EFFECTS OF RICE HUSK ASH (RHA) PRODUCED FROM DIFFERENT TEMPERATURES ON THE PERFORMANCE OF CONCRETE

LEONG TUCK LUN

A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Environmental Engineering

Faculty of Engineering and Green Technology
Universiti Tunku Abdul Rahman

May 2015

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : _______________________________

Name : LEONG TUCK LUN

ID No. : 09AGB02734

Date : _______________________________

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"EFFECTS OF RICE HUSK ASH (RHA) PRODUCED FROM DIFFERENT TEMPERATURES ON THE PERFORMANCE OF CONCRETE"** was prepared by **LEONG TUCK LUN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Environmental Engineering at Universiti Tunku Abdul Rahman.

Approved by,

Signature : _________________________

Supervisor : Dr Ng Choon Aun

Date : _________________________

ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Ng Choon Aun, Mr. Chang Kok Yung, Dr. Noor Zainab Habib and Dr Guo Xin Xin for their invaluable advice, guidance and their enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parent and friends as well as my housemates who had helped and given me encouragement along the way. Besides, I would like to thank all the lab officers, who permitted all the required equipment and knowledgeable advices to complete the research study. Lastly, I would like to thank to the people who giving me such a hardship suffering in the particular embarrassed situation.

EFFECTS OF RICE HUSK ASH (RHA) PRODUCED FROM DIFFERENT TEMPERATURES ON THE PERFORMANCE OF CONCRETE

ABSTRACT

This project is about the addition of Furnace Incinerated Rice Husk Ash (RHA) into blended cement. The primary objective of this project is to investigate the mechanical properties of blended cement after RHA was used to replace cement partially at the ratio of 2.5 %, 5.0 %, 7.5 % and 10.0 %. The physical and chemical properties of RHA were determined by Particle Size Analyzer and Fourier Transform Infrared Spectroscopy (FTIR) Analysis. The pozzolanic reactivity of RHA is highly depended on the silica form. The silica form in the RHA is determined by the incineration process to decide if it is under amorphous form or crystalline form. It was that the optimum cement replacement ratio of RHA incinerated at the temperature of 600 ℃ and 700 ℃ both were at 5 %.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

BS EN	British Standard
CH	Calcium hydroxide
C-S-H gel	Calcium silica hydrate
FTIR	Fourier Transform Infrared Spectroscopy
L	Length, mm
RHA	Rice Husk Ash
T	Time, µs
V	Pulse velocity, km/s
6RHA	Rice husk ash incinerated at 600 ℃
7RHA	Rice husk ash incinerated at 700 ℃

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Shelter referred to the basic architectural structure or building that provides cover to the mankind or living organisms. World population has come to a peak that is over 7 billion peoples and continually increasing. According to United Nations Population Division, the world population of 2.5 billion people from year 1950 had increased to 6.9 billion people from year 2010 (United Nations Population Division, 2015). Although the annual growth rate is currently declining but the total population is still very high. Shelter, workplace and infrastructure that are essential in human needs and these caused the rapid development of construction. Global construction had reached 8.7 trillion USD in year 2012 and has been expected to rise to 15 trillion USD in year 2025 (Global Construction Perspectives, 2015).

Cement is the fundamental building material as a binder that used in construction industry. The demands of cement are growing rapidly due to the rapid development and construction worldwide. A data from U.S Geological Survey shows that the world cement production of year 2011 is 3.6 billion tons and year 2012 the production is 3.7 billion tons (USGS, 2015). The data shows that the demand of the cement is continuously increasing. The primary product to produce cement is limestone and required 1400 ℃ to heat in the kiln. The emission of carbon dioxide (CO_2) can be directly and indirectly. CO_2 release as a by-product when the production of clinker that calcium carbonate is calcinated and turn to line and it considered as directly emission. While indirectly emission is come from the requirement of burning fossil fuels to heat the kiln, approximately 4.9 million kJ is required to produce a ton of cement. Therefore, producing a ton of cement will generate approximately a ton of CO_2 (Shivaram, 2014). CO_2 is a well-known greenhouse gas that attributed to global warming and greenhouse effect. As shown in Figure 1.1, the CO_2 emission of Malaysia from years 2005 to 2010. The CO_2 emission of years 2010 had reached 216804 kilotons (World Bank, 2015).

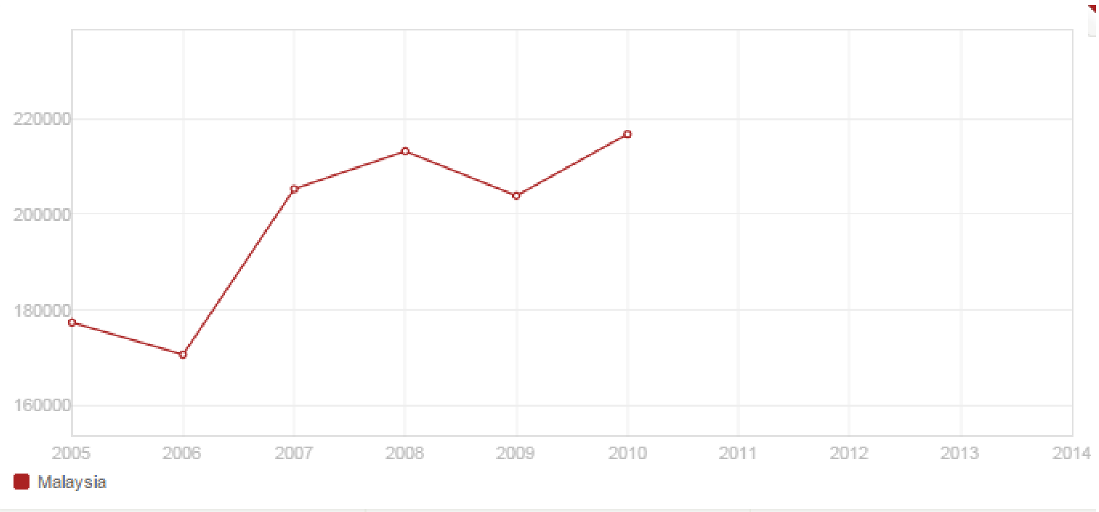

Figure 1.1: CO_2 emission of Malaysia from years 2005 to 2010 (World Bank, 2015).

Rice is a primary food source for billions of people and few hundred million tons of rice paddy are plant per year. According to Food and Agriculture Organization of the United Nations, the data shows that the production of rice paddy is increasing annually. World rice paddy production for year 2010 is 701 million tons, year 2011 is 722 million tons, year 2012 is 734 million tons and year 2013 is 740 million tons (Food and Agriculture Organization of the United Nations, 2015). Rice husk is the outer cover of paddy and it covers 20-25% the paddy weight. In general, hundred million tons of rice husks are produced annually and create the disposal problem. In Malaysia, rice paddy production according to Food and Agriculture Organization of the United Nations for year 2010 is 2.4 million tons, year 2011 is 2.5 million tons, year 2012 is 2.6 million tons and year 2013 is 2.6 tons approximately (FAO, 2015). The demand of rice paddy is increasing and about 0.52 tons of rice husk, an agro-waste is produced annually. This causes the environmental problem to disposal such agro-waste due to its abundance. Generally the rice husk will be burned in open air or being sent to land fill but both methods are creating enormous CO_2 emission to the atmosphere (Kartini, 2011).

Increasing demand of the building materials had come into concern of public and related industries. The issue is not only the chronic shortage of building materials but also the great impact to environment. Government and cement industry had developed several strategies to overcome this issue. One of it is to reuse the by-product generated from agricultural and industrial production activities. Examples for the agro-waste generated from agricultural sources are rice husk, jute fibre, coconut husk and etc. (Maduwar, Ralegaonkar & Mandavgane, 2012). These agro-wastes can be remade into sustainable building materials. Reuse of such agro-waste is not only overcome the pollution to environment, shortage of building materials but also the disposal problem of agro-waste. Malaysia has a great potential to reuse the agro-waste to reduce the environmental issues generated from the cement industry and agro-waste and achieve the objective of sustainable development.

1.2 Problem Statements

Malaysia is a developing country, growth in population, rising standards of living and increasing of urbanization had led to large demand of building material and food source. Cement is a common binder and important material that used in construction. The production of cement is expensive, requires high energy, diminishes natural resources and emits large amount of CO_2. It has been reported that the production of one ton of cement generates approximately one ton of CO_2 directly and indirectly (Khan et al., 2011). CO_2 is a known greenhouse gases that cause global warming and greenhouse effect.

The demand of food source is increasing due to the rapid growth of population in Malaysia. The massive expansion of plantation in Malaysia has generated large amount of agro-waste and huge environmental concerns. Rice is the major food source of Malaysia, 22 % of rice husk is generated after going through rice milling process. Rice husk is an agro-waste that creates great environmental problems due to its abundance. Normally rice husk will be burned in open air or land fill but both approaches emit large quantity of CO_2 to the atmosphere.

Concrete technologists are finding solution to reduce the CO_2 emission generated from cement production and application of supplementary cementitious materials (SCM) to replace cement. From previous studies, rice husk can be converted into rice husk ash (RHA) by burning process. RHA fulfils the physical characteristics and chemical composition of mineral admixtures (Zain et al., 2010). RHA contains around 85-90 % of silica which is mostly in amorphous state and it is a highly reactive pozzolanic material in the production of concrete due to its high silica content and high surface area (Jamil et al., 2013). It has been reported that optimum quantity of RHA can increase the mechanical properties of concrete. The optimum combustion temperature for obtaining highly reactive RHA is 600 ℃ (Xu et al., 2011). Addition of RHA can enhance the strength and reduce the water absorption of concrete (Tashima, 2004). Rice husk as an agro-waste if being utilized correctly not only reduce the environment problems but also reduce the CO_2 emission to the atmosphere by bringing down the production of cement. Previous studies show that the RHA produced from 700 ℃ above will be crystallized and the mechanical properties of the mixed concrete will be affected.

1.3 Research Objectives and Aims

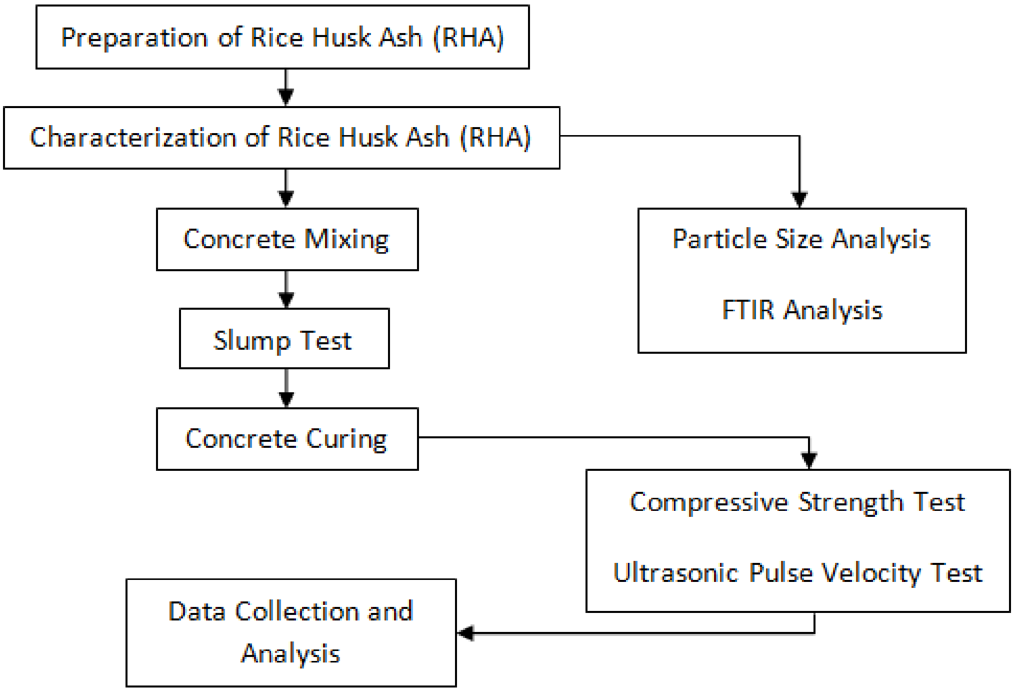

Figure 1.2: Experimental flow chart

- To determine the mechanical properties of Furnace Incinerated Rice Husk Ash concrete with various replacement ratio.
- To determine the properties of Furnace Incinerated Rice Husk Ash with different temperatures.
- To optimize the replacement ratio of Furnace Incinerated Rice Husk Ash in blended cement.

1.4 Scope of Study

Cement is the primary material that needed most in construction and the need of cement is increasing annually with a great quantity. Great amount of CO_2 is produced during the production of cement. CO_2 is a knowing greenhouse gases that affect global warming and greenhouse effect. Furthermore, the disposal problem of rice husk had become a serious environmental issue due to their abundance. This study was conducted to determine the replacement ratio of cement with rice husk ash. The replacement of cement with rice husk ash can reduce the production of cement further reduce the production of CO_2 and solve the disposal problem of numerous rice husks produced.

The parameters of the study are including the temperature of producing rice husk ash, composition of rice husk ash, replacement ratio of cement with rice husk ash, compressive strength of concrete and microstructure of concrete. The experiment was done in UTAR, Perak campus within 3 months begin from May 2015. The collected rice husk was burned in the furnace by using the temperature of 600 ℃ and 700 ℃. After that the rice husk ash was tested using FTIR machine to examine the composition. Other researchers found that the optimum replacement ratio would be 10 %. Therefore, this study replaced cement with rice husk ash in concrete design with the ratio of 0.0 %, 2.5 %, 5.0 %, 7.5 % and 10.0 %. The concrete had complied Grade- 40 concrete design. Mechanical properties of the concrete were tested within the range of 3, 7, 28 days according to the normal concrete testing period. The compressive strengths of the concrete samples were also tested.

1.5 Thesis Outline

There are five chapters included in this report. First chapter is the overview of the study, problem statement, scope of study and the objectives. Second chapter is the literature review which includes recent studies on RHA. Chapter three is the methodology which includes experimental work, materials and analytical methods. Fourth chapter includes the key findings and discussion in this study. The last chapter consists of conclusion and discussion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The demand of cement according to U.S Geological Survey is increasing rapidly from time to time as shown in Figure 1.1. In Malaysia, the supply of cement is still meets the demand but the price of cement has increased. In other word, cement can be considered as the most expensive material in the construction industry. On the other hand, production of cement is also caused depletion of natural sources and generate large amount of CO_2 into the atmosphere. It has been reported that to produce a ton of cement will generates approximately a ton of CO_2 greenhouse gas (Mehta, 1994). Reuse of agricultural waste as a supplementary material in construction is suggested to be a way to sustain the natural resources, reduce greenhouse gases emission and also lower down the environmental impact by the disposal of agricultural waste. Reuse of agricultural waste is suitable apply in agro-based developing country such as Malaysia. Rice Husk is an agricultural waste generated after the rice milling process and about hundred million tons of the 740 million tons of rice produced annually worldwide (FAO, 2015). The pozzolanic effect of RHA has been reported by many researchers. RHA is potential to be used as supplementary cementitous materials. The related information of RHA and concrete will be discussed further in this chapter.

2.2 Concrete

Concrete is the most important building material that widely used in construction due to its properties. It is made by mixing cementitious materials, water and aggregates in required proportions (Gambhir, 2004). Concrete history can be traced down to 7000 years ago in the Yugoslavia (Hunt, 2000). Modern concrete is the evolution of improving and combine of the concrete materials over thousands years.

2.2.1 Cement

Cement is binder that is widely used in construction because of its adhesive and cohesive properties. It provides a binding medium for the ingredients of concrete. Cement is functioned to bind the fine aggregates and coarse aggregates together and fill the voids in between both aggregates particles to form a compact mass (Gambhir, 2004).

2.2.2 Portland Cement

Portland cement is a type of cement that is commonly used in construction. It is made from a combination of argillaceous and calcareous materials to a partial fusion at about 1450 ℃ (Gambhir, 2004). The argillaceous materials are clay, slate, shale and selected blast-furnace slag. The calcareous materials are usually chalk and limestone. There are two types of method to manufacture cement, dry and wet process. Normally dry process is used to produce cement. The materials are first crushed, ground and mixed before fed into a cement kiln and heated at a high temperature of 1450 ℃. The product after heating is known as clinker is then cooled and ground into fine powder form and cement is formed. On the other hand, the materials needed to grind with water before entering the kiln for wet process. Wet process requires more energy to evaporate the water inside the kiln. However, both processes emit large amount of CO_2 to the atmosphere.

2.2.4 Aggregates

Aggregate is defined as the inert filler which can incorporate with cement paste to form concrete. The reasons of using aggregate in the construction of concrete are due to the economic reasons, volume stability and durability for concrete (Gambhir, 2013). Aggregates constitute 70 % to 80 % of the whole concrete volume and their price is much lower than the cement. Besides, aggregate also provide the volume stability to hardened concrete. Aggregate can be categorized into fine aggregate and coarse aggregate.

Fine aggregate is defined as the particle which is smaller than 4.75 mm (passing through sieve 4.75 mm). The function of fine aggregate is to help in producing workability and uniformity concrete mixture. Fine aggregate can be classified into natural sand, crushed stone sand and crushed gravel sand. Most of the fine aggregate that used in concrete industry are river sand and mining sand or even crushed stone sand. In addition, fine aggregate also functions in holding the coarse aggregate in suspension.

Coarse aggregate is defined as the particle size of stone which is larger than 4.75 mm (retained on sieve 4.75 mm). Coarse aggregate generally come from crushed gravel or stone, uncrushed gravel or stone, and partially crushed gravel or stone. There are several researchers reported that the size and types of aggregate have significant effect on the strength and workability of concrete formed (Kozul 1997).

2.3 Supplementary Cementitious Materials (SCM)

SCM is defined as mineral additives that contribute to the strength concrete by chemical or physical action through its hydraulic or pozzolanic activity (Gambhir, 2004). SCM is normally produced by waste and by-product of industries or agriculture. For example, silica fume, fly ash, rice husk ash, palm oil fuel ash and etc. SCM is widely used as pozzolanic materials in improving the properties of concrete due to the extra strength by pozzolanic reaction. Pozzolanic materials or pozzolan are defined as a siliceous material that is not adhesive by itself but shows adhesive and cementitous properties by the reaction with Calcium Hydroxide, ($Ca(OH)_2$ or represent by CH) in the presence of humidity at standard temperature (Hesami, Ahmadi & Nematzadeh, 2013). Pozzolan is generated from agro-waste such as sugarcane bagasse ash, wheat straw ash, rice husk ash, hazel nutshell ash can be used to replace cement partially (Evi et al., 2014). Pozzolan can make better precipitation of C-S-H gel than normal concrete in blended cement which can blocking the pores more effectively and reduce the permeability. The calcium hydroxide produce by hydration of cement is water soluble and the entry of water into the concrete can cause leaching of calcium hydroxide. With the assist of pozzolan, pozzolanic reaction occurs to combine with the calcium hydroxide to produce more C-S-H gel in order to reduce the leaching of calcium hydroxide and fill up the voids. Thus a denser and less permeability concrete can be formed (Sumadi & Lee, 2008).

2.3.1 Rice Husk Ash (RHA)

Rice husk is the outermost part of rice paddy, it covers about 20 to 25 % of the rice weight. RHA is a SCM and being studied in a past few decades in order to replace cement through its pozzolanic properties. RHA is obtained from raw rice husk changed into ash by combustion method to remove volatile organic carbon such as cellulose and lignin. It has a very high surface area of 50000 to 100000 m^2 per kg (Gambhir, 2004). RHA is a very fine material and its average particle size of RHA is ranged from 5 to 10 micron (Evi et al, 2014). RHA is composed mostly of silica in amorphous form (85-90%) and it has a highly micro-porous structure which is suitable to replace cement through its pozzolanic reaction. The amorphous silica of RHA can react with the calcium hydroxide crystal that formed during the hydration of concrete. Secondary C-S-H gel is formed to fill up the pore structure in concrete. Besides, RHA also can improve the interlocking between the concrete mixture and fill up the space between cement particles (Hesami, Ahmadi & Nematzadeh, 2013). Thus, a denser and higher strength can be produced.

The form of silica produced and the reactivity of RHA is dependent on the conditions of incineration. Fineness of RHA is another important factor that could influence the reactivity of RHA. RHA is basically finer and less reactive compared to Portland cement but it could disperse in the mixture and create a numerous quantity of nucleation sites for the precipitation of CH which can refer as pozzolanic reaction. This reaction creates a denser and more homogenous concrete (Isaia, Gastaldini & Moraes, 2003). RHA exist in concrete can reduce permeability, w/c-ratio, make denser packing and increase the hydration of cement (Sumadi & Lee, 2008). RHA is influencing the mechanical properties of concrete through its chemical and physical properties. Tables 2.1 and 2.2 show the chemical and physical properties of RHA from several researchers.

Table 2.1: Chemical properties of RHA (Weight percentage)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	References
87.20	0.15	0.16	0.55	0.35	0.24	1.12	3.68	Mehta, 1992
87.30	0.15	0.16	0.55	0.35	0.24	1.12	3.68	Zhang et al., 1996
86.98	0.84	0.73	1.40	0.57	0.11	2.46	-	Bui et al., 2005
97.50	0.73	1.18	0.18	-	0.49	0.10	1.39	Sumadi & Lee, 2008

Table 2.2: Physical properties of RHA

Specific gravity (g/cm^3)	Mean particle size (μm)	Fineness: passing 45 μm (%)	References
2.06	-	99	Mehta, 1992
2.06	-	99	Zhang et al., 1996
2.10	7.4	-	Bui et al., 2005
0.90	-	96	Sumadi & Lee, 2008

2.3.2 Composition of RHA incinerated at different temperatures

RHA is generated by the incineration of rice husk under controlled condition. The reactivity of RHA is based on its properties of amorphous silica. At the temperature of 500 ℃ to 700 ℃, amorphous silica is formed and at the temperature higher than 700 ℃, crystallization will occur. Crystallization is the process of substantial amount of highly reactive amorphous silica converted into non-reactively crystalline silica. Amorphous silica contains the molecules which are arranged in a random three-dimensional repeating pattern. The specific area is large and the chaotic formation of the structure is open with holes in the network where electrical neutrality is not satisfied. On the other hand, crystalline silica structure is made by the repetition of a basic unit. The structure of crystalline silica had reduced the surface area of RHA and thus reduced the reactivity of RHA.

Xu et al. (2012) reported that the RHA incinerated at 500 ℃ and 600 ℃ contain pure amorphous silica and without crystalline silica formed. Crystalline silica appeared in the RHA when it is incinerated at 700 ℃ and high crystalline silica content in the RHA incinerated at 800 ℃. Della et al (2002) found that 95 % of silica powder could be produced at the temperature of 700 ℃. A study conducted by Onojah et al. (2013) regarding to the composition of RHA incinerated of temperature ranged from 1000 to 1400 ℃. The results showed that the polymorphs of silica present in the silica dioxide are cristobalite and tridymite at all the sintering temperatures. Cristobalite is the major phase from 1000 to 1200 ℃. Tridymite phase become prominent at the temperature ranged from 1200 to 1400 ℃.

Table 2.3: Composition of RHA found at different temperatures.

Temperature	Composition	References
500 to 600 ℃	Amorphous silica only	Xu et al., 2012
700 ℃	Amorphous silica and Cristobalite	Xu et al., 2012
800 ℃	Crystobalite and tridymite	Xu et al., 2012
700 ℃	95 % of amorphous silica	Della et al, 2002
1000 to 1200 ℃	Cristobalite and little tridymite	Onojah et al, 2013
1200 to 1400 ℃	Mainly tridymite	Onojah et al, 2013

2.4 Pozzolanic Reaction

Pozzolanic reaction refers to the process of a siliceous material react with the calcium hydroxide ($Ca(OH)_2$ or represent by CH) content in the concrete in the presence of water to form C-S-H gel (Papadakis et al., 2002). According to Englehard et al (1995), Calcium silica hydrate (C-S-H) and CH are formed in the hydration of two main compounds of cement which are tricalcium silicate (C_3S) and dicalcium silicate (C_2S). The reaction of hydration is presented below.

$$2(3CaO.2SiO_2) + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2 \quad \text{(Eq.2.1)}$$

$$2(2CaO.2SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2 \quad \text{(Eq.2.2)}$$

$$2SiO_2 + 3Ca(OH)_2 \rightarrow 3CaO.2SiO_2.3H_2O \quad \text{(Eq.2.3)}$$

Where

$2CaO.2SiO_2$	=	dicalcium silicate, C_2S
$3CaO.2SiO_2$	=	tricalcium silicate, C_3S
$3CaO.2SiO_2.3H_2O$	=	calcium silicate hydrate (C-S-H gel)
$Ca(OH)_2$	=	Calcium hydroxide, represent by CH

The C-S-H gel which is produced in the hydration of cement could act as strengthening constituent. The excessive amount of CH formed during the hydration of cement will reduce the concrete strength due to the porosity increase in the concrete (Givi et al., 2010).

Pozzolan reaction will occur when CH is produced in the concrete and represented by Equation 2.3. The OH^- and Ca^{2+} will react with the SiO_2 or Al_2O_3-SiO_2 from the pozzolan to form extra C-S-H gel and calcium aluminate ferrite hydrate (C-A-H) (Sumadi & Lee, 2008). The combination of C-S-H gel and C-A-H gel are also known as cement gels which is hardened with concrete age and enhanced concrete strength. The reaction is slow and basically begins after one week and resulted in more permeable in early age of concrete but becomes denser with time

(Givi et al., 2010). The delay of the reaction is due to two reasons: Firstly, the pozzolan particles become precipitation sites for the early hydration of C-S-H and CH that deter the reaction. Secondly, glass phase only can be broken down by the alkalinity of the pore water which requires some period to attain the high PH after the hydration process. Cement gels can reduce the pore size of concrete and blocking the capillary pores in order to make the concrete more durable and stronger (Sumadi & Lee, 2008).

2.5 Pore Structure

Porosity is defined as the volume of the pores inside concrete which are either connected or not connected restricted the flow of a fluid (Sumadi & Lee, 2008). Pore structure can be categorized into capillary pores and gel pores.

Gel pores are generally lesser in volume and contain large amount in concrete that is due to the existing cavities in the products of hydration process. The gel pores are interconnected interstitial spaces between gel particles but the permeability are very low (Sumadi & Lee, 2008). In contrast, capillary pores are relatively bigger in volume and the formation is dependent on the evaporation of water in the concrete. Capillary pores will reduce with the process of hydration by filling up the pores by the products of hydration which resulted in the decreasing of the volume and size of pores and form segmentation of the capillaries. Adding of pozzolan in concrete mixing can produce more homogenous hydration products by filling and segmentation of the capillary pores and there denser and more impermeable concrete can be formed (Guneyisi et al., 2006). The total porosity of concrete incorporate with pozzolan will be greater normal concrete but the permeability is lesser. In the addition of pozzolan, the capillary pores will be filled up and the volume of smaller pores will increase. However, the pore structure in the normal concrete will be continuous due the large crystal is formed by the high hydration products.

2.5.1 Porosity and Permeability

As previously mentioned, the amorphous silica of RHA reacts with CH in the hydration process and the amount of RHA is reduced, leading to the production of the C–S–H gel. Thus porosity and permeability increase and the compressive strength decreases with the increase of RHA. Although, using a further amount of RHA causes reduction in the compressive strength. From this stage on, the RHA had a negative effect on the hydration of cement and results in an increase of porosity in the cement paste and consequently increases concrete porosity and permeability. This is because high specific surface area of RHA and lack of required water absorption by RHA particles cause the compressive strength to reduce and consequently increase the permeability and porosity (Ramadhansyah et al., 2013).

2.6 Factors influencing the mechanical properties of concrete

The strength and durability of concrete is normally to be governed by such factors as water binder ratio (cementitious content), the efficiency of curing, compactness, admixture and also content of cement in the mix.

2.6.1 Water-cement ratio (w/c ratio)

About 25 % of water is needed for average composition of concrete mass for chemical reaction. Besides, water is needed to fill up the gel pores inside concrete. There is a direct relationship between w/c ratio and concrete strength, the lesser the water the stronger the strength (Gambhir, 2013). W/c ratio should be in between 0.4 to 0.5 in order to get lower permeability and higher strength of concrete. Concrete that used lower w/c ratio will have a lower porosity resulting in a higher durability and strength due to there is sufficient gel to fill up the pore structure (Sumadi & Lee, 2008). While there are excessive of w/c ratio, segregation, internal and external bleeding will occur to the concrete. If the w/c ratio is too little will cause uniformly mixing of the mixture and resulted in weak bonding.

2.6.2 Curing Process

Curing is a very important process that could affect the concrete strength. Curing is defined as the process of creation of an environment for the concrete to setting and hardening right after the concrete is placed and compacted (Gambhir, 2013). Curing which mean by putting the concrete immediately after set and compacted to the suitable condition of water and temperature. Concrete needed curing is because of the hydration of cement which can only happen in water-filled capillaries. Upon the concrete contacts with water, the hydration of cement will occur internally and externally. The hydration products will get deposit outside of the cement particles while the nucleus of unhydrated cement will reduce gradually inside of the concrete. In order to obtain a concrete of complete strength development, evaporation should be prevented and have enough of water for hydration process.

2.6.3 Compactness

Compaction is one of the important factors that influencing concrete strength. The process of compaction is mainly to reduce the entrapped air in the concrete and group the mixture together to become more uniformity. The bonding of concrete mixture is improved and resulted in an enhancement of concrete strength. Voids are defined as the empty space in concrete that mostly formed by air bubbles or entrapped air (Gambhir, 2013). The existence of voids in concrete can cause the reduction of concrete strength. Even 5 % of voids exist in the concrete can reduce 30 % of concrete strength (Neville, 1995).

2.6.4 Superplasticizer

Superplasticizer is a known water reducing agent to enhance workability of the concrete and reduce the amount of water used. Dispersion of cement particles manipulated the concrete flow behaviour and subsequently affects the properties of concrete (Sumadi & Lee, 2008). The function of superplasticizer is to provide a better dispersion of cement particles. The dispersion can let cement to have a larger surface area to hydration which progresses at a higher rate in the early stages. Superplasticizer gives negative charge on the cement particles so that they are kept in a dispersed state due to inter-particle repulsion (Gambhir, 2013). Besides, superplasticizer has been reported can improve the strength of concrete by the highly reduction of water-cement ratio and without affecting the workability (Sumadi & Lee, 2008). Superplasticizer only contributes to the early strength gain of concrete but no effect on the long term strength. Superplastizer can be used with SCM such as RHA for early strength gain due to the delayed pozzolanic reaction.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Experimental Work

In this study, the mechanical properties of Rice Husk Ash (RHA) of 600 and 700 ℃ and different partial replacement of RHA in cement in casted concrete as stated in Table 1 will be determined. The physical characteristics and chemical composition of RHA will be determined by particle size analysis and Fourier Transform Infrared Spectroscopy (FTIR) analysis. Different ratio of partial replacement of cement with RHA will be carried out by mixing concrete. The mechanical properties of RHA concrete which include compressive strength and microstructure will be tested. The scheme of experimental work is shown in Figure 3.1.

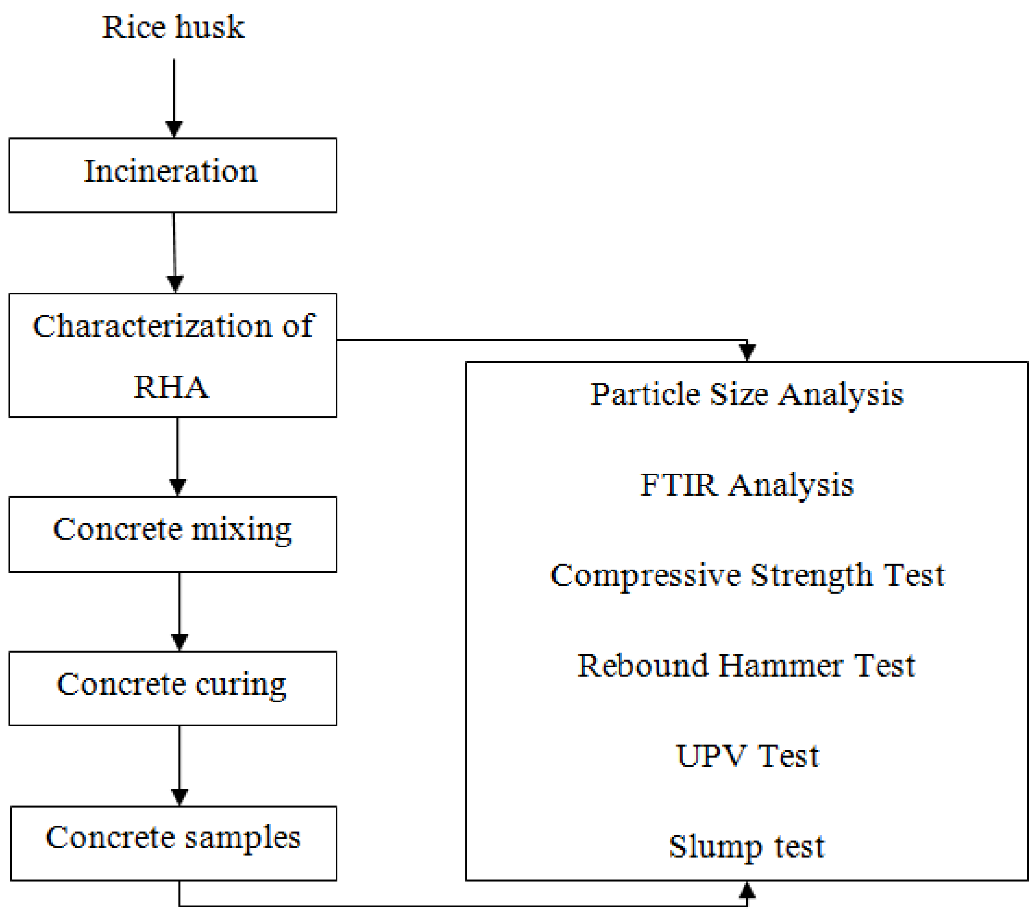

Figure 3.1 Scheme of experimental work

3.2 Materials

Materials used during this experimental study are listed below.

- Portland Composite Cement

  YTL Portland composite cement was used in this research work which is locally processed, produced and distributed by YTL Berhad. The quality of YTL Portland composite cement was proved by SIRIM (certified to MS 522-1:2007) and BS EN 197-1:2000, CEM II/B-L 32.5N. The cement was stored away from air moisture in the workshop to ensure the material was in good condition during the experimental period.

- Fine aggregate

  The fine aggregate that used for concrete mixing was mining sand. Mining sand was selected because it is easier to obtain and it was free from clay, organic material and chemical compared to river sand. The mining sand was checked to ensure that it was free from other organic materials inside before used.

- Coarse aggregate

  Granite was used in concrete mixing in this experimental study. Granite is formed naturally from stone that was quarried and crushed to produce various sizes of aggregate. It is commonly used in construction industry as coarse aggregate. The aggregate used was cleaned and dried under the ambient temperature before concrete mixing.

- Water

  Tap water was chosen for the concrete mixing and curing process. Water is considered as an important ingredient that required for concrete mixing. Impurities in the water and the pH value may affect the setting time, compressive strength of the concrete and also may causes staining on the concrete surface (Sumadi & Lee, 2008). The quality of tap water satisfied the requirements of concrete mixing.

- Superplasticizer

  Superplasticizer is a known water reducing agent to enhance to workability of the concrete and reduce the amount of water used. PYE Kwiset superplasticizer was used in concrete mixing of this study as a chemical admixture to reduce the water-cement ratio of the concrete and enhance the workability of concrete formed. Besides, the voids ratio also can be reduced in order to increase the strength and decrease the porosity of the concrete (Sumadi & Lee, 2008).

Figure 3.2 Plasticizer

- Rice husk ash (RHA)

  The rice husk was collected from local rice mills and burned into RHA. The details of RHA are discussed in the section 3.3 Preparation of rice husk ash (RHA).

3.3 Preparation of rice husk ash (RHA)

Rice husk collected from local mill was burnt in a muffle furnace which located in the EV laboratory under fixed controlled temperature of 600 ℃ and 700 ℃ for two hours respectively. The percentage weight of RHA was recorded for reference purpose. According to Tashima et al. (2004), about 20% of RHA can be obtained from the unburned rice husk. RHA was then collected and ground into certain fineness by RT Blender which located in the Faculty of Science laboratory. Hamid et al. (2013) has reported that the RHA fineness will directly influence the amount of C-S-H gel formed in the concrete. Finer RHA will increase concrete strength but reduce the workability due to increasing in demand of water. As discussed in previous section, increase in the amount of C-S-H gel will enhance the concrete strength.

3.4 Mixing proportions of G- 40 Concrete

Grade- 40 concrete was chosen to be the mixing grade of concrete. G- 40 concrete refers to the tested concrete will achieve compressive strength of 40 N/mm^2 at 28 days. The mix designations are the same for both concrete using 600 ℃ and 700 ℃ RHA respectively. The mixing designation of G- 40 concrete was listed below.

Table 3.1 Mix designation of material composition for 1 m^3 of G- 40 concrete

Mix designation	C	R1	R2	R3	R4
RHA (%)	0.0	2.5	5.0	7.5	10.0
w/c ratio	0.42	0.42	0.42	0.42	0.42
Cement (kg/m^3)	469.0	457.3	445.5	433.8	422.1
Fine aggregate (kg/m^3)	625	625	625	625	625
Coarse aggregate (kg/m^3)	1196	1196	1196	1196	1196
Water (kg/m^3)	197	197	197	197	197
Plasticizers (L/m^3)	4.69	4.69	4.69	4.69	4.69

Table 3.2 Mix designation of RHA and Portland Composite Cement

Sample	Incineration Temperature of RHA (℃)	Percentage replacement of cement (%)	Portland Composite Cement (%)
C	-	0.0	100.0
R1	600	2.5	97.5
R2	600	5.0	95.0
R3	600	7.5	97.5
R4	600	10.0	90.0
R1	700	2.5	97.5
R2	700	5.0	95.0
R3	700	7.5	92.5
R4	700	10.0	90.0

3.5 Casting process

Mixing of concrete was carried out in the construction workshop. Hand mixing of concrete was used in this study and all the mixing was done in a piece of plywood. All the materials were weighted accurately before mixing. The surface of plywood was wetted before putting the materials to reduce the water loss. Mining sand, granite, RHA and cement were put on the plywood accordingly and mixed well with shovel. The superplasticizer was added into the water before poured into the dry mixture. Then the mixture of water and superplasticizer was added slowly to the dry mixture and mixed consistently to form fresh concrete. After the fresh concrete was formed, slump test was performed to check its workability. The fresh concrete was then poured into the steel mould to form dimension of 100 mm × 100 mm × 100 mm concrete cube. A layer of lubricant oil was coated on the inner surface of the steel mould for the ease of demould. The concrete was demoulded after 24 hours and cured in a tank of water. The concrete samples were tested at the concrete age of 3, 7, 14 and 28days after curing.

3.6 Characterization of rice husk ash (RHA)

The chemical and physical properties were determined by Fourier Transform Infrared Spectroscopy (FTIR) analysis and particle size analysis. The chemical properties as discussed in previous section are important in determining the pozzolanic reactivity of RHA. Fineness of RHA can influence the pozzolanic reactivity as well.

3.6.1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

FTIR Spectroscope (Perkin Elmer Spectrum, RX1, made in USA) was used in this research work to identify the functional groups present in the RHA. The functional groups of RHA were identified through the absorption of wavelengths of infrared light from the sample.

3.6.2 Particle Size Analysis

Particle size of RHA was determined by Particle Size Analyzer (Malvern Mastersizer 2000) which located in EV laboratory. The analyzer is able to determine the average particle size distribution from range 0.02 to 2000 µm. As mentioned, the size range of RHA could influence the concrete strength and workability.

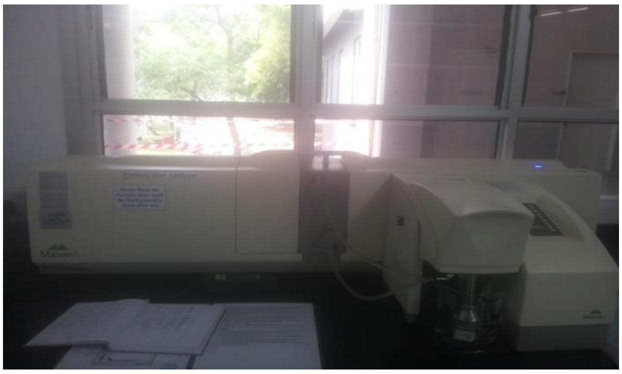

Figure 3.3 Particle size analyzer

3.7 Mechanical Test

Slump test, Ultrasonic Pulse Velocity Test and Compressive strength test were done to determine the mechanical properties of the concrete samples.

3.7.1 Slump Test

Slump test was used in this study to investigate the workability of the fresh concrete according to British Standard (BS EN 12350-2: 2009). Workability can be defined as the property of fresh concrete which determines the ease in handling, placed, consolidating and compacting and the degree to which it is resists segregation (Gambhir, 2004). The apparatus of slum test consists of base plate, compacting rod and mould. The steel mould was in cone shape with 200mm diameter of bottom base, 100mm diameter of top and height of 300mm. The mould and base place must be damped before testing workability. Then the fresh concrete mixture was filled into the mould in three layers and each layer was compacted by using compacting rod for 25 times. After filling up to the top surface, the mould was lifted upward steadily with no lateral or torsional motion. The difference between the height of the mould and the highest point of the sample was measured and recorded as slump height.

Figure 3.4 Slump test apparatus

3.7.2 Ultrasonic Pulse Velocity (UPV) Test

UPV test is a non-destructive test that was used in this study to determine the uniformity, cracks and defects of casted concrete incorporate with RHA (BS EN 12504-4: 2004). The test was conducted on the mixed concrete of standard dimension of 100 mm × 100 mm × 100 mm on the concrete curing age of 14 and 28 days. The transducer will generate a pulse of vibration at an ultrasonic frequency at one surface of concrete and pass through the concrete and received by second transducer at another surface of concrete (Neville & Brooks, 2010). The vibration passing through the concrete will received and converted into an electrical signal. Transit time of the pulse can be measured by the electronic timing circuits. The pulse velocity can be calculated by knowing the path length and transit time travelled through the concrete. The formula is presented below.

$$V = \frac{L}{T}\ 1 \qquad \text{(Eq.3.1)}$$

Where:

V = pulse velocity, km/s;

L = path length of the concrete, mm;

T = time taken by the pulse to transverse the length, µs.

Figure 3.5 Ultrasonic pulse velocity test machine

3.7.3 Compression Strength Test

Compressive strength is the main property of concrete as mentioned before. Kenco Compressive Strength Testing Machine which located in Construction Management workshop was used to determine the compressive strength of the concrete sample. Cube test which according to British Standard (BS EN 12390-3: 2002) was conducted with the standard dimension of 100 mm × 100 mm × 100 mm. Sample was loaded to failure and the maximum load sustained by the sample was recorded and generated the compressive strength. The capacity of this machine is 200kN with the rate of 40 kN/s. The weight of concrete sample was recorded before conducting the test for reference purpose. The platen of the testing machine and the surfaces of the sample were wiped before testing to ensure the accuracy of date collected. After the sample was placed and locked, the load was started until no greater load can be sustained by the concrete and the data was recorded.

Figure 3.6 Compressive strength test machine

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Characterization of RHA

Characterization of RHA was done through FTIR analysis and particle size analysis of RHA. The details of the analysis are explained below.

4.1.1 Fourier Transform Infrared Spectroscopy (FTIR) analysis

The reactivity of RHA is highly depends on the chemical group in the RHA. FTIR analysis was performed to investigate the major functional groups in the samples raw rice husk (RRH), 6RHA and 7RHA.

Table 4.1 Summary of Peaks in the samples

Sample	RRH	6RHA	7RHA
Wavelength, cm^{-1}	3422	3403	3412
	2929		
	2373-2342	2373-2346	2373-2342
	1640	1577	1463
	1071	1098	1102
	897		
	798	799	803
	467	467	467

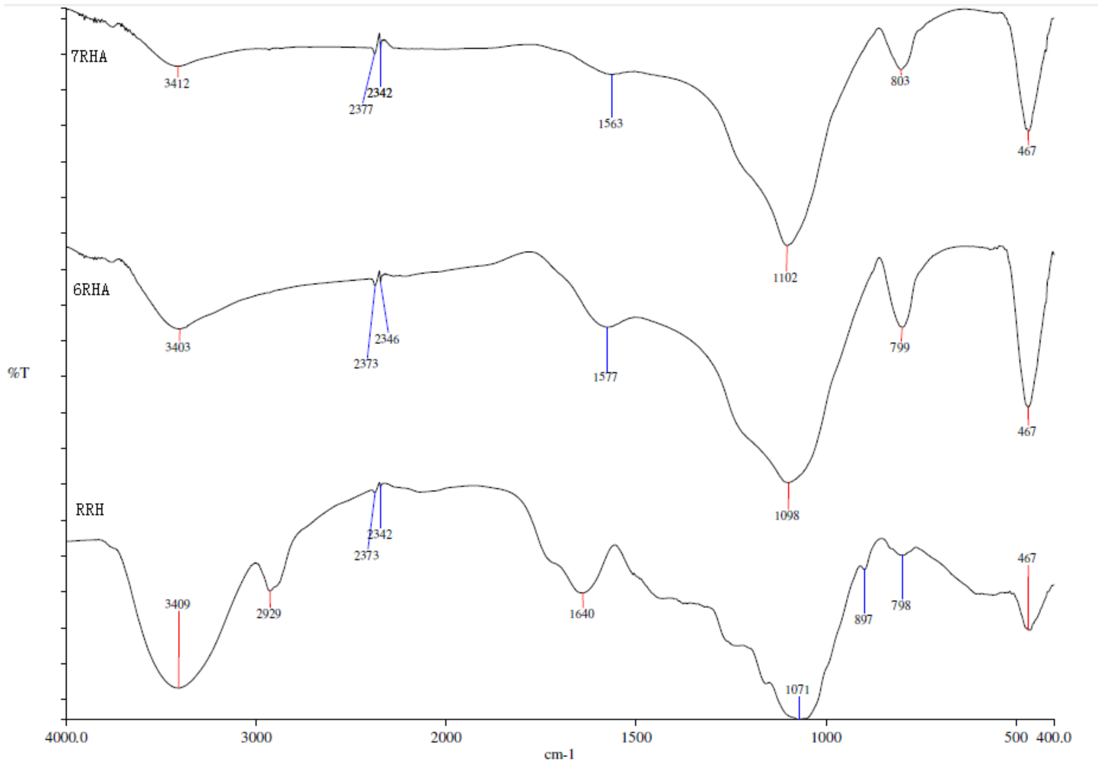

Figure 4.1 FTIR Spectrum of 6RHA and 7RHA

Figure 4.1 shows the common functional groups in raw rice husk (RRH), 6RHA and 7RHA which had the bandwidth ranged between 3400 to 3450 cm^{-1} and caused by surface O-H vibration. This band is due to silanol, SiO-H groups and the HO-H vibration of the absorbed water molecules bound to the silica surface. These modified silica gels are basically a high moisture product made up of a network of interconnected pores with a silicon dioxide core consisting of the silanol groups (Adam et al., 2006). This surface silanol groups are responsible for physically adsorbing water molecules and holding them in place by hydrogen bonding. The water entrapped in the core, the silanol hydroxyl groups and the physically adsorbed water together represent the moisture content in the silica gel samples. The strength of the silanol bond is decreasing as the temperature of incineration increased due to dehydroxylation in which the bandwidth is shifted to lower number (Abadi et al., 2015).

Bandwidth 2929cm^{-1} was confirmed to the presence of amorphous cellulose which is only presence in RRH. Bandwith of 2342 to 2373 cm^{-1} was assigned to the CH_2 bond. Abadi et al. (2015) reported that the wavenumbers will shifted lower as the temperature of incineration increase. The bandwith of 1563 to 1640 cm^{-1} are assigned to a symmetric CH_2 bending vibration.

The strong band at 1071 to 1102 cm^{-1} is due to the structural siloxane framework, which is the vibration frequency of the Si-O-Si bond. This peak shifted to higher value as the temperature of incineration increased, which is normally observed in the incineration of rice husk. This band was observed in three samples and it is the most prominent characteristics of any silica material having the Si-O-Si bond as the back bone. The bandwidth at 798 to 803 cm^{-1} was assigned to symmetric Si-O-Si stretching vibration and this shifted to 803 cm^{-1} upon incineration. The bandwidth at 897cm^{-1} was assigned to C-O-C stretching bond which is only present in RRH (Ciolacu et al., 2010). The bandwidths at 467 cm^{-1} for three samples are associated with a network of Si-O-Si bond rocking modes (Abadi et al., 2015).

4.1.2 Particle Size Analysis

Particle size distributions of the two samples of RHA were determined by performing particle size analysis. Average particle size of RHA has significant effect on the pozzolanic reactivity of the RHA incorporated in concrete mixing. Habeeb et al. (2010) and Hamid et al. (2013) reported that the finer in average particle size can enhance the concrete strength by increasing the pozzolanic reaction with CH to produce more C-S-H gel. Besides, the fine RHA particle also can acts as microfiller and refining the pore structure. The volume distribution (D_{50}) curve shown in Figure 4.2, 7RHA have bigger particle size compared to 6RHA. Figure 4.3 also shown that 6RHA have finer particle than 7RHA.

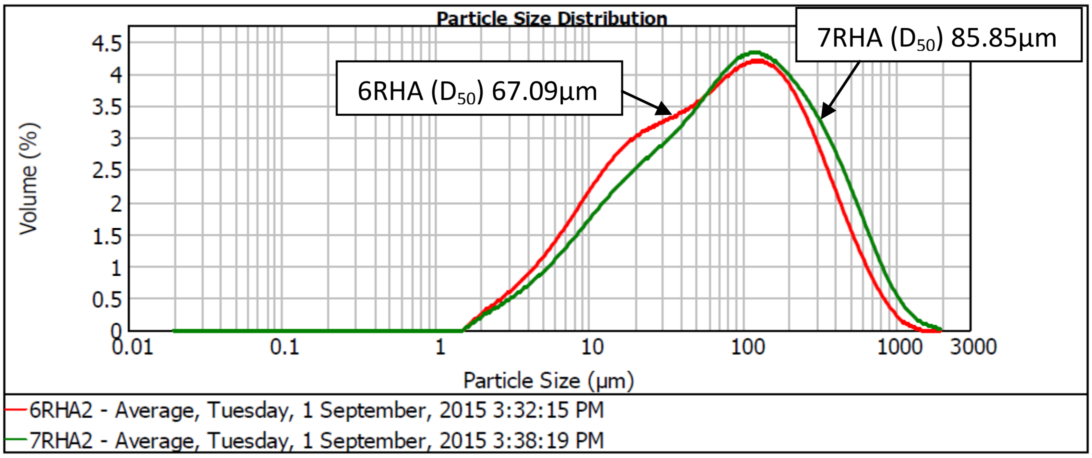

Figure 4.2 Particle size distributions of 6RHA and 7RHA

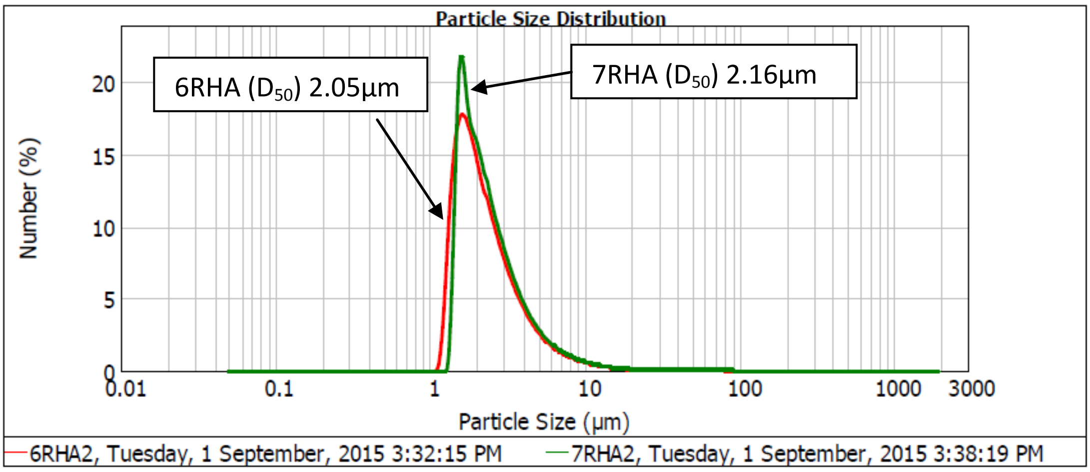

Figure 4.3 Particle size distributions of 6RHA and 7RHA

4.2 Mechanical Tests

The mechanical tests on the performances of both RHA mixed concretes were discussed below.

4.2.1 Slump Test

Workability can be defined as the property of fresh concrete which determines the ease in handling, placed, consolidating and compacting and the degree to which it is resists segregation (Gambhir, 2004). In this study, the workability of control and RHA mixed concrete was determined by performing the slump test according to BS EN 12350-2: 2009. Table 4.2 and 4.3 indicate the slump height of 6RHA and 7RHA as compared to Control.

Table 4.2 Slump height and the w/c ratio of 6RHA

Sample	w/c ratio	Slump (mm)
Control	0.42	120
6R1	0.42	109
6R2	0.42	91
6R3	0.42	75
6R4	0.42	62

Table 4.3 Slump height and the w/c ratio of 7RHA

Sample	w/c ratio	Slump (mm)
Control	0.42	120
7R1	0.42	95
7R2	0.42	81
7R3	0.42	69
7R4	0.42	59

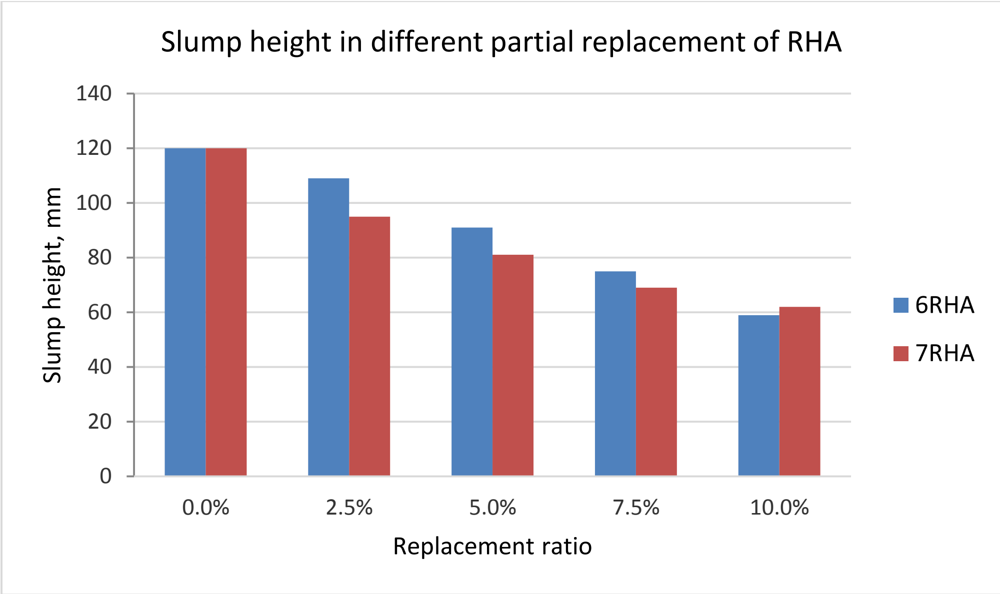

Figure 4.4 Slump heights for both samples

Figure 4.3 shows the slump height for both the 6RHA and 7RHA samples are decreasing when the amount of RHA in the sample is increasing which means by the workability is decreasing. RHA has high specific surface area and will increase the water demand of the concrete mixture to produce a workable concrete (Sumadi & Lee, 2008). RHA have finer particles which have higher surface area compared to cement particle. RHA particles will fill into the spaces between the cement grains resulted in stabilizing and increase the cohesiveness of the concrete but adversely affecting the workability (Givi et al., 2010). The water absorbing characteristics of RHA increase the demand of water with the increasing amount of RHA in the mixture.

4.2.2 Ultrasonic Pulse Velocity Test

UPV test is a non-destructive test that was used in this study to determine the uniformity, cracks and defects of casted concrete incorporate with RHA (BS EN 12504-4: 2004). The test was conducted on the mixed concrete of standard dimension of 100 mm × 100 mm × 100 mm on the concrete curing age of 14 and 28 days. The pulse velocity of both the samples and control were calculated by the Equation 3.1. The pulse velocity of control, 6RHA and 7RHA were tabulated in Tables 4.5 and 4.6.

Table 4.5 Pulse velocity of samples 6RHA

Samples	Pulse velocity, km/s	
	14days	28days
Control	3.83	4.50
6R1	4.23	4.60
6R2	4.29	4.42
6R3	4.38	4.52
6R4	4.12	4.25

Table 4.6 Pulse velocity of samples 7RHA

Samples	Pulse velocity, km/s	
	14days	28days
Control	3.83	4.50
7R1	3.94	4.45
7R2	3.96	4.54
7R3	4.10	4.44
7R4	4.33	4.60

As seen from Table 4.5 and Table 4.6, the pulse velocities for both concrete samples were increasing from 14 to 28 days which can say that the concrete become more homogenous from time to time. As discussed before, the addition of RHA is able to refine the pore structure and blocking the capillary pores by the C-S-H gel. The pulse velocity had increased which mean the pore structure of the concrete is decreasing. The capillary pores of the concrete added with RHA will reduce with the C-S-H gel produce by the reaction. The pore structure is filling up and segmented by the C-S-H gel and resulted in more homogenous and impermeable concrete. However, the effect of the RHA in the concrete is not significant as the pozzolanic reaction can prolong up to a years. The concrete strength will develop in long-term. In contrast, the pore structure in the normal concrete will be larger and seem to be continuously because of the large CH crystals formed by the hydration process.

4.2.3 Compressive Strength Test

Compressive strength Test indicates the major compressive strength which was carried out according to BS EN 12390-3: 2002. The sample cubes with the dimension of 100 mm × 100 mm × 100 mm were tested. The sample cubes were cured in water and tested for compressive strength at the curing age of 3, 7 and 28 days. The compressive strength average was taken from the result of three sample cubes. Figure 4.4 and Figure 4.5 show the average compressive strength of the different RHA replacement sample cubes with curing age of 3, 7 and 28 days.

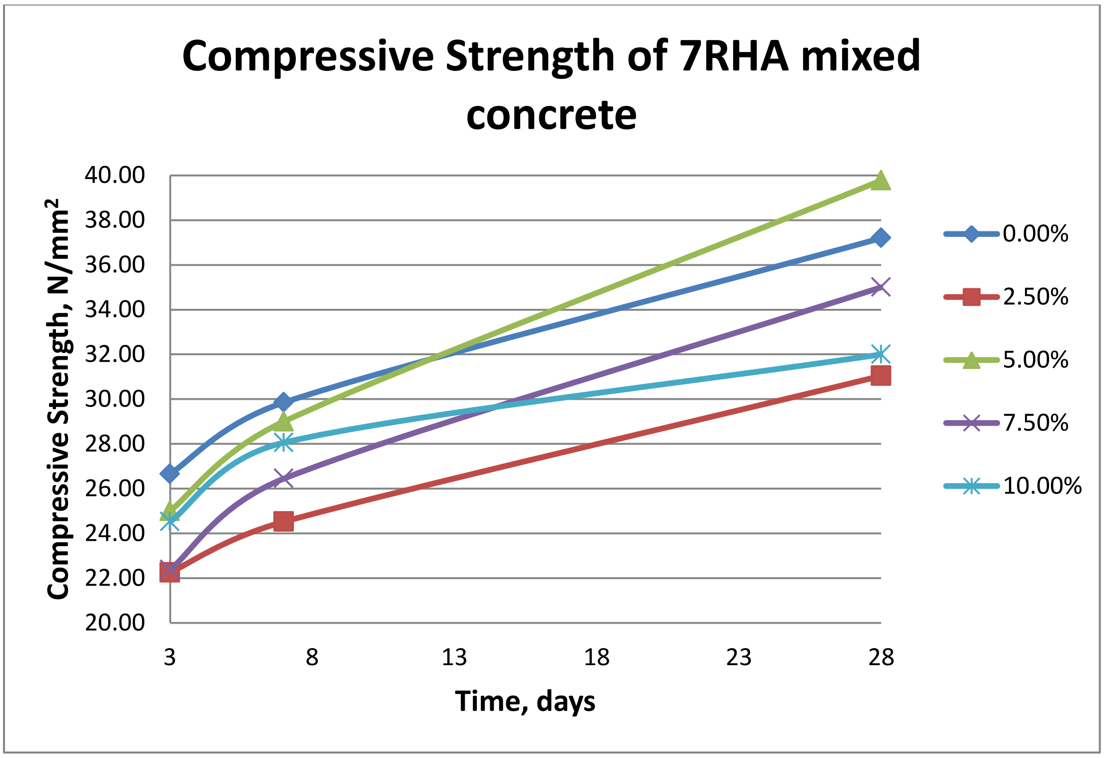

Figure 4.5 Compressive strength of 7RHA

Figure 4.4 shows the result of RHA incinerated at 700 ℃ with different replacement ratio of cement at different curing age. At day 3, the four samples of partial replacement of RHA are about 2.5 %, 5.0 %, 7.5 % and 10.0 % have the coincidence of having lower compressive strength compare to concrete with 0.0 % of RHA. The reduction of early strength gained as compared to normal concrete is due to the slow pozzolanic reaction of the silica and the CH in the concrete (Shatat, 2013). Givi et al. (2010) reported that the pozzolanic reaction is slow and normally starting after one week onwards which caused more permeable concrete in the early stage. The reason of the delayed reaction might due to the silica content in the RHA only can breakdown by the alkalinity of the pore water which required some time to attain the high pH after hydration process (Sumadi & Lee, 2008). For 28 days, the compressive strength ranking was 5 % > 0 % > 7.5 % > 10 % > 2.5 %. For the partial replacement of 7.5 % and 10.0 %, the compressive strength is slightly lower than the normal concrete. The trend of the result is similar to Bie et al. (2015) of that the compressive strength of the samples with cement replacement ratio above 5 % was lower than the control concrete. This is due to the crystalline silica present in the RHA and lower specific surface area compared to the RHA incinerated at 600 ℃. Crystalline silica refers to the amorphous silica of RHA converted to non-reactive silica when the incineration temperature more than 700 ℃. The pozzolan reactivity of the crystalline silica is reduce due to its structure and reduced surface area (Hwang, Bui & Chen, 2011).

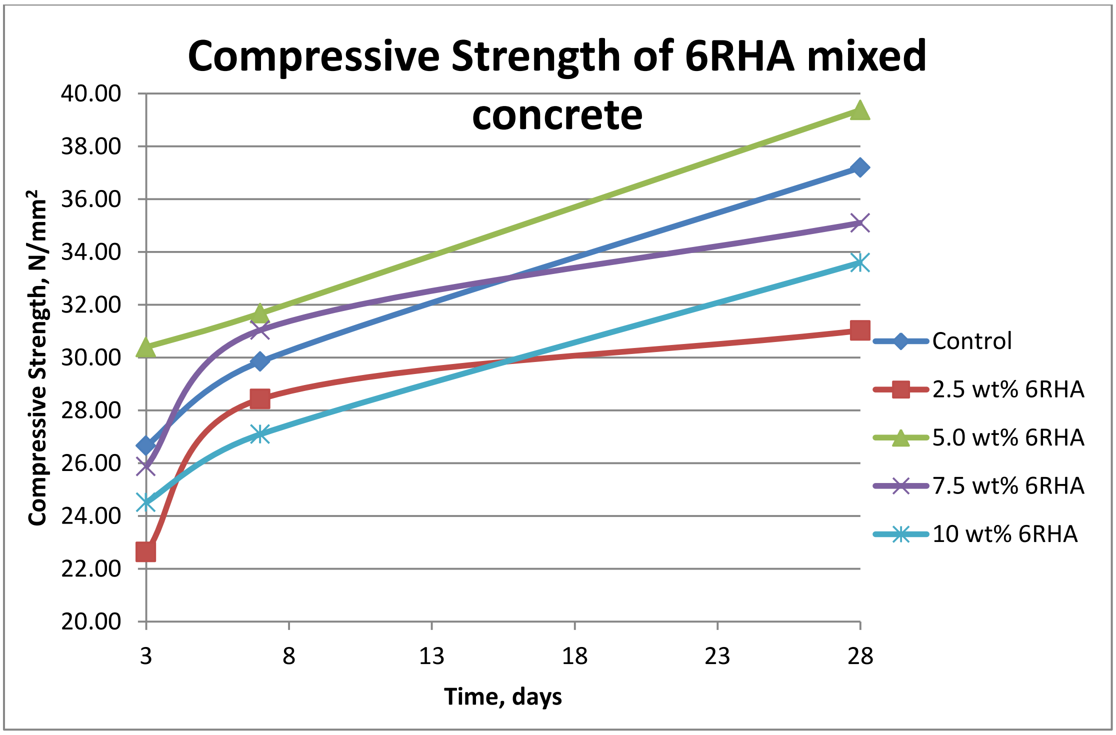

Figure 4.6 Compressive strength of 6RHA

Figure 4.5 shows the compressive strength of the concrete incorporated with the addition of RHA incinerated at 600 ℃. Several researchers stated that the form of silica obtained from the incineration of RHA less than 700 ℃ are only amorphous form. Amorphous silica referred to the highly reactive silica that can perform pozzolanic reaction with the hydroxide product of hydration. For the partial replacement of RHA incinerated at 600 ℃, the sample with 5.0 % of RHA have a compressive strength higher than control at early stage which indicate the RHA in the concrete mixture improved the early strength gain. According to Bie et al. (2015), the effect of the increased strength is due to the amorphous silica content and high specific surface area of the RHA. The higher compressive strength compared to the normal concrete is due to the silica inside the RHA begins to react with the hydration product in the concrete which is called pozzolanic reaction. The silica reacts with the calcium hydroxide to form the secondary C-S-H gel which is the main constituent to the compressive strength. C-S-H gel will fill up the capillary pores in the concrete. The C-S-H gel is refining the pores structure of the concrete thus the compressive strength is increased. For the 2.5 % RHA mixed concrete, the compressive strength is very low compared to other samples. This might be due to the silica in the concrete mix is not able to enhance the concrete strength. The amount of silica provided from the 7.5 % and 10.0 % of RHA reacted with only small portion of the hydration product, CH so the C-S-H gel formed by the pozzalanic reaction was limited (Habeeb et al., 2010). This is due to excessive amount of silica in the concrete and the reduction of cement. The silica is higher than the amount of hydration product so there is not enough CH to react with the silica therefore the silica would act as inert material which does not have any effect on the concrete strength. The excess silica would leach out and resulted in the deficiency in strength (Shatat, 2013, Habeeb et al., 2010).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The mechanical properties of RHA incorporated into concrete were studied through a series of experimental which included the FTIR analysis, particle size analysis, compressive strength test, rebound hammer test, ultrasonic pulse velocity test and slump test.

- 5 % of replacement of cement with RHA was optimized for both the sample incinerated at 600 ℃ and 700 ℃

- The compressive strength of the RHA incinerated at 700 ℃ of 5 % replacement ratio had the highest compressive strength.

- The workability of the concrete is reduce while increase the amount of RHA.

5.2 Recommendations

Methods to improve the mechanical properties of the RHA mixed concrete are suggested below:

- The chemical composition and crystalline phase of the RHA should be performed by X-Ray Diffraction Analysis (XRD)

- Specific surface areas have to be tested in order to investigate the degree of incineration and reactivity

- Research can be carried out to determine the optimization of average size particle of RHA.

- Research can be carried out to investigate the compressive strength of combination of more types of pozzolans inside concrete.

- Nitrogen adsorption should be carried out to investigate the specific surface area of RHA.

- Curing age of sample should be prolonged to 91 days in order to determine the pozzolanic effect of RHA in the concrete.

- Test on durability of the RHA can be carried out to test the hydrochloric acid resistance and water penetration.

REFERENCES

Abadi, M.H.S., Delbari, A., Fakoor, Z. & Baedi, J., 2015. Effects of Annealing Temperature on Infrared Spectra of SiO_2 Extracted From Rice Husk. *J. Ceram. Sci. Tech.*, 06(01), pp. 41-46.

Adam, F., Saraswathy, B. & Wong, P.L., 2006. Rice Husk Ash Silica as a Support Material for Ruthenium Based Heterogenous Catalyst. *Journal of Physical Science*, Vol. 17(2), pp. 1–13.

Ali, F. & Al-Shawabkeh., 2015. Evaluation of the Potential Use of Waste Tires as Supplementary Fuel in Jordan Cement Industry. *Council for Innovative Research*.

Ali, M.B., Saidur, R. & Hossain, M.S., 2011. A Review on Emission Analysis in Cement Industries. *Renewable and Sustainable Energy Reviews*.

Anderson, J.E., Wulfhorst, G. & Lang, W., 2015. Energy Analysis of the built Environment—A Review and Outlook. *Renewable and Sustainable Energy Reviews.*

Antiohos S.K., Papadakis V.G. & Tsimas, S., 2014. Rice husk ash (RHA) effectiveness in cement and concrete as a function of reactive silica and fineness. *Cement and Concrete Research.*

Aprianti, E., Shafigh, P., Bahri, S. & FarahanI, J.N., 2014. Supplementary cementitious materials origin from agricultural wastes. *Construction and Building Materials 74*, pp. 176–187.

Bie, R.S., Song, X.F., Liu, Q.Q. Ji, X.Y. & Chen, P., 2014. Studies on effects of burning conditions and rice husk ash (RHA) blending amount on the mechanical behavior of cement. *Cement & Concrete Composites 55*, pp. 162–168.

British Standard Institution, 2009. *BS EN 12350-2: 2009 Testing fresh concrete Part 2: Slump-test*.

British Standard Institution, 2002. *BS EN 12390-3: 2002 Testing hardened concrete Part 3: Compressive strength of test specimens.*

British Standard Institution, 2004. *BS EN 12504-4: 2004 Testing concrete Part 4: Determination of ultrasonic pulse velocity*.

Bui, D.D., Hu, J. & Stroeven, P., 2005. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. *Cement and Concrete Composites*. 27(3), pp. 357–366.

Ciolacu, D., Ciolacu, F. & Popa, V.I., 2010. Amorphous cellulose – structure and characterization. *Cellulose Chemistry and Technology.*

Della, V.P., Kuhn, I. & Hotza, D., 2002. Rice husk ash as an alternate source for active silica production. *Materials Letters 57*, pp. *818–821.*

Gambhir, M.L., 2013. Concrete Technology Fifth Edition. Published by McGraw Hill Education (India) Private Limited, P-24, Green Park Extention, New Delhi 110 016.

Ganesan, K., Rajagopal, K. & Thangavel, K., 2007. Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete. *Construction and Building Materials.*

Givi, A.N., Rashid, S.A., Aziz, F.N.A. & Salleh, M.A.M., 2010. Contribution of Rice Husk Ash to the Properties of Mortar and Concrete. *Journal of American Science.*

Global Construction Perspectives, 2015.*Company PDF Report*. [Online] Available at: http://www.globalconstruction2025.com/uk/company-pdf-report.html [Accessed 25 March 2015].

Guneyisia, E., Ozturanb, T. & Gesoglu, M., 2007. Effect of initial curing on chloride ingress and corrosion resistance characteristics of concretes made with plain and blended cements. *Building and Environment*. 42(7), pp. 2676–2685.

Food and Agriculture Organization of the United Nations (FAO), 2015. *FAO statistics division, Crops production of Malaysia.* [Online] Available at: http://faostat3.fao.org/download/Q/QC/E [Accessed 19 March 2015].

Habeeb, G.A. & Mahmud, B.H., 2010. Study on properties of rice husk ash and its use as cement replacement material. *Material Research*, 13(2).

Hamid, R., Ibrahim, N. & Jamadin, A., 2013. Influence of grinding or rice husk ash to the workability and strength of concrete. *International Refereed Journal of Engineering and Science (IRJES)*, 2(2), pp. 50-54.

Hesami, S., Ahmadi, S. & Nematzadeh, M., 2013. Effects of rice husk ash and fiber on mechanical properties of pervious concrete pavement. *Construction and Building Materials 53*, pp. 680-691.

Hunt, K., 2000. NEW "HERITAGE MATERIALS". *MATERIAL EVIDENCE Conserving historic building fabric.*

Hwang, C.L., Bui, L.A. & Chen, C.T., 2011. Effects of rice husk ash on the strength and durability characteristics of concrete. *Construction and Building Materials*, 25, pp. 3768-3772.

Isaia, G.C., Gastaldini, A.L.G. & Moraes, R., 2003. Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete. *Cement and Concrete Composites*, 25(1), pp. 69–76.

Jamil, M., Kaish, A.B.M.A., Rahman, S.N. & Zain, M.F.M., 2013. Pozzolanic contribution of rice husk ash in cementitious system. *Construction and Building Materials.*

Karim, M.R., Zain, M.F.M., Jamil, M., Lai, F.C. & Islam, M.N., 2012. Strength of Mortar and Concrete as Influenced by Rice Husk Ash. *World Applied Sciences Journal*, 19 (10).

Kartini, K., 2011. RICE HUSK ASH – POZZOLANIC MATERIAL FOR SUSTAINABILITY. *International Journal of Applied Science and Technology*, 1(6).

Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A.N. & Mirza, J., 2011. Reduction in environmental problems using rice-husk ash in concrete. *Construction and Building Materials.* ISSN 0950-0618. Elsevier Science.

Kozul, R. & Darwin, D., 1997. Effects of Aggregate Type, Size, and Content on Concrete Strength and Fracture. *THE NATIONAL SCIENCE FOUNDATION Research Grants No. MSS-9021066 and CMS-9402563.*

Kulkarni, M.S., Mirgal, P.G. Bodhale, P.P. & Tande, S.N., 2014. Effect of Rice Husk Ash on Properties of Concrete. *Journal of Civil Engineering and Environmental Technology*.

Li, X.G., Yang, L.V., Ma, B.G., Chen, Q.B., Yin, X.B. & Jian, S.W., 2014. Utilization of Municipal Solid Waste Incineration Bottom Ash in Blended Cement. *Journal of Cleaner Production*.

Maduwar, M.V., Ralegaonkar, R.V. & Mandavgane, S.A., 2012. Application of agro-waste for sustainable construction materials: A review. *Construction and Building Materials,* 38, pp. 872-878.

Narayanan, S.P., Kalaikumar, V., Yusoff, M.F., Anwar, A., Haron, M.F. & Alias, M.N., 2014. Properties of Rice Husk Ash (RHA and MIRHA) Mortars. *Research Journal of Applied Sciences, Engineering and Technology*, 7(18), pp. 3872-3882.

Neville, A.M., 1995. Properties of Concrete, Edition 4. Longman

Onojah, A.D., Agbendeh, N.A. & Mbakaan, C., 2013. RICE HUSK ASH REFRACTORY: THE TEMPERATURE DEPENDENT CRYSTALLINE PHASE ASPECTS. *IJRRAS*, 15 (2).

Papadakis, V.G. & Tsimas, S., 2002. Supplementary cementing materials in concrete: Part I: efficiency and design. *Cement and Concrete Research*, 32(10), pp. 1525-1532.

Ramadhansyah, P.J., Bakar, B.H.A., Azmi, M.J.M. & Ibrahim, M.H.W., 2011. The mechanical properties of normal concrete grade 40 containing rice husk ash at different grinding times. *International Journal of Technology*, 1, pp. 10-19, ISSN 2086-9614.

Ramezanianpour, A.A., Khani, M.M. & Ahmadibeni, G., 2009. The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes. *International Journal of Civil Engineerng*, 7(2).

Ramezanianpour, A. B., 2014. Cement Replacement Materials: Properties, Durability, Sustainability. ISSN 2194-3176 Springer Heidelberg New York Dordrecht London.

Shatat, M.R., 2013. Hydration behaviour and mechanical properties of blended cement containing various amount of rice husk ash in presence of metakaolin. *Arabian Journal of Chemistry*.

Shivaram, M.S., 2014. Measures to Contain Pollution Caused Due to Cement Productions:-A review. *International Journal of Emerging Technology and Advanced Engineering*, 4(11).

Sumadi, S. & Lee, Y.L., 2008. Development of Blended Cements for Water Proofing Application. *Jabatan Struktur dan Bahan Fakulti Kejuruteraan Awam Universiti Teknologi Malaysia.*

Tashima, M.M., Silva, C.A.R., Akasaki, J.L. & Barbosa, M.B., 2004. The possibility of Adding the Rice Husk Ash (RHA) to the Concrete. In the Proceedings of the 2004 International RILEM Conference on the Use of Recycled Materials in building and Structures. pp. 778 – 786.

The World Bank, 2015. *CO2 emission (kt).* [Online] Available at http://data.worldbank.org/indicator/EN.ATM.CO2E.KT/countries/all?display=graph [Accessed 23 March 2015].

United Nations Population Division, 2015. *World Population Prospects, the 2015 Revision*. [Online] Available at: http://esa.un.org/unpd/wpp/DVD/ [Accesed 23 March 2015].

U.S. Geological Survey, 2015. *Minerals Information.* [Online] Available at: http://minerals.usgs.gov/minerals/pubs/commodity/cement/ [Accessed 26 March 2015].

Van, V.T.A., Christiane, R., Bui, D.D. & Ludwig, H.M., 2014. Pozzolanic reactivity of mesoporous amorphous rice husk ash in portlandite solution. *Construction and Building Materials.*

Xiong, L.M., Sekiya, E.H., Sujaridworakun, P., Wada, S. & Saito, K., 2009. Burning Temperature Dependence of Rice Husk Ashes in Structure and Property. *Journal of Metals, Materials, and Minerals*, 19(2), pp. 95-99.

Xu, W., Tommy, Y.L. & Shazim, A.M., 2011. Microstructure and reactivity of rich husk ash. *Construction and Building Materials.*

Yuzer, N., Cinar, Z., Akoz, F., Biricik, H., Gurkan, Y.Y., Kabay, N. & Kizilkanat, A.B., 2013. Influence of raw rice husk addition on structure and properties of concrete. *Construction and Building Materials.*

Zain, M.F.M., Islam, M.N., Mahmud, F. & Jamil, M., 2010. Production of rice husk ash for use in concrete as a supplementary cementitious material. *Construction and Building Materials.*

Zerbino, R., Giaccio, G. & Marfil, S., 2014. Evaluation of Alkali–Silica Reaction in Concretes with Natural Rice Husk Ash Using Optical Microscopy. *Construction and Building Materials.*

APPENDIX

Material Safety Data Sheet of PYE Kwiset

MATERIAL SAFETY DATA SHEET		MSDS No: 8001
PYE KWISET	Date of Issue : January 2008 Version No. 3	PAGE: 1 of 5

PYE Products (M) Sdn Bhd (206933-D)	**Address:** Lot 4993, $5^{1/2}$ Mile, Jalan Meru, 41050 Klang **Tel: (603)- 3392 104, 3392 8112** **Fax: (603) – 3392 8087** **Email:** enquiry@pyeproducts.com **Website:** www.pyeproducts.com

1. PRODUCT IDENTIFICATION

Product Name:	**PYE KWISET**
Other Names:	Plasticising Accelerator
Manufacturer's Product Code:	**BUKW**
Use:	To speed up setting time and increase early strength
UN Number:	Not Applicable
Dangerous Goods Class And Subsidiary Risk:	Not Applicable
Hazchem Code:	Not Applicable
Poison Schedule No:	Not Scheduled

2. PHYSICAL AND CHEMICAL PROPERTIES

Appearance :	Liquid
Colour:	Dark brown
Odour/Taste:	Sweet smell
Solubility (H2O):	Soluble
Density/Specific Gravity:	1.30g/ml
Viscosity	Not determined
Boiling Point	Not applicable
Particle Size	Not determined
pH	Not determined
Vapor Density (Air = 1)	Not applicable
Shelf Life	Min 12 months
Vapor Pressure (Mm-Hg)	Not applicable
Melting Point	Not applicable
Evaporation Rate (Butyl Acetate = 1)	Not applicable

MATERIAL SAFETY DATA SHEET		MSDS No: 8001
PYE KWISET	Date of Issue : January 2008 Version No. 3	PAGE: 2 of 5

3. COMPOSITION / INFORMATION ON INGREDIENTS

COMPONENTS	CAS NUMBER	PROPOTIONS
Water	NA	NA
Additives	NA	NA

4. STABILITY AND REACTIVITY

Stability: Stable

Incompatibility: Incompatible with oxidizing agents.

Hazardous Combustion & Decomposition Products: When water evaporates, it produce carbon dioxide.

5. HAZARDS IDENTIFICATION

POISONS SCHEDULE: None

RISK: None under normal conditions.

6. TOXICOLOGY INFORMATION

Acute Effects Of Overexposure:

Swallowing: None currently known

Skin Absorption: None currently known

Inhalation: None currently known

Skin Contact: None currently known

Eye Contact: None currently known

Chronic Effects Of Overexposure: None currently known

Other Health Hazards: None currently known

MATERIAL SAFETY DATA SHEET		MSDS No: 8001
PYE KWISET	Date of Issue : January 2008 Version No. 3	PAGE: 3 of 5

7. ECOLOGY INFORMATION

Environmental Toxicity: Not determined.

Ecotoxicity Value: Not determined.

8. FIRE AND EXPLOSION HAZARD DATA

General Fire Hazards: Combustible liquid. On burning may emit toxic fume.

Flash Point: Not Determined

Extinguishing Media: Water fog, (or if unavailable fine water spray), foam, dry agent(CO_2, dry chemical powder.

Special Fire Fighting Procedure: Wear appropriate personal protective equipment.

9. FIRST AID MEASURES

Skin: In case of irritation wash with large amounts of water; use soap if available. If irritation persists, seek medical attention.

Eyes: Flush eyes with large amounts of water for 15 minutes or until irritation subside. If irritation persists, get medical attention.

Inhaled: Go to open area with fresh air until coughing and other symptoms subside. Seek medical attention if discomfort persists.

Swallowed: Wash mouth with plenty of water. Drink large amounts of water if ingestion has occurred.

10. EXPOSURE CONTROLS AND PERSONAL PROTECTION

PROTECTIVE CLOTHING & EYE PROTECTION: Safety goggles and protective gloves.

RESPIRATORY PROTECTION: Wear a fine particle mask at normal conditions.

VENTILATION: General (mechanical) room ventilation is expected to be satisfactory.

OTHER PROTECTION: Eye bath.

11. ACCIDENTAL RELEASE MEASURES

Personal Precautions:	Wear sufficient protective equipment. Isolate spill area, preventing entry by unauthorized persons.
Environmental Precautions:	Minimize entry of material into drainage systems.
Methods For Containment:	Contain spill immediately.
Methods For Clean-Up:	Flush area of spill with water to remove final traces. Bury in suitable landfill where permitted under appropriate government regulations

12. DISPOSAL CONSIDERATIONS

DISPOSAL METHODS: Bury in suitable landfill where permitted or other appropriate guidelines issued under government regulations.

13. HANDLING AND STORAGE

Handling: Keep containers closed when not in use. Wash after handling. Do not eat or drink while handling.

Storage: Store in dry area. Reseal container after use.

14. TRANSPORT INFORMATION

International (Land, Air, Sea)
Domestic (Land, Air, Sea)
Proper Shipping Name: PYE KWISET

Information Reported For Product/Packing: 1 Lit, 4 Lit, 20 Lit, & 210 Lit

15. REGULATORY INFORMATION

Safety Phrases: In case of eye contact, rinse immediately with plenty of water. Wear suitable protective clothing, gloves & eye/face protection

16. OTHER INFORMATION

PYE PRODUCTS makes no representatives or warranties, either express or implied, including without limitation any warrant of merchantability, fitness for a particular purpose with respect to the . Information set forth herein or the product to which the Information refers accordingly, PYE PRODUCTS (M) SDN BHD will not be responsible for damages resulting from use of or reliance upon this information.