EFFECTIVENESS OF USING EMPTY FRUIT BUNCH, COCONUT FIBER AND SUGARCANE BAGGASSE FOR LOW THERMAL CONDUCTIVITY CLAY BRICKS

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A thesis submitted in fulfillment of the requirement for the award of the Degree of Master of Civil Engineering

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DEDICATION

Bismillahirrahmanirrahim…

Appreciate to all those who helped directly or indirectly in completing this project.

To my beloved father and mother, Hamzah bin Jasin and Jambi binti Ismail, a tremendous thanks for will educate your son up to his present level.

To family members, thank you for the support given.
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Thank You
ABSTRACT

Approximately 45% of the average household electricity in Malaysia is consumed by air conditioners to create an acceptable indoor environment. This high energy consumption is increase due to poor thermal performance of the building envelope. Therefore, selecting a low thermal conductivity of brick wall is of considerable important in creating low energy building consumption. Numerous studies have reported the potential use of agricultural waste as an additive in building materials to enhance their thermal insulation properties. The objective of this study is to examine the use of agricultural wastes from empty fruit bunch (EFB), coconut fibre (CF) and sugarcane bagasse (SB) as additive agents in a fired clay brick manufacturing process to produce a low thermal conductivity clay brick. In this study, these agricultural wastes are individually mixed with clay soil in different proportions ranging from 0%, 2.5%, 5%, 7.5% and 10% by weight. Physical and mechanical properties including soil physical properties, as well as thermal conductivity has been examine in accordance with BS 1377: Part 2: 1990, BS 3921: 1985 and ASTM C518. The results of this study reveal that incorporating 5% of EFB as an additive component into brick making process significantly enhance the production of a low thermal conductivity clay brick as compared to other waste alternatives tested. The control brick (CB) and 5% EFB masonry wall at size 1 m x 0.102 m x 1 m is built to access thermal surface temperature of the masonry wall model. The results reveal that the 5% EFB brick reduces the thermal conductivity value as well as reduces the thermal surface temperature of the constructed masonry wall model at night, where the significant on thermal imaging colour show much faster release heat. The outcome of this research suggests clearly that EFB waste is a potential additive material for thermal insulation enhancement of the building envelope. Thus, the temperature of the outer surface of the wall give impact inside building, where EFB waste bricks able to give thermal comfort inside building during at night.
ABSTRAK

Di Malaysia dianggarkan purata penggunaan elektrik sebanyak 45% hasil daripada penggunaan penghawa dingin yang digunakan untuk pengudaraan persekutuan. Penggunaan tenaga yang tinggi selalunya dikaitkan dengan kelemahan prestasi terma di dalam bangunan. Oleh itu, pemilihan dinding yang mempunyai kekonduksian haba yang rendah amat dititikberatkan bagi menghasilkan bangunan yang rendah tenaga. Dalam kajian-kajian sebelum ini, telah banyak penyelidik melaporkan potensi penggunaan sisa pertanian sebagai bahan tambah di dalam bahan binaan bagi mempertingkatkan sifat – sifat penebatan terma. Tujuan kajian ini dijalankan adalah untuk menilai penggunaan bahan pertanian dari Tandan Buah Kelapa Sawit (EFB), Sabut Kelapa (CF) dan Hampas Tebu (SB) sebagai ejen bahan tambah di dalam penghasilan batu bata bakar untuk menghasilkan batu – bata tanah liat rendah keberbalikan terma. Dalam kajian ini, bahan – bahan sisa pertanian secara individu dicampurkan kepada bermula dari 0%, 2.5%, 5%, 7.5% hingga 10% mengikut timbangan berat. Sifat – sifat fizikal dan mekanikal termasuk sifat-sifat fizikal tanah serta kekonduksian terma dinilai mengikut piawaian BS 1377: Part 2: 1990, BS 3921: 1985 dan ASTM C518. Hasil keputusan menunjukan penggunaan bahawa 5% EFB sebagai bahan tambah di dalam proses penghasilan batu – bata secara signifikan dapat mempertingkatkan penghasilan batu-bata tanah liat yang rendah kekonduksian terma berbanding bata dengan lain-lain sisa pertanian. Dinding bata kawalan (CB) dan bata dari 5% sisa pertanian Tandan kepala Sawit (EFB) bersaizkan model 1 m x 0.102 m x 1 m telah dibina untuk menguji suhu pretasi permukaan dinding terma. Hasil keputusan menunjukan 5% penggunaan EFB di dalam batu – bata dapat mengurangkan nilai konduksian terma dan juga suhu terma permukaan struktur dinding terutama pada waktu malam, di mana warna imej terma menunjukan secara signifikasi lebih cepat membebaskan haba. Hasil kajian mencadangkan sisa EFB berpotensi sebagai bahan tambahan bagi peningkatan penebatan terma konduksian tutupan bangunan. Oleh itu, suhu permukaan luar dinding akan memberi impak pada suhu dalam bangunan, dimana batu-bata sisa EFB dapat memberikan keselesaan terma di dalam bangunan terutama pada waktu malam rendah penggunaan tenaga.
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</tr>
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<td>A</td>
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<tr>
<td>A</td>
<td>Ampere</td>
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<tr>
<td>Boe</td>
<td>Barrel of Oil Equivalent</td>
</tr>
<tr>
<td>C</td>
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<td>CO₂</td>
<td>Carbon dioxide</td>
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<td>ha</td>
<td>hectare</td>
</tr>
<tr>
<td>I</td>
<td>Initial rate suction</td>
</tr>
<tr>
<td>K₂O</td>
<td>Potassium oxide</td>
</tr>
<tr>
<td>k</td>
<td>Thermal conductivity</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>kg/m³</td>
<td>Kilogram per meter cube</td>
</tr>
<tr>
<td>kg/m².min</td>
<td>Kilogram per meter square per minute</td>
</tr>
<tr>
<td>kN</td>
<td>Kilo newton</td>
</tr>
<tr>
<td>L</td>
<td>Wide brick</td>
</tr>
<tr>
<td>Lp</td>
<td>Length of bulk brick</td>
</tr>
<tr>
<td>Ld</td>
<td>Length of dry brick</td>
</tr>
<tr>
<td>MgO</td>
<td>Magnesium oxide</td>
</tr>
<tr>
<td>MPa</td>
<td>Mega Pascal</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
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<tr>
<td>--------</td>
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</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>(m^1)</td>
<td>Weight of dry brick</td>
</tr>
<tr>
<td>(m^2)</td>
<td>Weight of wet brick</td>
</tr>
<tr>
<td>(N/mm^2)</td>
<td>Newton per millimeter square</td>
</tr>
<tr>
<td>(Na_2O)</td>
<td>Sodium oxide</td>
</tr>
<tr>
<td>(P_2O_5)</td>
<td>Phosphorus pentoxide</td>
</tr>
<tr>
<td>(\rho_d)</td>
<td>Dry density</td>
</tr>
<tr>
<td>(\rho_w)</td>
<td>Wet density</td>
</tr>
<tr>
<td>Q</td>
<td>Watts</td>
</tr>
<tr>
<td>(SiO_2)</td>
<td>Silicon Dioxide</td>
</tr>
<tr>
<td>(SO_3)</td>
<td>Sulfur trioxide</td>
</tr>
<tr>
<td>(\Delta T)</td>
<td>Different temperature</td>
</tr>
<tr>
<td>(TiO_2)</td>
<td>Titanium dioxide</td>
</tr>
<tr>
<td>(T_S)</td>
<td>Total shrinkage</td>
</tr>
<tr>
<td>(\mu)</td>
<td>micro</td>
</tr>
<tr>
<td>(%)</td>
<td>Percentage</td>
</tr>
<tr>
<td>(\degree)</td>
<td>Degree</td>
</tr>
<tr>
<td>V</td>
<td>Volume</td>
</tr>
<tr>
<td>V</td>
<td>Voltage</td>
</tr>
<tr>
<td>W</td>
<td>Water content</td>
</tr>
<tr>
<td>(W/m^2)</td>
<td>Watts per meter square</td>
</tr>
<tr>
<td>(W_w)</td>
<td>Weight of wet brick</td>
</tr>
<tr>
<td>(W_A)</td>
<td>Water absorption</td>
</tr>
<tr>
<td>(W_d)</td>
<td>Weight of dry brick</td>
</tr>
<tr>
<td>(W/m.K)</td>
<td>Watt per Kelvin</td>
</tr>
<tr>
<td>(ZrO_2)</td>
<td>Zirconium dioxide</td>
</tr>
</tbody>
</table>
#### LIST OF ABBREVIATION

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BC</td>
<td>Before Century</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>BSRC</td>
<td>British Soil Classification System</td>
</tr>
<tr>
<td>BIA</td>
<td>The Brick Industry Association</td>
</tr>
<tr>
<td>CF</td>
<td>Coconut Fibre</td>
</tr>
<tr>
<td>CB</td>
<td>Control Brick</td>
</tr>
<tr>
<td>CBR</td>
<td>California Bearing Ratio</td>
</tr>
<tr>
<td>CETP</td>
<td>Code on Envelope Thermal Performance for Building</td>
</tr>
<tr>
<td>CETDEM</td>
<td>Centre for Environment, Technology &amp; Development, Malaysia</td>
</tr>
<tr>
<td>CW</td>
<td>Coffee Waste</td>
</tr>
<tr>
<td>DOSM</td>
<td>Department of Statistics Malaysia</td>
</tr>
<tr>
<td>EFB</td>
<td>Empty Fruit Bunch</td>
</tr>
<tr>
<td>EN</td>
<td>British Standard European Norm</td>
</tr>
<tr>
<td>FKAAS</td>
<td>Faculty Kejuruteraan Awam dan Alam Sekitar</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>IRS</td>
<td>Initial Rate Suction</td>
</tr>
<tr>
<td>IRT</td>
<td>Infrared thermograph</td>
</tr>
<tr>
<td>LL</td>
<td>Liquid limit</td>
</tr>
<tr>
<td>MS</td>
<td>Malaysia Standard</td>
</tr>
<tr>
<td>MPOB</td>
<td>Malaysia Palm Oil Board</td>
</tr>
<tr>
<td>MF</td>
<td>Mesocarp Fruit</td>
</tr>
<tr>
<td>MOA</td>
<td>Ministry of Agriculture and Agro-Based Industry Malaysia</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>OP</td>
<td>Oil Palm</td>
</tr>
<tr>
<td>OPT</td>
<td>Oil Palm Trunks</td>
</tr>
<tr>
<td>OPF</td>
<td>Oil Palm Fruit</td>
</tr>
<tr>
<td>OPL</td>
<td>Oil Palm Leaf</td>
</tr>
<tr>
<td>OPC</td>
<td>Ordinary Portland Cement</td>
</tr>
<tr>
<td>OMC</td>
<td>Optimum Moisture Content</td>
</tr>
<tr>
<td>OFPA</td>
<td>Oil Fruit Palm Ash</td>
</tr>
<tr>
<td>PL</td>
<td>Plastic Limit</td>
</tr>
<tr>
<td>PI</td>
<td>Plastic Index</td>
</tr>
<tr>
<td>PF</td>
<td>Palm Fruit</td>
</tr>
<tr>
<td>POME</td>
<td>Palm Oil Mill Effluent</td>
</tr>
<tr>
<td>POFA</td>
<td>Palm Oil Fly Ash</td>
</tr>
<tr>
<td>PKS</td>
<td>Palm Kernel Shell</td>
</tr>
<tr>
<td>PWT</td>
<td>Process Waste Tea</td>
</tr>
<tr>
<td>RH</td>
<td>Rice Husk</td>
</tr>
<tr>
<td>RHA</td>
<td>Rice Husk Ash</td>
</tr>
<tr>
<td>RM</td>
<td>Ringgit Malaysia</td>
</tr>
<tr>
<td>SIRIM</td>
<td>Scientific and Industrial Research Institute of Malaysia</td>
</tr>
<tr>
<td>SB</td>
<td>Sugarcane Bagasse</td>
</tr>
<tr>
<td>SCBA</td>
<td>Sugarcane Bagasse Ash</td>
</tr>
<tr>
<td>SEDA</td>
<td>Sustainable Energy Development Authority Malaysia</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Testing Machine</td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
</tr>
<tr>
<td>XRF</td>
<td>X-ray Fluorescence</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background of Research

The history of clay has recorded that the clay bricks were used for many past decades. Yang et al., (2014) reported that, China has been the largest producer for fired clay bricks widely used as a building material and flooring since the Qin Dynasty (476-206BC), although a few lines of evidences show that fired clay bricks may have been invented as early as 5500 years ago in the Eastern Central China. A study by Shakir et al., (2013) indicated that the bricks, which were manufactured using an ancient method were existed since 600 B.C where the process clay bricks manufacture were known as a soft mud process in which a relatively moist clay was pressed into simple rectangular moulds by hands. A study by Fernandes et al., (2009) found that clay bricks have become one of the oldest and most durable construction techniques used by mankind.

The demand of energy efficient design and construction has become progressively vital with the growing of energy costs that increasing the awareness on the effect of global warming (Mydin, 2011). The energy used daily becomes a priority due to the thermal that effects the comfort inside homes. Hence, mention by Azzmi & Jamaludin (2014) state that a good comfortable home is a part of the sustainable development agenda to improve the quality of life. According to Tenth Malaysia Plan, the continuous efforts may ensuring Malaysia citizens all level income to have opportunity to acquire houses that refer to “adequate, affordable and good quality” (Sufian & Ibrahim, 2011).
Over half of the world’s total palm oil today is derived from the oil palm industry in Malaysia, agricultural waste from oil palm is especially high since Malaysia produces about 17.7 million tons of palm oil on 4.5 million hectares of land (Awalludin et al., 2015; Alwani et al., 2014; MPOB, 2011). Over half of the world’s total palm oil today is derived from the oil palm industry in Malaysia. There are at least 417 productive palm oil extraction mills nationwide (MPOB, 2011). These mills generate more than 12.4 million tonnes of EFB as solid waste (green weight) yearly (MPOB, 2011). A considerable amount of solid waste in the form of fibres, kernel shells and empty bunches discharges are produced during palm oil (Mangesh et al., 2013; Mannan & Ganapathy, 2004; Salleh et al., 2011). These wastes are simply disposed of without any economic return (Awal & Husin, 2011).

In Malaysia, one of the most important crops is the coconut palm. Statistics show that the total production of coconut palm increased from 512,699 in year 2006 to 555,120 metric ton in year 2008 (MOA, 2009). According to the Department of Statics Malaysia, the capita consumption, agricultural waste coconut increased from year 2013 at 18.5 kilograms/year to year 2014 at 18.9 kilograms/year in Malaysia. Das et al., (2016) stated that production of coconut stands at 11.9 million tonnes, which is the second highest waste in the world.

Khuenpet et al., (2016) and Dotaniya et al., (2016) state that sugarcane is a vital crop in the world, particularly for the tropical countries, with the majority of sugarcane being used for sugar and alcohol production. Meanwhile, sugarcane bagasse is a residue produced in large quantities by the sugar industry. Typically, 1 tonne of sugarcane generates about 280 kg of bagasse. About 54 million dry tonnes of bags were produced annually throughout the world (Cerqueira et al., 2007). A study by Mekhlilef et al., (2011) stated that sugarcane cultivation produces granulated sugar, molasses, bagasse, dry leaves of sugarcane trees and cane tops. Nearly 30% of the sugarcane cultivation produced bagasse, but the main production was granulated sugar. The excess bagasse accumulated presents a waste problem for the sugar industry (Shaikh et al., 2009). Moreover, the burning of bags will produce carbon monoxide and methane; gases that cause air pollution and may affect the people’s health and well-being.
1.2 Problem Statement

The waste materials increase daily and are unable to be recycled in a short time. According to Manaf et al., (2009), the per capita generation rate is at approximately 0.5 - 0.8 kg/person/day in which domestic waste is the primary source in Malaysia. However, huge quantity of municipal solid waste generation, particularly in Peninsular Malaysia, has increased from 16,200 tonnes per day in year 2001 to 19,100 tonnes per day in year 2005 or an average of 0.8 kg/capita/day (Ying & Manaf, 2014; Johari et al., 2010; Tarmudi et al., 2010; Tarmudi et al., 2009). According to Fazeli et al., (2016) the increase of municipal solid waste for grant total waste in Malaysia in year 2012 was about 29,711.8 tonnes per day and expected to increase about 3,6165.4 tonnes per day in year 2020.

Malaysia produces a vast amount of agricultural wastes and agricultural wastes from sugarcane, coconut, pineapple, and banana plants are notably high (Alwani et al., 2014). Manaf et al., (2009) reports that the Malaysia had generates in excess of 15,000 tons of solid waste per day in the form of biomass that consists of forest and mill residues, wood wastes, agricultural wastes, and municipal waste. Moreover, more than 2 million tonnes of agricultural waste in Malaysia are produced annually and are either burned or dumped as a waste and are a great environment threat, causing damage to the land and surrounding areas (Ghani et al., 2011). Raut et al., (2002) and Perera et al., (2015) mention that the most quantities of waste generated from agricultural sources are rice husk, sugarcane bagasse, jute fibre, coconut husk, cotton talk and other.

As Malaysia is located in the tropical region, the buildings are exposed to the full impact of the external temperatures and solar radiation, which affects the occupants comfort in a negative way. Qaltan et al., (2010) reports that about 70% of energy consumption in Malaysia was used for cooling the space environment and therefore, it was important to reduced energy consumption. Malaysia is one of the tropical rainforest that received more heat because of the location on the equatorial line. In addition, the tropical rainforest climate received higher solar radiation and terrestrial radiation reaching the building envelopes contributes to this problem (Azzmi & Jamaluddin, 2014). Buildings are overheated during the day due to solar
heat gain through the building envelope and radiant solar penetration through windows (Azzmi & Jamaluddin, 2014; Hampton, 2010; Mayer et al., 2007; Walter et al., 2007).

In Malaysia, 45% of the average household electricity is consumed by air conditioners to create an acceptable indoor environment (Deraman et al., 2017). This high energy consumption is mostly related to poor thermal performance of building envelope. Therefore, the thermal performance of the building envelope is one of the most important determinants of the building’s energy consumption (Deraman et al., 2017). Meanwhile, Al-Homoud et al., (2005) reported that the buildings has large consumers of energy that had influence in all countries and within regions with harsh climatic conditions, a substantial share of energy goes to heat and cool buildings. Mydin et al., (2011) stated that the connection between energy used in buildings and environmental damage arises because energy intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation and lighting caused severed depletion of precious environmental resources. Unwanted thermal energy may accumulate in building and dwelling from a variety sources such as radiation or convection-included heat transfer and air infiltration through walls (Raut et al., 2014).

Normally, the consummation of energy that used for heating and cooling flow inside building are approximately 70% in the building. Besides that, this percentage could be higher in other parts of the world with more harsh climatic conditions and less energy efficient buildings (Al-Homoud et al., 2005). According to Centre for Environment, technology & Development, Malaysia CETDEM (2006) and Mahlia (2007), suggested that the indoor temperature were in the range of optimum temperature, which was 24°C to prove the optimum comfort for building occupants in Malaysia.

Therefore in this research, the used of the agricultural waste that had higher waste in Malaysia would be selected and use for the fired clay bricks. The enhancement of fiber in clay bricks firing processing enables to create porosity inside bricks. The aim for this research to create low thermal bricks by using agricultural waste for reducing agricultural waste and low down the temperature inside building.
1.3 Objectives

The objectives of study are;

i. To determine the characteristic for clay soil, EFB, CF and SB.

ii. To identify the physical and mechanical properties of fired clay bricks using EFB, CF, SB and control bricks CB.

iii. To evaluate the surface temperature of small masonry wall model.

1.4 Scope of the Research

These materials were been collected in Johor district where it is easy to obtain. Besides that, it requires effortless to be collected at enormous quantity of agricultural waste. The agricultural waste that use are coconut fiber (CF), oil palm empty fruit bunches (EFB), and sugarcane bagasse (SB). The raw clay soil, collected from the Kilang Yong Peng Batu Bata Bhd, then it is dried under the sun at the Brick Laboratory located at the same place.

This study was conducted at several laboratory to test with the physical, mechanical and thermal properties for clay bricks. In these scopes of research the chemical composition test was conducted to identify the chemical composition of the internal component. The aim of chemical tests and microscope test is to identify the chemical properties and the size of porosity inside the fired clay bricks. The X-ray Fluorescent Test (XRF) was conducted in an Analytical Laboratory Environment, UTHM.

In addition, based on the Geotechnical properties test, several tests were conducted whereas it has been tested in the Geotechnical laboratory, which follow the British Standard BS 5930: 1999, The code of practice for site investigation and BS 1377-2: 1990, Soil Classification. For obtaining, the optimum moisture content, Protocol Compaction test was carried out by following the procedure American Association of State Highway and Transportation Official (AASHTO) ASTM D698 and AASHTO T99.

Besides that, the engineering properties of fired clay bricks namely the density, shrinkage, compressive strength and initial rate suction test. Moreover, the physical and mechanical properties, clay bricks are followed by BS 3921:1985 specification for clay bricks. The compressive strength test that conducted in Lightweight Structure
Laboratory. However, for the water absorption test are using the cold water method where the bricks soak for 24 hours and followed by the Malaysia Standard MS 76:1972 Part 2 Clay Bricks. Thus, the initial rate suction (IRS) was done following BS 3921:1985 Specification for clay bricks to test capillary action inside the bricks.

In addition, the thermal properties were carried out to identify the thermal conductivity test in Malaysia Palm Oil Board, MPOB. These evaluation of thermal performance tests normally included take parameter such as temperature, thermal surface and heat scanning infrared thermography on the masonry wall model.

On the modelling sample, the scale model of two (2) brick wall was constructed with dimension height (1 m), width (0.102 m) and length (1 m) based on the optimum percentage agricultural waste that has low thermal conductivity and the control bricks.

1.5 Significant of Research

These study expects that by using the agricultural waste into fired clay bricks able to lowering thermal conductivity by create porosity inside the bricks that has been fired. The enhancement of waste into clay brick create more porosity during ignition of firing.

By using the additive waste, the clay bricks has influence the physical and mechanical properties affected more as density. In the increasing of waste into clay bricks that may drop its strength. Although, there are some previous studies show that the agricultural waste provides a higher performance in strength. In addition, using agricultural waste into bricks show that potential material for lightweight bricks.

The main outcome of this research is able to produce low thermal bricks that solve thermal comfort, where the porosity inside bricks are react as insulation for brick wall. These low thermal bricks that can help the mankind in future to reduce energy consumptions, reduce waste problem and suitable material for building envelopes.

1.6 Thesis Outline

In Chapter 1 provides an overview of agriculture’s waste problem and thermal consumption issue in Malaysia. The objective were briefly explained which cover physical and mechanical properties, characteristic of material and thermal
conductivity in these study. The concern regarding of insufficient of building material for construction activates, aware attempt has been made to produce by using different waste into fired clay bricks production. As conclusion, in Chapter 2 has be providing compressive literature review regarding the potential agricultural waste to be utilization into clay brick production for low thermal bricks. Follow by, Chapter 3 mostly cover the procedure testing for brick specimen under physical and mechanical test under scope fields. Next, Chapter 4 has provided the analysis the based on result testing, which acquire the finding and discussion thought Chapter 5.
CHAPTER 2

REVIEW ON AGRICULTURAL WASTE AND CLAY BRICKS PROPERTIES

2.1 Introduction

The production of agricultural waste is a pressing issue as the waste creates pollution. According to Das et al., (2016), natural materials such as fibres and coconut fibres are commonly used to reinforce the soil. This shows that there is a potential of producing bricks from waste which is compatible with the soil as well. Raut et al., (2011) mentions that the performance in terms of lighter density, lower thermal conductivity and higher compressive strength of the various waste bricks gives an economical option to design the green building. Agricultural waste can be used as a material in many fields. In these this literature review, the agriculture waste is used in the production of making clay bricks for contribution sustainable material construction.

Environmentally recycling materials and low energy consumption products are important elements to do in research field. The development of new technologies to recycle and convert waste materials into reusable materials is very important for the protection of the environment and the sustainable development of the society (Raut et al., 2014). Conservation of energy and energy efficiency of buildings are important global issues that influences the factor of lack economic issue and environmental concerns. The previous study, show that the potential of using agriculture waste as a material in clay bricks for alternative ways to the sustainable construction material by recycling waste into fired clay brick product (Kadir et al., ; 2016; Kadir et al., ; 2013; Banhidi & Gonze; 2008; Demir; 2008; Chan, 2011). There is a potential of the agro-
waste to contribute in reducing natural resources and energy as well. Hospodarova et al., (2015) stated that material recycling is the upcoming trend in the development of building materials and some waste materials can be used in construction as secondary raw material.

The attention of brick production was directed towards the thermal isolation capacity for building material clay brick (Kristaly & Gomze, 2008). A study by Kristaly & Gomze (2008) on traditional clay bricks, mentioned that the solution for increasing the thermal isolation capacity is the artificial increase of porosity. Mydin (2011) stated that the utilization of low thermal conductivity building materials is important to decrease heat gain through the envelope into the building in hot climate countries like Malaysia. Meanwhile, Shibib et al., (2013) and Shibib et al., (2015) indicated that the thermal and mechanical brick properties play an important role in designing modern buildings, especially when wall properties such as insulation, rigidity, weight and cost are deliberated. Therefore, selecting the proper thermal properties of a building envelope plays a major role in determining energy consumption patterns and comfort conditions in enclosed spaces (Ecem et al., 2014; Manioglu & Yilmaz; 2008; Elias et al., 2006).

2.2 Agricultural Waste

Malaysia is a producer of agricultural products, as the climate in Malaysia produces conditions for production different type of variation waste. Agricultural materials have played a major role in human life. Globally, 998 million tonnes of agricultural waste is produced annually and in Malaysia, 1.2 million tonnes of agricultural waste is disposed into the landfill annually (Kadir et al., 2016). In year 2015, the agricultural sector has contributed 8.9% to the Gross Domestic Product (GDP), which cost RM 94.1 billion as stated by Department of Statics Malaysia (DOSM, 2016). It concluded that the agricultural waste is an issue to environmental problem in Malaysia and therefore it needs to be controlled and studied.

The statics of agricultural waste are produce annually in year 1994 until year 1198 (Khedari et al., 2005). Provides in Table 2.1 the annual waste from 1994 until 2011 for every waste production. Coconut (Cocos nucifera), durian peel (Durio zibethinus) and coconut coir that has good thermos physical properties and more especially have low thermal conductivity (Khedari et al., 2005).
Table 2.1: Agricultural production in 1994 until 2016 (Khedari et al.; Mehkilef et al.; DOSM, 2016)

<table>
<thead>
<tr>
<th>Year</th>
<th>Coconut</th>
<th>Sugarcane</th>
<th>Oil Palm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1998</td>
<td>2007</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>1372</td>
<td>171</td>
<td>88.7</td>
</tr>
<tr>
<td>2007</td>
<td>171</td>
<td>234</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>88.7</td>
<td>54.9</td>
<td>-</td>
</tr>
<tr>
<td>2014</td>
<td>-</td>
<td>-</td>
<td>96,066.8</td>
</tr>
<tr>
<td>2015</td>
<td>-</td>
<td>-</td>
<td>98,344.1</td>
</tr>
</tbody>
</table>

Agricultural waste has the potential to be used as material for thermal insulation as a solution to reduce energy consumed by air conditions (Panyakaew & Fotios, 2008). According to Ghani et al., (2011), palm oil is the highest producer of agricultural waste in Malaysia whereby the palm oil milling process creates 0.07 tons of palm shell, 0.146 tons of palm fiber and 0.2 tonnes EFB. Table 2.1 shows the amount of fronds of coconut waste at approximately about 0.164 million boe as stated by Ghani et al., (2011).

Kristaly & Gomze (2005) incorporated agricultural waste additives material to improve compressive and bending strengths, capillary water up-take and capacity of heat conductivity, which are the main properties that characterize the building materials. Hospodarova et al., (2015) mentioned that the use of agricultural waste to produce new sustainable materials and to conserve non-renewable sources of raw material is based on plant fibres. Raut et al., (2011) stated that the using industrial or agricultural waste material develops sustainable construction material and designs the green building.

In this study, the use of material for additive bricks that can be used is empty fruit bunch (EFB), coconut fiber (CF) and sugarcane bagasse fibre (SB). The use of this material was chosen because these agricultural wastes are among the highest in Malaysia. Besides that, the agricultural waste has unlimited resource that can easily be obtained. This kind of agricultural waste is produced every day for production by the community.
2.2.1 Empty Fruit Bunch (EFB)

The oil palm tree (*Elaeis guineensis*) is a tropical palm plant, which is native to Africa. In less than 100 years, the cultivation of oil palm trees has evolved from being a relatively small-scale crop in Africa to one of the world's most profitable agricultural commodities. Oil palm tree scans grow well in the Malaysian climate (Awalludin *et al*., 2015). Ismail & Yaacob (2011) reported that in 2007, 4.3 million hectares of land were planted with palm oil trees and was a major agricultural industry in Malaysia. According to the measure in 2014 by Department of Statistics Malaysia (DOSM), Malaysia is the second largest producer of quantity palm oil approximately 19,667,016 tonnes, an increase of palm oil from 2014 to 2015 at 2.4 % annual waste yearly.

The wastes such as empty fruit bunches (EFB), palm kernel shell (PKS), mesocarp fibre (MF), palm oil mill effluent (POME), oil palm trunks (OPT), oil palm leaves (OPL) and oil palm fronds (OPF) are generated after the oil palm fruit is harvested, palm oil processing or during oil palm trees replantation as stated by the MPOB (2011). Table 2.2 shows the area in Malaysian states, which is a major area of the palm oil in Malaysia.

Table 2.2: Area of State Palm Area in Malaysia (MPOB, 2011)

<table>
<thead>
<tr>
<th>State</th>
<th>Mature Plant Area (ha)</th>
<th>Mature %</th>
<th>Immature Plant Area (ha)</th>
<th>Immature %</th>
<th>Total Plant Area (ha)</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johore</td>
<td>651,242</td>
<td>88.8</td>
<td>82,225</td>
<td>11.2</td>
<td>733,467</td>
<td>13.6</td>
</tr>
<tr>
<td>Kedah</td>
<td>80,767</td>
<td>93.7</td>
<td>5,415</td>
<td>6.3</td>
<td>86,182</td>
<td>1.6</td>
</tr>
<tr>
<td>Kelantan</td>
<td>99,783</td>
<td>68.9</td>
<td>44,979</td>
<td>31.1</td>
<td>144,762</td>
<td>2.7</td>
</tr>
<tr>
<td>Malacca</td>
<td>49,501</td>
<td>93.7</td>
<td>3,348</td>
<td>6.3</td>
<td>52,849</td>
<td>1.0</td>
</tr>
<tr>
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<td>84.1</td>
<td>26,865</td>
<td>15.9</td>
<td>169,368</td>
<td>3.1</td>
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<td>86.6</td>
<td>96,344</td>
<td>13.4</td>
<td>719,613</td>
<td>13.3</td>
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<tr>
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<td>89.6</td>
<td>40,370</td>
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<tr>
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<td>106</td>
<td>35.9</td>
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<td>895</td>
<td>6.3</td>
<td>14,204</td>
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<td>11,677</td>
<td>8.4</td>
<td>138,482</td>
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<td>29,538</td>
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<td>341,762</td>
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<td>205,183</td>
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<td>1,263,391</td>
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<tr>
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<td>361,152</td>
<td>13.0</td>
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<tr>
<td>MALAYSIA</td>
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<td>702,914</td>
<td>13.0</td>
<td>5,392,235</td>
<td>10.0</td>
</tr>
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</table>

Figure 2.1 displays the waste of palm oil produced from 2008 until 2011. In the palm oil mill, palm oil consists of only 10% of the total biomass. The rest, 90%
biomass were discarded as wastes. On average, five tonnes of fresh fruit bunches were required to produce 1 tonne crude palm oil.

Figure 2.1: Percentage of Waste Palm Oil from 2008 until 2011 (MPOB, 2011).

The agricultural waste has the highest knowledge on palm oil. Figure 2.1 shows that the produce of palm oil waste in Malaysia compared to other country, that had shown higher generate waste value from 2008 until 2011 (MPOB, 2011; Awalluddin et al., 2015). Figure 2.2 presents the palm oil fruit that have been used for the extract palm oil process.

Figure 2.2: Palm oil fruit (MPOB, 2011)

Moreover, for EFB, Kavitha et al., (2003) stated that the EFB chemical properties mainly contains lignocellulose material which contain lignin and cellulose. Meanwhile, Nazir et al., (2013) state that EFB is lignocellulosic composites, compared to compacted arranged cellulose, hemicelluloses and lignin with 44% cellulose fraction. Figure 2.3 displays the micrographs structure inside of the palm oil fibers.
2.2.2 Coconut Fibre (CF)

Coconut (*coco nucifera*) is categorized as coconut palm which belong to palm family (*Palmae*). In addition, the coconut coir is extracted from husk for coconut that is made up of natural fibre. This, fibre is founded between hard, internal shell and external shell of coat of a coconut. Enokela and Alada (2012) coconut fiber has high lignin content and thus low cellulose content, as a result of which it is resilient, strong and highly durable.

World production of coconuts is approximately of 40 to 50 million tonnes annually, producing around 15 to 20 million tonnes husk (Panyakaew & Fotios, 2008). The coconut cultivation can be found in most of Southeast Asia. According to Kadir et al., (2016) Malaysia is the large area of coconut plantation about 147 thousand hectares, and is the largest amount of waste without utilization but often dumped as agricultural wastes. Department of Statistic Malaysia also stated that in 2015, that coconut has the highest percentage than other fruit at 17.3 % for kg per year.

![Coconut Fiber](image)
Ali (2012) and Hadirwardoyo et al., (2013) mention that the natural fibres are low cost and coconut fibers are abundantly available in tropical region. Coconut fibers are derived from the husk of the coconut fruit, where it classified as the brown and white fibers. According to Nithiya et al., (2016) and Das (2016) the chemical properties of coconut fiber contains a percentage of lignin at 45.84%, cellulose at 43.44% percentage and hemi-cellulose at 0.025%. Figure 2.4 display the coconut fibers that have been collected before processing into smaller pieces.

Kadir et al., (2016) explains that coconut fibre is commonly used in material because of the advantages found such as resistant to fungi and rot, provides excellent insulation against temperature and sound. Moreover, Ali (2012) stated that coconut fibre were reported best for retaining a good percentage of its original tensile strength in all tested conditions. According to Das et al., (2016) coconut fibres has highly efficient mean of soil reinforcement. To prove that by Das (2016) mention that coconut fibres are commonly used to reinforce inside clay soil to gain high structure bonding within it.

Khedari et al., (2005) mentions that using CF with combination of cement and clay soil lowers the thermal conductivity by using CF and reduces the thermal conductivity and weight. Figure 2.5 presents the micrographs structure inside coconut fibers.

![Photo of coconut fibers](attachment:image1)
![SEM Micrographs Coconut Fibers](attachment:image2)

Figure 2.5: (a) Photographs Coconut Fiber; (b) and SEM Micrographs Coconut Fibers (Ebrahimi et al., 2017)

### 2.2.3 Sugarcane Baggasse (SB)

Sugarcane is the tallest perennial true grasses of genus *Saccharum*, whereby the south Asia are mainly focused for sugar production. Sugarcane is a measure of crop tropical
countries following the increasing demand for sugar in the last century (Panyakaew & Fotious, 2008). Loh et al., (2013) stated that the fibrous residue of sugarcane after crushing and extraction of its juice, known as “bagasse”, is one of the largest agriculture residues in the world. The SB is chosen as raw material because of the low cost and high quality green material and easy to obtain due to the processing of sugar. Figure 2.6 displays the sugarcane bagasse that has been squeezed for juice and has become an unwanted waste.

Sugarcane bagasse is organic pore-forming additives composed mainly of cellulose (Kristally & Gomze, 2005). Characteristic of the cellulosic fibers can provide adequate stiffness, strength and bonding capacity to cement-based matrices for substantial enhancement of their flexural strength, toughness and impact resistance (Hospodaraova et al., 2015). Dontaniya et al., (2016) suggested that there is a potential used as a binding material. A study Young et al., (1983) stated that chemical composition inside sugarcane bagasse that high percentage contain of cellulosic fibers, hemicellulose, lignin, ash, crude protein and glucose respectively.

Sugarcane ash and cane straw ash has the capability to partially replacement cement and act as a pozzolanic additive in the manufacturing of concrete and ash block (Loh et al., 2013). According to Dontaniya et al., (2016) sugarcane bagasse has major portion as cellulose, hemicellulose and lignin respectively. Figure 2.7 shows the micrographs structure inside sugarcane bagasse fibers.
2.3 History Clay Bricks

Basically, the brick has been exist from ancient time. Besides that, brick is one of oldest manufacture materials all around world. The use of clay brick has been well know other country with variation of size brick. At the first time clay brick was made up with mud soil that dry up under sun ray. Today, clay brick has been fired for increasing strength and ability to withstand weathering at different country.

2.4 Type of clay bricks

There are many types of brick that has been used in the Malaysia construction industry. Most of bricks that are available in market are clay brick, calcium silica/lime sand and cement brick. The factor of using specific bricks is usually depends on the purpose and suitability that depends on the condition and location of site construction.

2.4.1 Common bricks

The use of clay bricks mostly to revive the construction-housing, commercial, and structure industry. Although the clay brick has been through many variety-refining processes in the making, it remains in its original form commercial size. The size of the bricks still remain in terms of its original dimension, although a variety of sizes are existing at various places where it points to the fact that the larger brick will provide a higher level of insulation in places especially medium temperature especially.
Common bricks safety carry the load normally supported by brickwork, which has poor texture or color that are not in demand as the facing bricks. Common bricks usually used for internal walls and for rear walls for a view. Therefore, brickwork has to be rendered, plaster or unseen the finished work. Figure 2.8 displays the example of clay bricks that usually has be practice in construction industry.

![Figure 2.8: Common Bricks (Edenhall, 2016)](image)

When the clay bricks are used in the construction such a load bearing wall types, wall structure of the ground floor must be able to bear the weight of the load from the floor above. It is a clearly misleading fact of a structure where the higher it is, the structure, higher wall thickness is required by the structure at the bottom wall. In these modern times, various materials have been built and innovated as alternative measures to minimize the use of clay bricks in terms of cost, to ease the installation and based on the characteristics of the insulation.

Kristaly & Gomze (2005) stated that clay material causes the decomposition of carbonates, contraction of clay minerals and organic matter combustion, the introduction of pore-forming additives contributes to the increase of porosity of bricks. The structure of clay is determined by its calcareousity depending on CaO levels and if more than 6% CaO level that clay has been named as calcareous clay (Gorhan & Simsek, 2013). Soils produce unpredictable results due to undesirable chemical reactions with the stabilizer (Enokela & Alada, 2012).

### 2.4.2 Facing Bricks

The facing bricks are the widest range brick that has been fired to carry normal load. These bricks are able to withstand the effect of rain, wind, soot and frost without breaking up and have a good quality of appearance. This bricks has many types different of ideas that have pleasant looking bricks with vague classification. Facing
brick is available in huge variety of colour, texture, smooth, light or sandy. It is usually, often used on the surface wall for ecstatic factor. Figure 2.9 shows that facing bricks mostly have higher appearance.

![Figure 2.9: Facing bricks (Coleford, 2016)](image)

### 2.4.3 Engineering Bricks

Engineering bricks are manufactured at extremely high temperatures, forming a dense and strong brick, allowing the brick to limit strength and water absorption. These bricks are very solid and hard, able to carry heavier load compared to other bricks. In addition, these bricks has maximum strength of 70 N/mm² is classified as engineering bricks Class A and at 50 N/mm² is classified as engineering bricks Class B that are able to withstand higher temperature and used as loading bearing wall. Figure 2.10 shows the engineering brick that has higher strength, and based on British standard, this brick is classified as engineering bricks A and B.

![Figure 2.10: Engineering bricks (Edenhall, 2016)](image)

### 2.4.4 Calcium Silica Bricks

These bricks are made of content silica or calcium is also known as lime sand closer to the characteristics of the concrete. It is also particularly made of a mixture of sand
and stone powder with high silica content, but instead of using cement, it uses lime as the binder. The moist mixture is compressed according to the form set with the very high-applied pressure before baking in the auto clave steam at a temperature of 200°C for 8 hours. These bricks are very consistent in terms of color, shape and texture and it could be more expensive compared to common bricks. Figure 2.11 shows a picture of example of calcium silicate that is bricks in the marketing.

Figure 2.11: Calcium silicate bricks (Deraman, 2005)

2.4.5 Cement-Sand Bricks

Cement- sand bricks are composition that mixes with cement, sand and water that mix into mould working size bricks. These kind of bricks have strength as a concrete block and has standard grade. The use of cement for bricks is characterized as waterproof properties that prevent the moisture content of the water to penetrate into the joint of space bricks. In addition, these bricks are not fired and more to green material bricks. Figure 2.12 shows the appearance of cement-sand bricks that has been used in construction.

Figure 2.12: Cement-sand bricks (Unitedbricks, 2016)
2.5 Composition of Clay Bricks

The composition for produce clay bricks is important to create bonding inside bricks. Through this section, the explanation of the composition of clay bricks that need to use is provided. In addition, Karaman et al., & Esmeray et al., (2006) stated that the quality of brick usually depends on composition material, production method, firing method and firing temperature.

2.4.1 Clay Soil

In Peninsular Malaysia, the clay soil is usually located along west coast in the vicinity of Johor, Malacca, Port Klang, Alor Setar, where on east coast at Kuantan Port and also north down in parts of India. A study by Cox et al., (1968) states that clay soil are formation factor in geological features local that has become part of the processes of natural soil stabilization. Prove by Ting & Ooi (1977) and Yusof et al., (2006) also stated that sensitivity in soft clay Peninsular Malaysia is classified as moderately sensitive and little silt clay soil.

The clay is classified as a type of soil that contains the high percentage of clay particles. This clay can look different physically by the natural characteristics of the place. It will change to gentle when there is moisture, it is easy to harden and difficult to be used in the circumstances. In most cases, the definition is quite difficult to translated that reflect specific characteristic of clay composition due to various factors on soil physical.

Determination of soil classification matters is very important because different soil properties have its own benefits. Figure 2.13 displays the indicator of soil classification followed by particle distribution on clay soil, sand, and silt.
Figure 2.13: Soil Classification (Mueller et al., 2008)

Figure 2.13 illustrates the result of good quality clay brick within the range of higher percentage, within 70 % to 80 % and 40 % to 60% with less 40% to 20 % of silt, sand and clay distribution (Mueller et al.; 2008). Shibib et al., (2013) mentions that the clay soil chemical composition found is SiO₂ (35.4%), Al₂O₃ (10.7%), Fe₂O₃ (4.1%), CaCO₃ (40.6%), MgO (3.5%) that has an almost different composite oxide. Perera (2015) states that the investigation the chemical behaviour of clay materials found that the proportion of ratio Si₂/Al₂O₃ can improve the strength characteristics of clay.

2.4.2 Water

The water element is one of the basic ingredients that should be included as an essential ingredient mix in the production of bricks. Soil containing, content moisture which had approached to liquid will behave more on features of liquid element against a solid addition to an outstanding low shear strength between the particles (Zhang et al., 2005). According to Buhan and Felice (1997), the presence of excessive water content will also improve self-weight of the soil element that will increase the power cohesion and minimize friction between the properties of micro particles need in the soil.

Water is the element that is required as a duty to bind between two different mixtures of soil and cement. The water content must not contain any impurities and can interfere with the quality of external perfect brick production design.
specifications. Addition of water into a mixture of bricks was based on the overall ratio mixed use of which should be properly investigated in order to maintain the quality of soil mixture and mix the brick itself.

The proportion of water content for additive mixture in clay bricks was use from 15.57\% until 16.67\% (Bandihi et al., 2008) by weight. The addition of fiber to clay body will increase water required due to water content for the plasticity of the clay–waste mixture (Demir, 2008). Besides that, Demir et al., (2005) stated that the plasticity in is important parameter for the production of constructional clay brick.

Phonphuak (2013) highlights that the mixture for control and mixture residue for 2.5\%, 5.0\%, 7.5\% and 10\% ranges at approximately 25 -30\%. As a result, the water in mixture able to enhance the plastic condition in order to obtain the desired shape bricks. According to Chan (2011) the 40\% amount of water are use based on dry weight bricks for mixing fiber with clay bricks. Besides that, the amount of water depends on the liquid limit result as mentioned by Chan (2011).

2.4.3 Cement

Cement is a binder that is used for mixing substance for concrete use. Typically cement is mostly used in construction. Besides that, cement is mostly made from calcined lime and clay, where it is mixed with sand, gravel and water to produce concrete. Furthermore, cement is also a consumption in the production of brick that use Ordinary Portland Cement (OPC). The quality of soil is defined through plasticity index between the range of 15\% to 25\%, which is the most suitable for cement stabilization (Walker, 1997). In addition, the use of cement in clay soil enables to increase the plasticity inside clay soil that can stabilize its strength. Walker (1997) stated that the use of stabilized cement reduces the water absorption and capillary action. The reduce of low water absorption corresponds with the increment of the bricks’ strength.

The percentage of cement used in the production of brick actually can be a benchmark for medium durability of bricks that determines it as a stabilizer brick. Ahmad (2006) claimed that the ratio of cement used in preparation of a mixture of brick has shown a significant effect on elements physical compressive strength and water permeability of the bricks. The condition of particles of the cement content also
must always be in perfect condition to eliminate inequality of uniform size. Therefore, cement is needed to be sieved to provide it as a material for the production of bricks to be precise according to specification.

Khedari et al., (2005) points out that the bonding of cement and fibers can be affected by dimensions, surface condition and number of fibre. Soils with more than 30% clay tend to have very high shrinkage/swelling ratios which, together with their tendency to absorb moisture, may result in major cracks in the end product. High clay soils require very high proportions of relate cement of stabilizer or a combination of stabilizers (Enokela and Alada, 2012).

A study by Ismail & Yaacob (2011) mentioned on the use of 6% of cement by mixing oil palm empty fruit bunch fibers in clay bricks. However Chan (2011) used cement as binder at the range from 5% to 15% to serve as binder between soil and fibre. Bahobail et al., (2011) suggested that to overcome these defects, additives should be added to the soil to improve its quality and increase its capability to stand against these defects. Overall, the study by Chan (2011) showed more potential usage cement in firing with waste that has higher strength than non-firing brick.

2.5 Overview Manufacture of Fired Clay Brick Factory

The manufacturing of clay bricks can be divided into four general phase; mining and storage, forming the brick, drying process, firing and cooling (Marotta et al., 2010; Sarani, 2014). Before processing clay brick, the first stage of preparation clay soil is needed to been done by grinding, mixing, wetting and cleaning process to eliminate impurities. In the next stage, the mixture clay soil is processed into pug mills where it usually will blend clay with water. By controlling 18 – 25 % of water content is enough to produce good plastic, that is homogenously mass ready for moulding process (CBA, 2002 ; Sarani, 2012).

At the end, bricks will dry up and then under goes into firing process in tunnel kiln within 2 days (900°C to 1200°C). According to Johari et al., (2010), the best firing temperature is at 1200°C to have good mechanical properties performance. Lastly, the bricks will cool down and let it rest for arrange and packaging process. Figure 2.14 illustrates the process of firing clay brick under tunnel kiln.
The process of firing clay bricks is shown in Figure 2.15. The manufacture firing brick is moved by kiln. The process of brick at the first stage needs to be at preheating to avoid crack on surface bricks. Based on Lyons (2007), brick firing occurs from 900 to 1250 °C, and the process ends by cooling bricks before contribute to supplier. The process of manufacture fired clay brick can be refer on APPENDIX A.

### 2.6 Physical and Mechanical Properties of Clay Bricks

Raw material composition and the manufacture process affect all properties of brick. The most important properties of clay brick are as the following.

#### 2.6.1 Compressive Strength

Compressive strength is a capacity of material that allows holding the load and tensile strength that resists compression. The performance strength are been measured by compressive strength used by engineer to design building and other structure. The key of design building depends on strength, and the fracture of material shows their strength limit. The calculation of compressive strength is derived from the original cross-sectional area of specimen in compressive test. For compressive strength bricks type’s class in BS 3921-1985 show the specific value that depends on the compressive strength. The compressive strength classification bricks can be referred as in Table 2.3.
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