping or weight is wet specimen (g) and $W_{initial}$ is the weight before dipping or weight dry specimen (g)

Table 11: Result sample for porosity.

Sample Code	**W_{final} (g)**	**$W_{initial}$ (g)**	**Porosity**	**% Porosity**
B0	0.1456	0.1382	0.0535	5.35
B1	0.1386	0.1277	0.0856	8.56
B2	0.1298	0.1153	0.1258	12.58
B3	0.1223	0.1079	0.1335	13.35
B4	0.1097	0.0951	0.1535	15.35
B5	0.1015	0.0872	0.1640	16.40
B6	0.0909	0.0777	0.1699	16.99
B7	0.0716	0.0610	0.1738	17.38
B8	0.0579	0.0489	0.1840	18.40

iii. Compression Testing

Table 12: Data Compressive Test for sample B0.

Sample Code	**Compression Strength (MPa)**	**Maximum Load (kN)**
B01	7.844	15.266
B02	7.844	15.260
B03	7.847	15.263
Average	7.845	15.263

Table 13: Data Compressive Test for sample B1.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B11	12.565	6.866
B12	12.558	6.863
B13	12.566	6.863
Average	12.563	6.864

Table 14: Data Compressive Test for sample B2.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B21	10.250	5.889
B22	10.258	5.882
B23	10.260	5.881
Average	10.256	5.884

Table 15: Data Compressive Test for sample B3.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B31	8.365	4.894
B32	8.370	4.914
B33	8.360	4.901
Average	8.365	4.903

Table 16: Data Compressive Test for sample B4.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B41	5.319	3.919
B42	5.331	3.922
B43	5.325	3.928
Average	5.325	3.923

Table 17: Data Compressive Test for sample B5.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B51	4.328	2.938
B52	4.321	2.949
B53	4.326	2.939
Average	4.325	2.942

Table 18: Data Compressive Test for sample B6.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B61	3.261	2.448
B62	3.263	2.453
B63	3.259	2.464
Average	3.261	2.455

Table 19: Data Compressive Test for sample B7.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B71	1.655	0.979
B72	1.654	0.984
B73	1.653	0.980
Average	1.654	0.981

Table 20: Data Compressive Test for sample B8.

Sample Code	Compression Strength (MPa)	Maximum Load (kN)
B81	0.985	0.693
B82	0.986	0.693
B83	0.954	0.696
Average	0.985	0.694

Table 21: Result sample for maximum load and compression strength.

Sample Code	Cow Chips (%)	Maximum Load (kN)	Compression Strength (MPa)
B0	0	15.2630	7.8450
B1	10	12.5630	6.8640
B2	20	10.2560	5.8840
B3	30	8.3650	4.9030
B4	40	5.3250	3.9230
B5	50	4.3250	2.9420
B6	60	3.2610	2.4550
B7	70	1.6540	0.9810

APPENDIX F (UTeMEX 2013 - Bronze Medal)