THE INFLUENCE OF RICE HUSK AS PARTIAL REPLACEMENT MATERIAL IN FIRED-CLAY BRICK

by

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Especially Dedicated to,

My Beloved Father, Johari Bin Abdul Manan and My Lovely Mother, Rahimah Binti Syeed Ali

My Supporting Siblings, Azmarin Johari, Darwin Johari, Edayu Johari and Dalina Johari

&

To my Beloved Wife, Syamsuhaili Binti Said

Thank you for believing in me

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	American Society for Testing Material
CBRHA	Controlled Burning Rice Husk Ash
EDX	Energy-Dispersive X-ray
GRH	Ground Rice Husk
ICCD	International Centre for Diffraction Data
LOI	Loss on Ignition
Ltd.	Limited
RH	Rice Husk
RHA	Rice Husk Ash
SEM	Scanning Electron Microscopy
TG-DTA	Thermal Gravimetry – Differential Thermal Analysis
UCBRHA	Uncontrolled Burning Rice Husk Ash
UTM	Universal Testing Machine
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

KESAN PENGGUNAAN SEKAM PADI SEBAGAI BAHAN GANTI SEPARA DALAM BATA TANAH LIAT BAKAR

ABSTRAK

Penyusutan bekalan tanah liat sebagai bahan sumber asli untuk penghasilan bata tanah liat bakar dan permintaan yang tinggi dari industri pembinaan telah memerlukan para penyelidik untuk memperkenalkan bahan binaan baru menggunakan sisa pertanian atau kaedah alternatif kepada pembuat bahan binaan tradisional seperti bata tanah liat bakar terutamanya ketika krisis ekonomi. Tesis ini melaporkan kesan penggunaan tiga jenis bahan ganti separa dalam bata tanah liat bakar. Penyelidikan yang dijalankan adalah termasuk proses pembuatan, proses pembakaran, ujian fizikal dan mekanikal dan juga kebolehan bata tanah liat bakar dijadikan sebagai dinding. Tiga jenis bata tanah liat bakar dengan lima jenis nisbah campuran (5-30%), termasuk satu jenis bata kawalan (0%), dihasilkan menggunakan mesin penyemperitan. Bagi menentukan suhu pembakaran yang optimum, bata tanah liat kawalan dibakar pada suhu yang berbeza dari 800-1250°C. Suhu pembakaran optimum ditentukan berdasarkan keputusan kekuatan mampatan dan suhu ini juga digunakan untuk penghasilan bata tanah liat bakar. Bata tanah liat bakar yang dipilih digunakan untuk membuat dinding bata berskala kecil dengan menggunakan mortar dengan nisbah campuran 1 : ½ : 4½. Berdasarkan keputusan yang diperolehi daripada bata tanah liat bakar kawalan (0%), suhu pembakaran yang optimum adalah 1200°C dengan kekuatan mampatan 89.52 N/mm^2,

kadar penyerapan air 6.6%, kadar sedutan air awalan 0.34 kg/m^2.min dan keliangan 14.2%. Penambahan dari segi kekuatan mampatan kepada 93.45 N/mm^2, kadar penyerapan air 6.6%, dan keliangan 21.2% dicatat pada bata tanah liat bakar dengan kandungan 20% sekam padi yang dibakar secara kawalan. Kadar sedutan air awalan berkurangan kepada 0.0872kg/m^2.min. Bata tanah liat bakar dengan kanduangan 5% sekam yang dibakar secara tidak dikawal masing-masing menunjukkan pengurangan dari segi kekuatan mampatan, kadar penyerapan air, keliangan dan kadar sedutan air awalan kepada 83.51 N/mm^2, 6.2%, 13.0% dan 0.1509 kg/m^2.min. Bagi bata tanah liat bakar dengan kanduangan 5% sekam padi kisar masing-masing menunjukkan pengurangan kekuatan mampatan dan kadar sedutan air awalan kepada 51.35 N/mm^2 dan 0.3026 kg/m^2.min. kadar penyerapan air meningkat kepada 7.3% manakala keliangan kekal pada 14.2%. Abu sekam padi yang dibakar secara terkawal merupakan bahan ganti terbaik dalam menghasilkan bata tanah liat bakar berbanding abu sekam padi yang dibakar secara tidak dikawal dan sekam padi kisar.

THE INFLUENCE OF RICE HUSK AS PARTIAL REPLACEMENT MATERIAL IN FIRED-CLAY BRICK

ABSTRACT

The depletion of clay as a natural resource for making fired-clay bricks is in contrast with the high demand from the construction industry. This situation has obliged the researcher to introduce new construction materials using agricultural waste or to provide an alternative method to the manufacturing of traditional building material such as fired-clay brick, particularly during the current economic crisis. This thesis reports the effect on the usage of three types of rice husks as partial replacement material for clay in fired-clay brick. The investigation includes the manufacturing process, firing process, physical and mechanical testing and also the performance of fired-clay brick as masonry wall. Three types of fired-clay bricks with five different mix proportions (5-30%), including one type of control brick (0%), were produced using an extruder machine. In determining the optimum firing temperature, the control bricks were fired inside a muffle furnace with different temperatures ranging from 800-1250°C. The optimum firing temperature was verified based on the controlled brick compressive strength result and used as the optimum firing temperature for the production of fired-clay bricks. Selected fired-clay bricks were used for the construction of a small scale masonry wall using mortar with a designation of 1 : ½ : 4½. Based on the results obtained from controlled fired-clay brick (0%), the optimum firing temperature was found to be 1200°C with compressive strength of 89.52 N/mm^2, water absorption of 6.6%, initial rate of suction of 0.34 kg/m^2.min and porosity of 14.2%. Fired-clay brick with 20% replacement of CBRHA increase in strength, water absorption and porosity to 93.45 N/mm^2, 11.3% and 21.2%, respectively. The initial rate of suction reduce to 0.0872 kg/m^2.min. Fired-clay brick with 5% replacement of UCBRHA reduce in strength, water absorption, porosity and initial rate of suction to 83.51 N/mm2, 6.2% and 13.0%, 0.1509 kg/m^2.min, respectively. Fired-clay brick with 5% replacement of GRH reduce in strength and initial rate of suction to 51.35 N/mm^2 and 0.3026 kg/m^2.min, repectively. The water absorption increase to 7.3% and porosity remain the same at 14.2%. Controlled burning rice husk ash (CBRHA) is the best material to be used as replacement material in the production of fired-clay bricks compared to uncontrolled burning rice husk ash (UCBRHA) and ground rice husk (GRH).

CHAPTER 1

INTRODUCTION

1.1 Introduction

Clay brick is the first man made artificial building material and one of the oldest building materials known. Its widespread use is mainly due to the availability of clay in most countries. Its durability and aesthetic appeal also contribute to its extensive application in both load bearing and non-load bearing structures. The properties of clay units depend on the mineralogical compositions of the clays used to manufacture the unit, the manufacturing process and the firing temperature (Hendry, 1991).

Building materials form the single largest input in construction, accounting for 50-80% of the total value of construction and out of that, brick, roughly accounts for an average of 15% of the materials cost. In some structures, the cost of bricks can be as high as 55% (Abdullah and Othman, 2004). In Malaysia, the dominance of reinforced concrete (RC) system in construction industry become one of the reason why masonry is less favoured than in the European and American continents. Bricks in Malaysia are most preferred to be used as fillers between columns or as partitions inside buildings. However, recently we faced a sudden price increase for reinforcement and structural steel and that consequently affected the construction industry (Abdullah, 2009). For that reason, it is very important to study the possible use of new construction materials and technology.

The recycling of industry-generated wastes as alternative raw materials is not a new process and has been done successfully in a lot of countries. The reasons that motivate the recycling of waste products are due to the exhaustion of natural resources, conservation of non-renewable resources and reduction in waste disposal costs (Romualdo et al., 2005). Besides, the idea is also to help to reduce the worsening environmental problems, to save the usage of primary raw materials, to find cheaper alternatives, to improve the quality of masonry materials as well as to provide substitute during crisis period (Abdullah, 2009).

A series of researches have been done to fully utilize waste produce from rice husk. Previous researcher, Rahman (1988), produced bricks using uncontrolled burning rice husk ash and reported that the ash has potential to increase the compressive strength of bricks. After Rahman (1988), De Gutierrez and Delvasto, (1995) from Colombia has produced fired-clay brick using ground toasted rice husk (RH) and controlled burning rice husk ash (RHA). The findings concluded that the brick containing ontrolled burning rice husk ash RHA gave better results than the brick incorporated with ground toasted rice husk (RH). Recently, Danupon et al., (2008) from Thailand investigated the potential use of uncontrolled burning rice husk ash (RHA) to produce lightweight fired-clay brick. From the results obtained, they found that lightweight brick could be produced by increasing the RHA replacement. However, the compressive strength of the brick was reduced.

To date, there is no systematic scientific information published regarding the use of three type of rice husk in its various forms. Therefore, the main aim in this study is to investigate the effect of using these waste materials in fired-clay bricks and how the bricks perform as wall panel.

1.2 Problem Statement

A market study carried out by Bronzeoak Ltd. (2003) shows that approximately 600 million tonnes of rice paddy is produced each year. On average, 20% of the rice paddy is husk, which gives an annual total production of 120 million tonnes. In a majority of rice producing countries, much of the husk produced from the processing of rice is either burnt or dumped as waste (Paya et. al, 2000). Rice husk is a waste product of agricultural activity in most countries in Asia, including Malaysia. Rice husk has created a major problem of disposal to the rice milling industry in Malaysia and elsewhere in the world (Farook et al., 1989). The Department of Statistics, Malaysia (2008), reported that the production of paddy amounted to 2,389,000 tonnes in the year 2008. According to Beagle (1978), the husk generated from this paddy was 20% by total weight. Rice husk wastes are commonly used as animal feed, fertilizer and fuel for energy production, but not in the field of construction. A few works has been carried out to develop the utilization of rice husk ash (RHA) in the production of fired-clay brick.

Though fired-clay bricks are less favoured in the Malaysian construction industry, it was the most important material in housing. A firewall must be built as dividing wall to divide between two connected houses. This type of brick is usually expensive. Furthermore, it has also taken the heat from a recent price increase for reinforcement and structural steel. This sudden hike in price was due to a reduction of local production and abrupt increase in oil price, and has affected the construction industry considerably. Thus, it is imperative to study the other possibilities of construction materials and technology that can be introduced and used in order to reduce construction time and cost. The study would relieve pressure on the supply of traditional building materials such as fired-clay brick, particularly during the economic crisis, as well as provides alternatives to existing methods (Abdullah, 2009).

In Malaysia, the most common brick used in the construction industry is cement sand brick due to its cheaper price. Unfortunately, the cement sand brick has lower values of compressive strength, fire resistance and chemical-attack resistance, but higher values of water absorption and initial rate of suction compared to fired-clay brick. The conventional fired-clay brick still has a lot of room for improvement. Some fired-clay bricks have high values of compressive strength but are high in water absorption, and are really heavy. Tauber et al., (1974) noted that most of the organic materials present in green brick volatilises and escapes when the brick is fired, causing the brick to become lighter, thus cheaper and easier to handle and transport. In order to improve the performance of engineering properties of fired-clay brick in terms of compressive strength, water absorption, weight and etc., other materials can be considered to partially replace clay in the production of fired-clay bricks, such as agricultural waste materials i.e. rice husk or rice husk ash.

1.3 Objectives of the Research

Basically, the aim of this research is to produce a new type of fired-clay brick containing rice husk. Therefore, it is important to investigate the effect of partial replacement of clay and sand with rice husk in the fired-clay brick. A comprehensive experimental work has to be designed in order to determine and examine the performance of the bricks as a wall, which can also be classified as composite material. The objectives of this study are as follows:-

1. Characterising rice husk in determining it's potential use as clay and sand replacement in producing bricks
2. Determining the suitable mix ratio of rice husk to clay in brick.
3. To study the engineering properties of rice husk bricks and it's structure behaviour as a wall panel.

Three types of materials are used in this study, i.e. ground rice husk (GRH), controlled burning rice husk ash (CBRHA), and uncontrolled burning rice husk ash (UCBRHA). The characterizations of these raw materials were carried out to investigate their effects as replacement materials in fired-clay brick.

In the second objective, determining the mix ratio for controlled fired-clay brick and brick containing waste material.

In the third objective, four types of fired-clay bricks were tested to obtain their engineering properties and further investigation on the behaviour of wall panel was carried out.

1.4 Research benefits

Basically, this type of work is an effort to save the environment by converting waste material or agricultural waste into construction material. Besides that, new construction materials can be developed, providing new business in the construction industry.

For fired-clay brick manufacturers, reducing the usage of clay in brick production can extend their company's survival since clay is not a renewable resource. In the production of brick, the weight of one fired-clay brick unit is basically around 2kg. Roughly, one pallet of bricks contains 500 pieces of brick units, making the combined weight of 1 tonne. If a replacement level of up to 10% is used, the total weight of rice husk ash used for one pallet will be 100kg. This would help the manufacturer to reduce the use of clay in producing a pallet of bricks, and extends the use of clay in the overall brick manufacturing process.

1.5 Scope of work

This research deals with the inclusion of waste materials i.e. GRH, CBRHA and UCBRHA as partial replacement materials for clay and sand in fired-clay brick. The experimental work was divided into two sections. In the first section, prior to the production of the fired-clay brick unit, the characteristics of clay and the three types of replacement materials were determined. The optimum water content was obtained for each type of mix proportions. Three types of fired-clay brick with five different mix proportions, and one type of controlled brick, were produced using an extruder machine. These green bricks were cut to sizes using thin wire and were then left to dry in ambient temperature. To determine the optimum firing temperature, the controlled brick was fired inside a muffle furnace at different temperatures ranging between 800°C - 1250°C. The optimum firing temperature was verified based on the controlled brick's compressive strength results, and used as an optimum firing temperature in the fired-clay bricks production. Lastly, the engineering properties of the bricks were tested to choose the best fired-clay brick for each different type of waste material included.

In the second section, the chosen bricks for each type of fired-clay brick were used for the construction of a small scale masonry wall. The same type of mortar was used for all types of walls. Mortar designation of 1 : ½ : 4½ (cement : lime : sand) by mass was used in this research. In addition to that, a 75 mm x 75 mm x 75 mm cube from each batch of mortar were made to determine the mortar strength at 14 days. Before the construction of the walls, the suitable equipment for the brick-laying process was prepared. The wall specimens were constructed cautiously since they were small and fragile. The walls were built consisting of 9-stack courses with a height of 210 mm and 2½ brick with a length of 163.5 mm. After 14 days of being covered in a polythene sheet, the wall specimens were subjected to uniformly distributed loads to determine stress-strain value. Testing for all types of wall specimens were carried out using a Universal Testing Machine (UTM).

1.6 Outline of thesis

This thesis is divided into six chapters. In Chapter 1, a general introduction to the thesis will be discussed, including the history of bricks, the problem statement, thesis objectives, scope of work and the research benefits of this study.

The literature review in Chapter 2 discusses the behaviour and characteristics of clay as the base material for fired-clay brick. Reviews on both rice husk as a replacement material and the brick manufacturing process are also discussed to provide better understanding of the whole research. Findings from previous researchers in waste material usage and model testing attempted are also presented at the end of this chapter.

Chapter 3 consists of experimental details of the study. All materials i.e. clay, GRH, CBRHA and UCBRHA will be discussed in detail. It also contains the procedure of determining brick size, the method chooses for firing technique and configuration of the model testing. The construction of a small scale single-leaf wall is described and discussed.

Chapter 4 presents results from the early stage of the brick-making process until the testing of the small scale units. The experimental design stages will include the determination of properties for material used, firing method for producing rice husk ash, determination of water for extruding process, drying and sintering of brick, testing of brick unit and lastly, model testing. Discussion of results obtain are presented in this chapter, except for the specific study.

Chapter 5 discusses the stress-strain behaviour of four types of small scale walls constructed using small scale fired-clay bricks.

Chapter 6 presents the conclusions of this study based on the analysis and findings from the experimental results and discussion. Recommendations for future studies are also included.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Fired-clay brick in masonry wall construction has undergone considerable changes in the course of the last few decades with the introduction or extended use of lightweight materials and new types of units. The main objective underlying these developments was to reduce operation cost while improving the quality of brick units to support the rapid growing of construction industries. In comparison between normal fired-clay brick and brick with alternative materials, there would appear to be an excellent future for the continued use of fired-clay brick in masonry construction (Hendry, 2001).

Chapter 2 deliberates and discusses usage of waste materials in brick production published by previous researchers. This chapter also discusses the potential of rice husk in brick manufacturing and the process of manufacturing brick, including the problems that arise during the operation process. In addition, characteristics of the raw materials used and the basic properties of brick are also discussed at the end of this chapter.

2.2 Environmental issues

Large amounts of paddy production and the development of agro-based industries in many countries of the world have brought about the production of large quantities of rice wastes, most of which are not adequately managed and utilized (Danupon et al., 2008). Recently, the method used for industrial waste treatment is solidification and thermal process (incineration). These treatments could be the alternative for the land disposal method, but unfortunately, these technologies still produce waste disposal and hence, create secondary pollution problems. Consequently, the disposal of this waste material in dumps and landfills will cause water contamination (Eduardo and Rosa, 1996). Due to this situation, more efficient resource recovery alternatives should be considered (Chiang et al., 2004).

For some countries, a very limited number of dumping landfill sites are available and are generally considered to be environmentally unfriendly. Furthermore, as a consequence of environmental and financial considerations, there is a growing demand for wastes to be re-used or recycled (Medhat et al., 2007). However, in common with other service industry wastes, finding an environmentally satisfactory and permanent disposal solution for this by-product is a growing concern (Anderson et al., 2002).

2.3 Rice husk and rice husk ash

The rice plant covers 1% of the earth's surface and is a primary source of food for billions of people. Globally, approximately 600 million tonnes of rice paddy is produced each year. On average, 20% of the rice paddy is husk, giving an annual total production of 120 million tonnes. In the majority of rice producing countries, much of the husk produced from the processing of rice is either burnt or dumped as waste (Bronzeoak Ltd., 2003). This ash is treated as a waste material usually dumped at the backyard causing unforeseen environmental hazards. Table 2.1 shows the production of paddy in Malaysia until 2008. The husk generated from this paddy is 20% by weight, amounting to 477,800 tonnes for the year 2008. The abundance of this agricultural waste is shown in Plate 2.1.

Therefore, an effective treatment should be introduced as a solution for this particular waste problem. Otherwise, the traditional disposal method of open burning would remain a practice thus creating more environmental pollution and health problems for human beings (Plate 2.2 and 2.3).

Table 2.1: Production of paddy in Malaysia

Year	2004	2005	2006	2007	2008
Production of Paddy (tonnes)	2,278,000	2,314,000	2,187,000	2,371,000	2,389,000

Source: Department Of Statistics Malaysia 2008

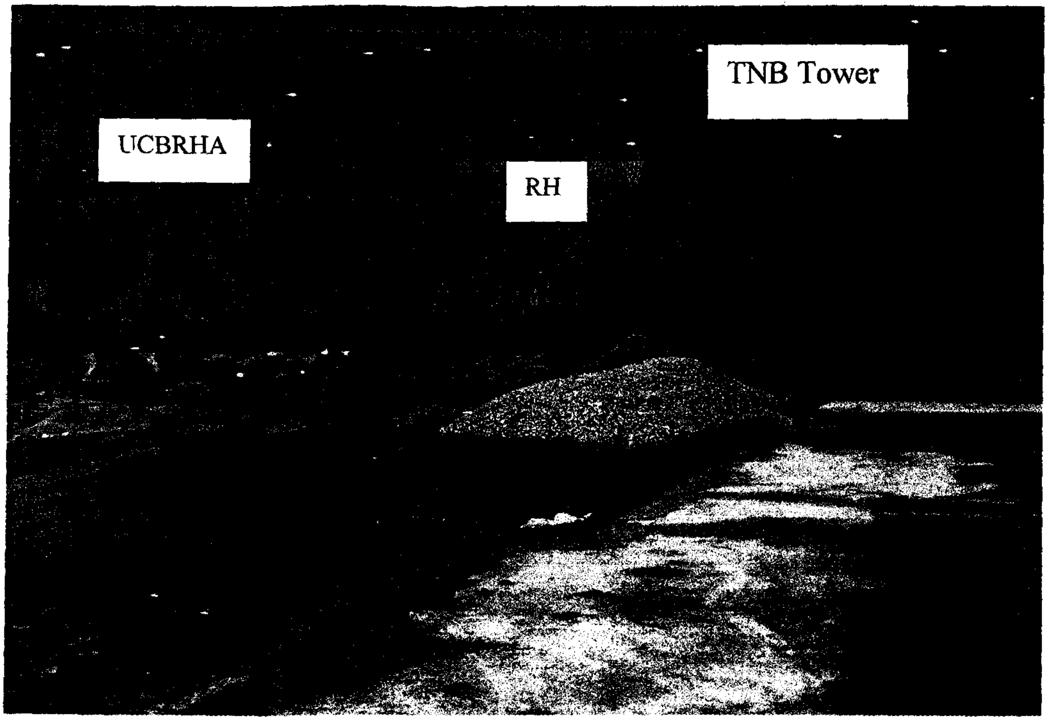

Plate 2.1: Rice husk waste

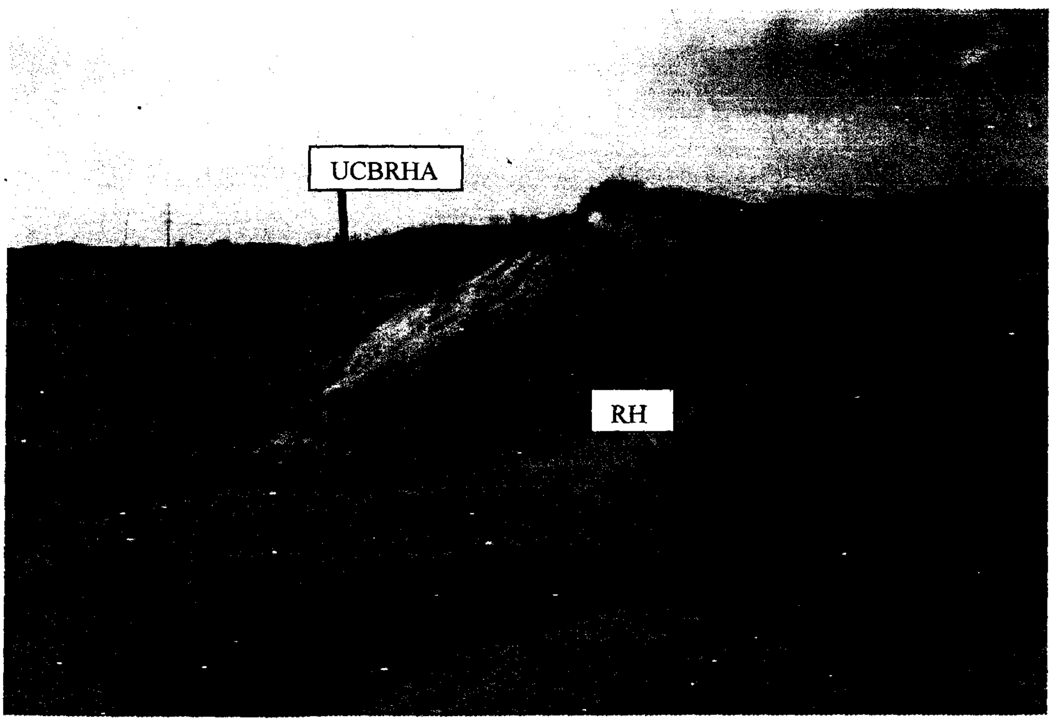

Plate 2.2: Open burning of rice husk

Plate 2.3: Disposal of Rice Husk Ash

Rice husk ash (RHA) is produced after burning rice husk at certain temperatures. It is one of the high silica-content raw materials in the family of agricultural wastes, containing about 90-98% silica (after complete combustion). Ash which has undergone the maximum extent of combustion is highly desirable as it contains a higher percentage of silica. It appears white-grey in colour, compared to the black coloured ash obtained from incomplete combustion (Mittal, 2007). The silica in the ash undergoes structural transformations depending on the conditions (time, temperature etc.) of combustion. At 550°C – 800°C, amorphous ash is formed and higher crystallization of silica will occur. These types of silica have different properties. It is important to produce ash of the correct specifications according to the particular end use (Bronzeoak Ltd., 2003). RHA has been used in the manufacturing of refractory bricks. Refractory bricks are used in furnaces which are exposed to extreme temperatures, such as in blast furnaces used for producing molten iron, and in the production of cement clinker (Boateng and Skeete, 1990).

2.4 Clay

The term 'clay' is applied to the natural earth deposits which possesses a unique property called plasticity. This property is very easy to detect, yet difficult to define. Clay occurs in deposits of greatly varying natures in many parts of the world. No two deposits have exactly the same 'clay', and different samples of clay frequently come from the same deposit. Clay can be formed in two ways. Firstly, clay is a secondary 'rock', where it is formed by the weathering of certain rocks. Secondly, clay can be formed through a mixture from a variety of sources of rock (Felix and Sonja, 1963).

For most of man's civilized existence, clay minerals have been extracted from their natural environments as a primary raw material. In past centuries, clays were used in producing building materials and ceramics because of their properties. In this century, clays have become an important part of industrial technology, taking many roles in manufacturing processes, and are major constituents in products such as plastics and foodstuffs. These uses depend upon the special properties of the clay particles (Velde, 1992). In Malaysia clay has been used in a wide range of industries, ranging from building materials and pottery up to agricultural and ceramic. All these industries exploit the properties that clay can be moulded into any shape and fired to dry without losing its form. Therefore the physico-elemental-mineralogical properties of clay do not only determine the clay samples characteristics, but also influences the physical characteristics such as colour and plasticity, hence determine its economic importance and usage (Saat, et al., 2008)

There are two types of clay; residual clay and sedimentary clay. Residual clay comes directly from gradual weathering of rock into very fine particles. The particles become mixed with water and material from the surrounding soil. The sedimentary clay is formed when particles of weathered rocks are carried from the place in which they were formed, usually by streams of water, and deposited in another place. Classification of clay according to their general composition and properties; Kaolin is a fine white clay consisting chiefly of the mineral kaolinite; Ball clay contains kaolinite and certain micas, and has strong bonding properties; Fire clay is basically kaolinite with some iron oxides, magnesia, and alkalies and it can resist high temperatures; Common clay contains more impurities than fire clay, and does not have great resistance to heat.

Ball clays are important raw material and are mined all over the world as natural resources for various applications such as bricks, cooking pots, art objects, and dishware. Other than that, this clay is also used in many industrial processes, such as paper making, cement production and chemical filtering. This type of clay is classified as sedimentary plastic refractory clay. It is dark in its unfired state because of organic impurities, but burn white or cream coloured as long as they are not vitrified fully. They are fine-grained and plastic in nature.

The name is derived from the English mining method of cutting the clay out in cubes or 'balls' (Felix and Sonja, 1963). The wide variations in ball clay compositions are illustrated in Table 2.2. If the so-called siliceous ball clays are included, the maximum SiO_2 content rises to 80% and the minimum Al_2O_3 content falls to 15%. Outside these limits, the deposits can no longer be regarded as clays and fall into the categories of sands or loams. The principle clay mineral of ball clay is kaolinite of various degrees of disorder (Worrall, 1986).

Table 2.2: The variations of chemical compositions of ball clays (Worrall, 1986)

Oxide	Range of variation (%)
SiO_2	40-60
Al_2O_3	25-40
Fe_2O_3	0.25-4.0
Na_2O	0-0.75
K_2O	0.5-4.0

Bricks may be made from a number of different kinds of material, but they must usually possess (or be capable of developing) a certain amount of plasticity, so clay and allied materials such as argillaceous shales are the main sources and important constituents for making fired-clay brick (Searle, 1956). Therefore, good quality clay will eventually enhance the performance of the building component or structures that it is used in (Felix and Sonja, 1963). The possible number of different clay minerals is probably very large, but for the purposes of brick manufacturing, it is not necessary to distinguish each variation or type. It is sufficient to arrange the different clay minerals into only three groups which are kaolinite, montmorillonite and illite or mica group (Searle, 1956).

However, in recent decades, the growing consumption and the consequent increase of industrial production have led to a fast decrease of available natural resources (raw materials) (Demir and Orhan, 2003). This is one of the reasons why much of the research that has been done strives to invent a new type of fired-clay brick by incorporating potential waste materials.

2.5 Plastic property of clay

Plasticity allows clay, upon addition of a limited amount of water, to be shaped by pressure, and to retain that form when the pressure is relaxed. The property of plasticity is lost when the absorbed water is removed from clay in drying, but the form will be retained. Plasticity can be restored by wetting the clay again, but the shaped form will disappear. Upon heating or burning, clay becomes hard and extremely resistant to weathering. Above certain temperatures, the capacity for plasticity is permanently eliminated (Rice, 1987). The plasticity developed depends on the nature of the clay, particle size, proportion of water added and the carefulness of the grinding, mixing or other treatment.

According to Felix and Sonja (1963), the ceramic industry could be said to be founded on the fact that clay has the property of plasticity. However, this important feature cannot be properly defined or measured. When the term 'plastic' is applied to clay, it is accepted as to mean that clay will take up water and with given quantity, it will achieve a condition where applied pressure can deform it without rupture, yet when the pressure released, the new shape is retained. If the clay is dried, the ability to deform will gradually be lost, and the clay becomes relatively hard and brittle.

Plasticity can be defined as the property of a body which enables it to yield readily to light mechanical pressure, but when the pressure has been removed, the shape of the body remains as though the pressure were still upon it (Felix and Sonja, 1963).

2.6 Innovation of composite fired-clay brick

Recycling of wastes generated by the industries as alternative raw materials has been done successfully in many countries. The reasons that motivate these countries are generally; the exhaustion of the natural resources, the conservation of non-renewable resources, improvement of the population health and society, preoccupations with environmental matters and reduction in waste disposal costs (Romualdo, et al., 2005).

In brick production, better knowledge of raw materials such as clay and its properties can help to improve the overall quality of the brick product. Many researchers have tried to invent new types of construction materials, such as by incorporating waste materials into the brick production line. The use of agricultural waste material i.e. rice husk and rice husk ash has been proven to improve the physical and engineering properties of brick in terms of lightweightness, density, strength, water absorption and etc. (Rahman, 1988; De Gutierrez and Delvasto, 1995; Danupon, et al., 2008). These waste materials also provide an economical contribution and serves as energy-efficient materials for buildings and are, of course, friendly to the environment.

Rahman (1988), conducted a research on fired-clay brick containing rice husk ash. The materials used in his study were clay, sand and rice husk ash. The clay soil was taken from a pit in Ilesha, Nigeria. It was then mixed with sand and RHA that had been sieved passing sieve sizes 600μm and 75μm, respectively. The RHA used was whitish grey in colour, with a high silica content of 89.52%. The loss on ignition (LOI) value was 3.59%. In order to improve the consistency and workability of clay, 30% by weight of dry soil of sand was added to the mixture. In this investigation, different workable mixing water contents were obtained for different percentages of RHA mixed. The workable mixing water content increased with the increase of RHA content, since RHA had more affinity for water.

For research purposes, a small scale sample using hand moulding technique was chosen in Rahman's study. The mixture was thrown into a mould with dimensions of 50 mm x 50 mm x 50 mm, and the excess material on top of the mould was trimmed using thin wire. Bricks were stored and exposed under sunlight for 8 days at the ambient temperature of 30°C. After that, bricks were oven dried at 105°C for 1 day prior to firing. This is to obtain a dry surface condition before the firing stage. The bricks were then fired using a muffle furnace using a firing curve as shown in Figure 2.1. Rahman (1988) reported that liquid limit and plastic limit increased linearly with RHA content. RHA will absorb water and as a result, more water will be added to achieve its plastic and liquid limits. It is also noted that the use of RHA can reduce brick density and increase its water absorption. This is due to the effect of increasing amount of pores inside the fired-clay brick. Nevertheless, Rahman (1988) managed to achieve optimum compressive strength when using 20% RHA, burnt at 1000°C for 4 hours, in making fired-clay brick.

There are a few reasons that cause the fired-clay brick to have high water absorption and low compressive strength and density. The first reason is low firing temperature. The firing temperature of 1000°C can be considered as biscuit firing where porous structures are formed. After the oxidation period, all the carbonized material inside the brick will dissolve into the air, leaving behind pores. These pores consequently lower the strength and increase the water absorption rate of the brick. The second reason is the technique of producing the brick. In general, the best method to produce bricks is by extruding and pressing. The extrusion method produces uniform clay blocks with a certain amount of pressure to make it dense and less void due to the effect of using a vacuum extruder machine. Another method is the pressing method, where pressure is applied to compact the clay in the steel mould, causing air bubbles to be forced out from the clay, making it dense and less void. The hand throwing technique used by Rahman (1988) can cause air bubbles to be trapped inside the mould which leads to a porous structure after the firing process.

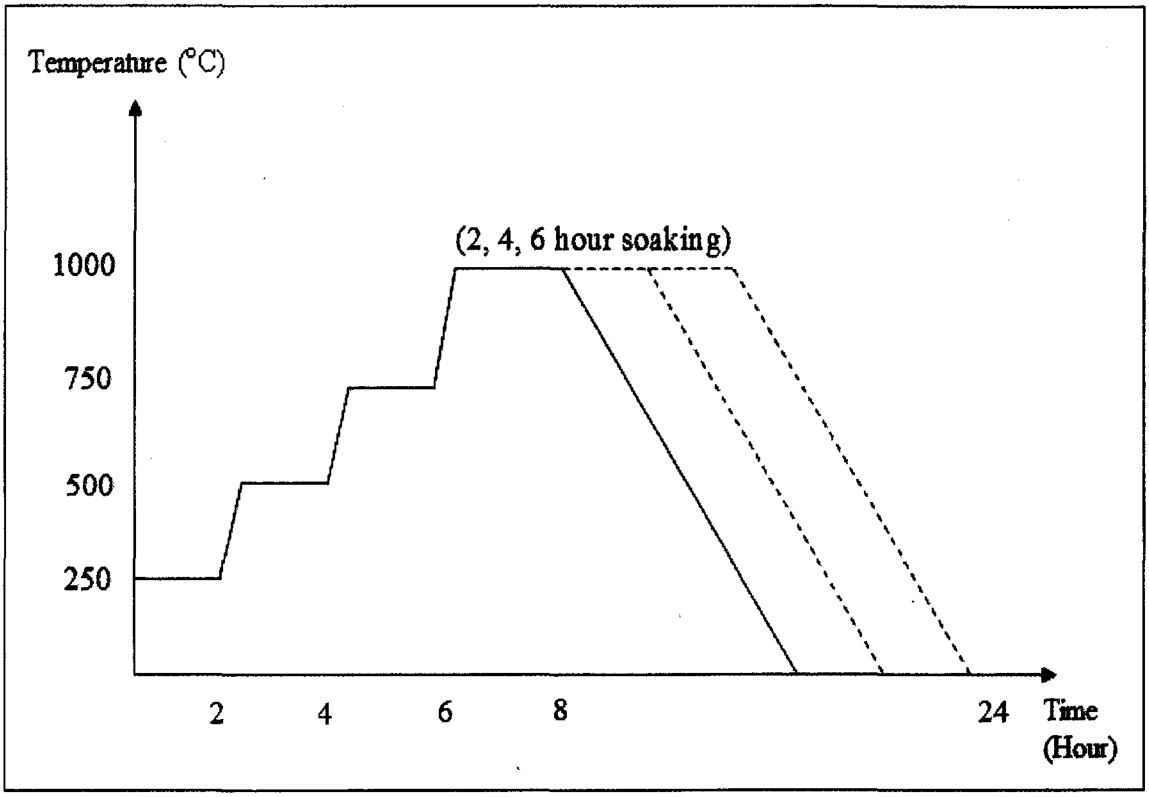

Figure 2.1 : Firing curve used in the production of brick from clay, sand and RHA mixes by Rahman (1988)

Later, De Gutierrez and Delvasto (1995) from Colombia also produced fired-clay brick using rice husk (RH) and rice husk ash (RHA). Natural rice husk and rice husk ash (after burning rice husk at 700°C for 1 hour) was incorporated in proportions of up to 40% by weight to plastic clay traditionally used for brick making. The RHA used had a high silica content of 90.26%, and the loss on ignition was 2.33%. The hand moulding technique was used in this study with a mould size of 38 mm x 38 mm x 76 mm. The brick was then fired in the muffle furnace using the firing curve shown in Figure 2.2. From the results obtained, it was concluded that the plasticity index and brick apparent density decreased with the increase in RHA content, while water absorption showed an increase with increasing RH and RHA content. Compressive strength, on the other hand, decreased when RH and RHA content increases.

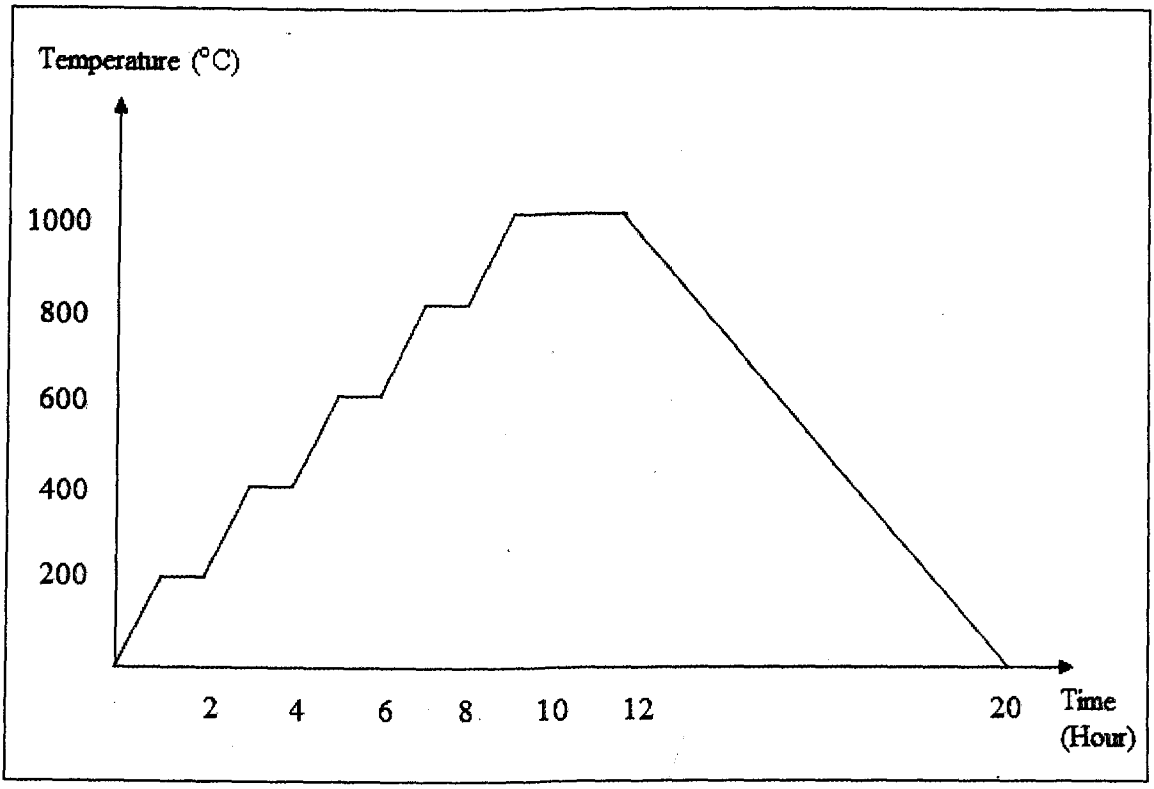

Figure 2.2: Firing curve used in the production of brick by De Gutierrez and Delvasto (1995)

Recently, Danupon et al. (2008) from Thailand investigated the potential use of rice husk ash (RHA) in making lightweight fired-clay brick. The brick was made using the pressing technique. It was axially pressed using a hydraulic machine with 1.00 MPa into a series of Thailand standard brick moulds, sized 140 mm x 65 mm x 60 mm.

The moulded specimens were air-dried at ambient room temperature for 1 day, and then oven dried at 100±5°C for another day to remove the water content. The green brick specimens were fired in an electrical furnace at a temperature of 1050°C. The electrical furnace was set to heat under a heating rate of 2°C/min from room temperature until 500°C, and then soaked for 30 minutes. Afterwards, the heating rate was adjusted to 5°C/min until it reached the maximum temperature, followed by 1 hour soaking. The specimens were then cooled to room temperature in the furnace. Danupon et al. (2008) reported that the optimum moisture content of clay-RHA mixture was increased as the RHA replacement level increases. Higher RHA additions require a higher water content to satisfy the water requirement for mixing process. The increase in RHA replacement produced a porous brick with higher water absorption, thus reducing its compressive strength. On the other hand, the brick was also fired at a temperature of 1050°C which is considered as biscuit firing. This is because, after the oxidation period all the carbonized material inside the brick will dissolve to air and left behind the pores and the shrinkage of brick didn't completely occurs since the sintering temperature is not high enough. The potential use of waste materials in brick production has been studied by many countries. Table 2.3 shows previous published works regarding innovations of new types of bricks as alternative construction materials carried out by researchers.