Effects of Mix Composition on Rice Husk Ash (RHA) Mortar

by

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

(NARAYANAN SAMBU POTTY)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MOHD FARID BIN HARON)

ABSTRACT

The research is done to investigate the effects of mix composition on Rice Husk Ash (RHA) mortar. The properties of RHA mortar are analyzed by varying the mixture compositions which are water-cement ratio (w/c) of 0.60 and 0.65, binder to sand ratio of 1:3 and 1:4, and varied RHA replacement (5%, 10%, 15%, 20%, 25% & 30%). This experimental research is intended to further analyze the results that have been found out by previous researcher which used the same methodology but with w/c of 0.50 and 0.55. The use of waste materials from paddy industry which is RHA saves the environment from the dumping activity of RHA which polluted our Mother Nature. It also reduces the content of cement in mortar or concrete mixtures and thus, helps save the environment by lessening the cement production. RHA was obtained from uncontrolled combustion of rice husks at BERNAS's factory at Sungai Ranggam, Perak and grinded using Los Angeles Abrasion Machine. RHA that is used in this research has coarser grain size than cement and finer than sand. The properties of RHA mortar with different composition are analyzed by conducting three tests. The compressive strength test is conducted at 7, 28 and 60 days of curing period. The initial rate of suction (IRS) test and water absorption test are conducted after 60 days of curing. The results show that the addition of RHA at 5% with 0.65 w/c and 1:4 binder to sand ratio resulted in highest compressive strength than respective control and RHA mortars. This research also found out that incorporation of RHA in the mortar with 1:3 binder to sand ratio did not give any significant contribution towards the properties of the mortar.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The world cement production is currently rising rapidly due to high demand from urbanization and development sectors. With a lot of new and ongoing implementation of infrastructure projects in Malaysia, the local cement demand is also expected to grow slightly in few years ahead. As cement is the major component in building construction especially for production of concrete and bricks, the continuous high demand of cement caused huge amount of CO_2 emission to the environment from production process and resources depletion over last decades (Rashid et al., 2010a). Due to this reason, many researchers have come up with solutions to reduce the usage of cement by replacing it with cement replacement materials that can act similarly or better than cement. A large number of researches have been done all over the world in utilizing waste materials as cement replacement material in order to meet the demand and at the same time, conserving the precious Mother Nature.

One of the most widely used cement replacement materials is Rice Husk Ash (RHA) which is a product obtained by burning the agricultural by-product, rice husks under controlled temperature and atmosphere. Rice husks are abundant and generally available at the rice mills with no cost involvement. The ash produced is usually dumped directly to the environment (Rashid et al., 2010a). Thus, in order to utilize the waste materials, researches and studies have been done throughout the years. Rukzon et al. (2006) stated that RHA is high in silica content in the form of noncrystalline or amorphous material silica and suitable to use as a pozzolanic material. The addition of RHA to Ordinary Portland Cement (OPC) improves the early strength of concrete and forms a calcium silicate hydrate gel around the cement particles which is highly dense and less porous which translate into higher strength of concrete against cracking (Abu Bakar et al., 2010).

1.2 Problem Statement

Rashid et al. (2010a) stated that the production of cement in the world has affected the environment through high emission of CO_2 from the combustion of fossil fuels and decarbonization of limestone. Moreover, the product from burning process of rice husks which is RHA has no useful application and usually dumped directly into the environment which later generates pollution and air contamination. Therefore, the use of by-products or waste materials to partially replace OPC in concrete and bricks production is highly regarded as responsibility to save the nature by reducing the pollution contributed by cement production and at the same time, solve the disposal issue of waste materials.

In addition, water-cement ratio (w/c) plays an important role in determining the three basic properties of concrete or mortar which are workability, strength, and durability. Although admixture such as RHA improves workability, compactibility, strength, impermeability, resistance to chemical attack and durability of mortar, w/c is still an important factor to be taken into account for that translates into low or high quality of mortar. Since previous research has analyzed the effects of mix composition on RHA mortars with w/c of 0.5 and 0.55 (Anwar, 2011), this project is significance to further analyze and investigate the properties of RHA mortars with mix composition of w/c (0.6 and 0.65), binder to sand ratio (1:3 and 1:4) and varied RHA replacement.

1.3 Objectives

The objective of this research is;

1. To investigate the effect of water-cement ratio, binder to sand ratio and RHA replacement on RHA mortar.

1.4 Scope of Study

For this particular research, RHA is taken from BERNAS Sungai Ranggam, Perak and it will be first prepared in UTP's Highway Engineering laboratory by grounding the sources using Los Angeles Abrasion machine. Once all materials are available and ready to be used, RHA mortar mixture samples will be produced in accordance to BS 1881: Testing Fresh Concrete. Variable aspects for this research have been determined which include;

1. Binder to sand ratio of 1:3 and 1:4.
2. Water-cement ratio of 0.6 and 0.65.
3. Varied RHA replacement of 5%, 10%, 15%, 20%, 25% and 30%.

All samples are cured using water and tested at the age of 7, 28 and 60 days. The tests to be conducted are as follows;

1. Compressive strength test
2. Initial Rate of Suction (IRS) test
3. Water absorption test

1.5 Relevancy & Feasibility of the Project

Few researches have been done in analyzing and investigating the effect of varied w/c on the properties of RHA mortar. This project is intended to further analyze experimentally the properties of RHA mortar with different w/c, binder to sand ratio and RHA replacement. The effects are analyzed by conducting the three tests as stated before.

The laboratory work for this particular research is expected to take around five months of duration. Once literature review and calculation for design mixes have been completed, the test samples will be prepared in UTP's Concrete Laboratory using available materials. Based on the scope of study, this research is realistic and feasible to be done completely within the allocated time frame.

CHAPTER 2

LITERATURE REVIEW

2.1 Mortar

Mortar is an essential material in building construction and becomes important components for certain structures. It is a mixture of sand (fine aggregate), a binder (lime, cement, etc) and water (Rashid et al., 2010b). The fine aggregates act as a filler and control shrinkage in mortar. Cement and lime contribute towards the durability, high strength, workability and early setting of mortar. Water on the other hands must be clean and free from acids, alkalies and organic materials.

Allen et al. (2003) in Hydraulic Lime Mortar for Stone, Brick and Block Masonry listed the primary functions of hardened mortar in a construction as follows;

1. To provide an even bed so that the load on the wall is distributed evenly over the whole bearing area of the masonry units;
2. To bond the units together and help them resist lateral forces, and
3. To seal the joints against the penetration of rain.

In addition, Allen et al. (2003) also stated the properties of mortar to achieve the required functions which are shown below;

1. Readily workable to allow the mason to produce satisfactory work at an economic rate;
2. Sufficiently resilient when hardened to accommodate minor structural movement, shrinkage or expansion of the construction;
3. No stronger than the unit masonry to be bonded;
4. Durable to suit the purpose of the element of the construction, and
5. Aesthetically pleasing in appearance, designed to avoid discord and lack of harmony with the wall finish.

2.2 Rice Husk Ash

Rice Trade produced the analysis of countries with highest rice production worldwide. The analysis on world rice production in 2009-2010 listed below countries as top ten rice producer with the amount of rice production.

Table 2.1: World Rice Production 2009-2010 (United States Department of Agriculture, Foreign Agricultural Service)

Country	Rice Production (Metric Tons)
China	166,417,000
India	132,013,000
Indonesia	52,078,832
Bangladesh	38,060,000
Vietnam	34,518,600
Thailand	27,000,000
Myanmar	24,640,000
Philippines	14,031,000
Brazil	10,198,900
Japan	9,740,000

The world rice production is estimated approximately about 600 million tons per year. On average 20% of the rice paddy is husk which contributes towards 120 million tons of waste material (Nuruddin et al., 2008). Rice husk has a high concentration of silica of about 80-85% as rice plants absorb silica from the soil and accumulate it into their structures (Rashid et al., 2010c). Rice husk has no useful application before and often burned in uncontrolled manner or dumped directly to the environment (Rashid et al., 2010a; Rashid et al., 2010c). This activity causes pollution and contamination which resulting in the depletion of ozone layer and damage to the land and surrounding (Nuruddin et al., 2008).

Thus, a large number of researches have been done to utilize this waste material of agricultural by-product which is RHA as cement replacement material. RHA, the material produced by burning the rice husks, is whitish or gray in color (Safiuddin et al., 2008). It consists of non-crystalline silicon dioxide with high specific surface area and high pozzolanic reactivity (Tashima et al., 2004; Naji Givi et al., 2010). RHA possesses excellent pozzolanic reactivity due to high silica content, reportedly about 90% to 95% amorphous silica which is greatly beneficial to be used as cement replacement material (Mehta, 1992; Safiuddin et al., 2008).

Mehta (2002) found out that most particles of RHA are in the size range of 4 to 75 μm. He also found that the median particle diameter is larger than that of silica fume which ranges from 6 to 38 μm. However, RHA has an extremely high specific surface area as its particles are porous and possess a honeycomb microstructure (Zhang et al., 1996; Safiuddin et al., 2008). After proper burning process and duration of rice husks, the silica content (SiO_2) of RHA is more than 80% - 85% and similar to that of silica fume (Mehta, 1992; Zhang et al., 1996). Mehta (2002) listed the typical chemical composition of RHA as follows;

Table 2.2: Typical Chemical Composition of RHA (Mehta, 2002)

Component	**Mass content (%)**
Silicon dioxide (SiO_2)	94.37
Aluminum oxide (Al_2O_3)	0.06
Ferric oxide (Fe_2O_3)	0.04
Calcium oxide (CaO)	0.48
Magnesium oxide (MgO)	0.13
Sodium oxide (Na_2O)	0.08
Potassium oxide (K_2O)	1.97
Phosphorus oxide (P_2O_5)	1.19
Titanium oxide (TiO_2)	0.02
Sulfur trioxide (SO_3)	0.01
Igneous loss	1.18

2.3 Pozzolanic Reaction

Papadakis et al. (2002) found out that a pozzolanic reaction occurs when a siliceous or aluminous material get in touch with calcium hydroxide in the presence of humidity to form compounds exhibiting cementitious properties. Within the hydration of two main components of cement namely tricalcium silicate (C_3S) and dicalcium silicate (C_2S) (C and S represent CaO and SiO_2) during the cement hydration development, the calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$ or CH) are released (Naji Givi et al., 2010). When pozzolanic material is added into mortar or concrete mix, the pozzolanic reaction will only start when CH is released and pozzolan/CH interaction exist. As one of the pozzolan material, RHA actively reacts with $Ca(OH)_2$ in the presence of water during cement hydration and produces additional calcium silicate hydrate (secondary CSH). The hydration and pozzolanic reaction are shown below.

Hydration reaction: C_2S or $C_3S + H_2O \rightarrow$ primary CSH + $Ca(OH)_2$

Pozzolanic reaction: $Ca(OH)_2$ + RHA (SiO2) + $H_2O \rightarrow$ secondary CSH

The crystallized compound of CSH which are called cement gel, formed a continuous binding matrix with a large surface of area when they are hardening over time. They are responsible for the development of strength in the cement paste (Kassim et al., 2004). The pozzolanic reaction decreases the formed CH to produce more CSH gel which later on translates to stronger and more durable concrete by reducing the pore size and blocks the capillary (Naji Givi et al., 2010). Figure 2.1 shows the pozzolanic effect of RHA that causes the occurrence of pore refinement which improves the interfacial bond between aggregates and binder paste (Safiuddin, 2008).

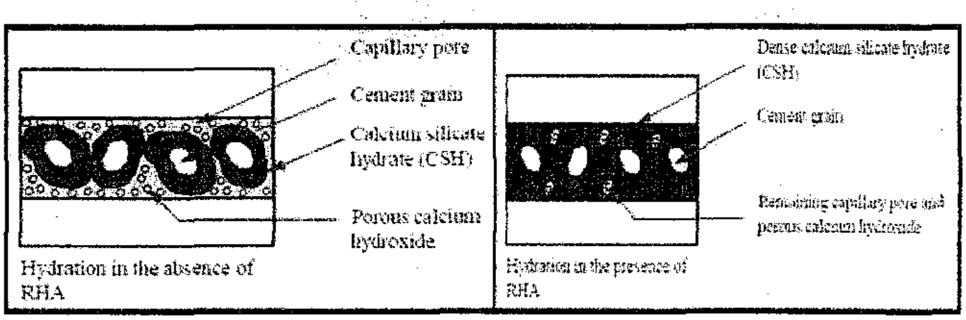


Figure 2.1: Pozzolanic Effect of RHA (Safiuddin, 2008)

2.4 Water Demand

The incorporation of RHA in OPC concrete results in the increment of water demand during its fresh state due to high specific surface of RHA (Malhotra, 1993).

Rashid et al. (2010a) have found out the water demand for mixtures containing different level of OPC replacement by RHA with fixed water cement ratio. The water cement ratio was fixed by flow table test and confirming a flow value of 110 ± 5mm in 25 drops. They observed the water demand from the result of flow table test. The water demand is increasing when RHA addition is increasing due to high fineness and porous surface of RHA. This finding supports the previous study done by Sumrerng et al. (2009) and Rukzon et al. (2006). Figure 2.2 shows the variation of water demand for RHA addition.

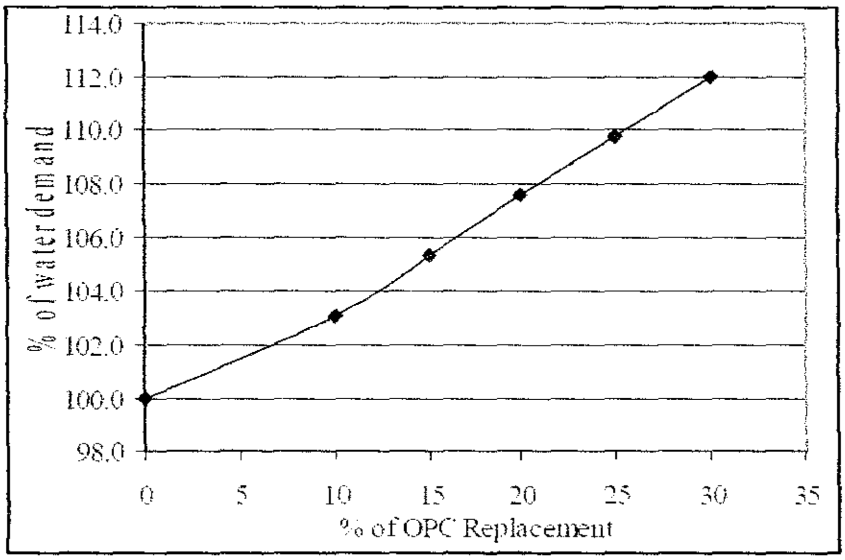


Figure 2.2: Variation of Water Demand for RHA Addition (Rashid et al., 2010a)

2.5 Compressive Strength, Water Absorption & Porosity

The strength of mortar depends on many variables including its constituents, additional pozzolan, the proportions, the water content, its age and the temperature and relative humidity at which it has matured (Allen, 2003).

Abdelalim et al. (2002) investigated the mechanical properties of the cementitious materials containing RHA. Various 0.5 w/c OPC mortar mixes containing different contents of RHA (0%, 5%, 20%, 15%, 20%, 25% and 35%) were prepared in cubical specimens for compressive strength test after 56 days of curing. The study showed that compressive strength of OPC mortar increases with increasing the amount of OPC replacement level by RHA till a certain optimum content of RHA which is 25% in this case. The compressive strength decreases afterwards with increasing RHA content. These findings further support the research conducted by Zhang et al. (1996). Figure 2.3 shows the compressive strength of mortar after 56 days of curing period.

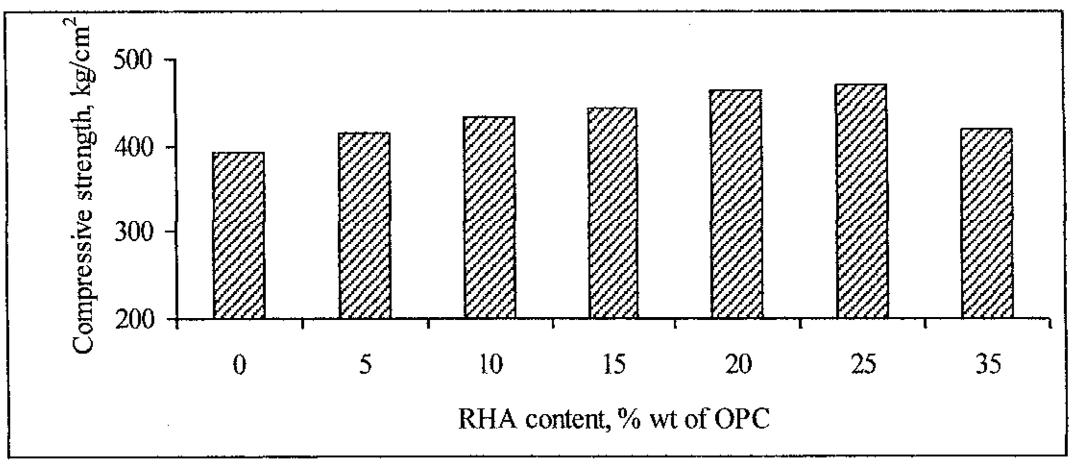


Figure 2.3: Compressive Strength of Various RHA Content after 56 Days Curing Period (Abdelalim et al., 2002)

RHA mortar tends to achieve higher compressive strength and decrease of permeability due to the reduction of porosity, calcium hydroxide content and width of the interfacial zone between the paste and the aggregate (Zhang et al., 1996).

In recent study, Anwar (2011) has conducted an experimental study to investigate the effects of mix composition on RHA mortars. Different variables were used for RHA mortars which include w/c of 0.5 and 0.55, binder to sand ratio of 1:3 and 1:4, and varied RHA replacement (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40% and 45%). The experimental study was done by casting 50mm cubical specimens from each mix for compressive strength tests after 7, 28 and 60 days of water curing. IRS and water absorption tests were done after 60 days of water curing.

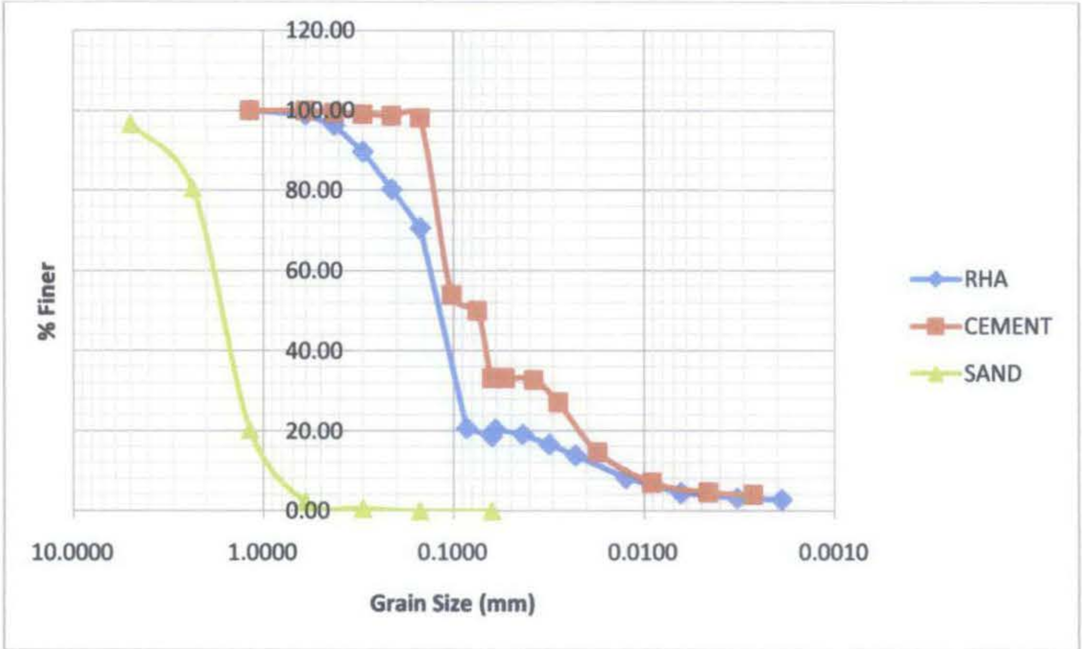


Figure 2.4: Particle Size Distribution of RHA, Cement and Sand (Anwar, 2011)

Figure 2.4 shows the particle size distribution of materials that were used in the research. Cement is the finest material among all constituents of the mixture. RHA, on the other hands, is having coarser grain size but it is really close to cement. Sand is the coarsest material that is used in the experiment research.

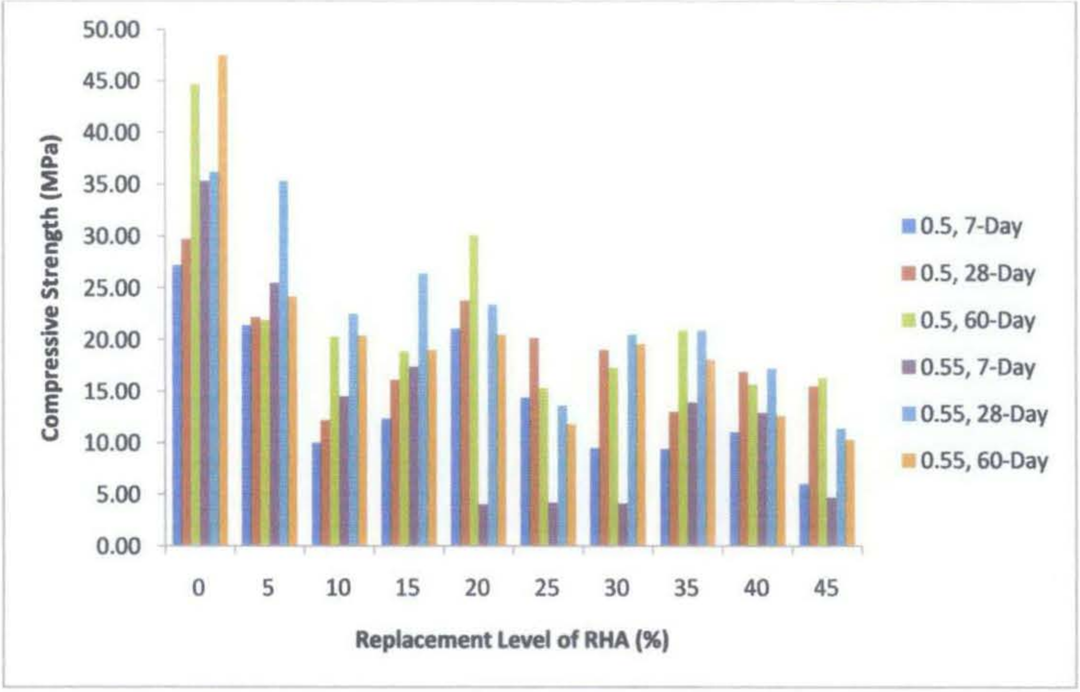


Figure 2.5: Compressive Strength Variation for 1:3 Binder to Sand Ratio Mortars of Different W/C at Different Days of Water Curing (Anwar, 2011)

Based on the experimental research, 1:3 binder to sand ratio RHA mortars have lower compressive strength than control mortar as shown in Figure 2.5. The replacement of OPC by RHA does not contribute towards the compressive strength of the mortars. However, for RHA mortar with w/c of 0.55, the compressive strength at 5% RHA replacement is higher than other percentage of RHA replacement. On the other hands, RHA mortar with w/c of 0.5 shows the higher compressive strength at 20% RHA replacement compared to other percentage of replacement.

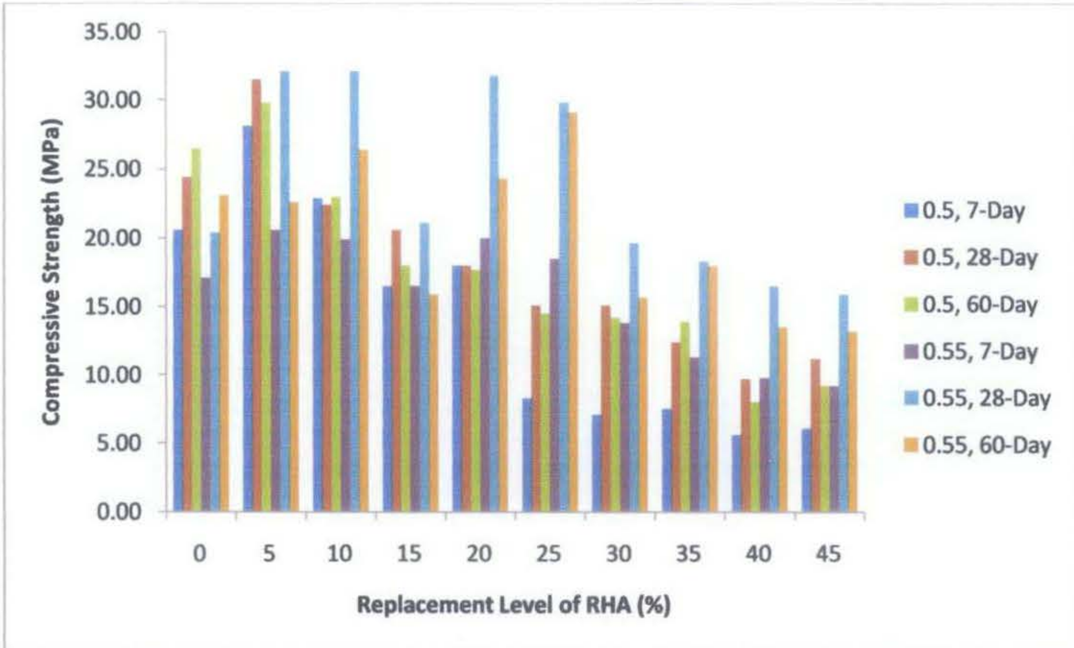


Figure 2.6: Compressive Strength Variation for 1:4 Binder to Sand Ratio Mortars of Different W/C at Different Days of Water Curing (Anwar, 2011)

The incorporation of RHA in 1:4 binder to sand ratio mortars resulted in higher compressive strength than control mortar. Anwar (2011) found that at 5% RHA replacement, 0.5 w/c RHA mortar has higher compressive strength than control mortar and it has the highest compressive strength compared to the other 0.5 w/c RHA mortars. As shown in Figure 2.6, the compressive strength for 0.5 w/c RHA mortars is decreasing after 5% RHA replacement. On the other hands, 0.55 w/c RHA mortar with 20% RHA replacement has the highest compressive strength compared to control mortar and other 0.55 w/c RHA mortars.

A lot of studies have identified that incorporation of pozzolan such as fly ash and RHA in mortar mixtures reduces the average pore size and cause an extensive pore refinement in the matrix and in the interface layer (Chindraprasirt et al.; 2005; Rodriguez et al., 2006). The water permeability of hardened mortar reduces throughout the hydration progress (Naji Givi et al., 2010). Saraswathy et al. (2007) reported that the coefficient of water absorption of RHA concrete at all levels was less than control concrete due to the microfilling and pozzolanic effect of RHA in cement mixtures (Safiuddin et al, 2008).

Anwar (2011) found out that 0.55 w/c RHA mortars have lower IRS and water absorption value compared to 0.5 w/c RHA mortars for both binder to sand ratio of 1:3 and 1:4. He also stated that the water absorption increases as the RHA replacement increases might be due to amorphous form of silica in RHA which requires more water to complete hydration process with cement and sand to form C-S-H bond (Alireza, 2010). The results of his findings are shown in Figure 2.7 and 2.8.

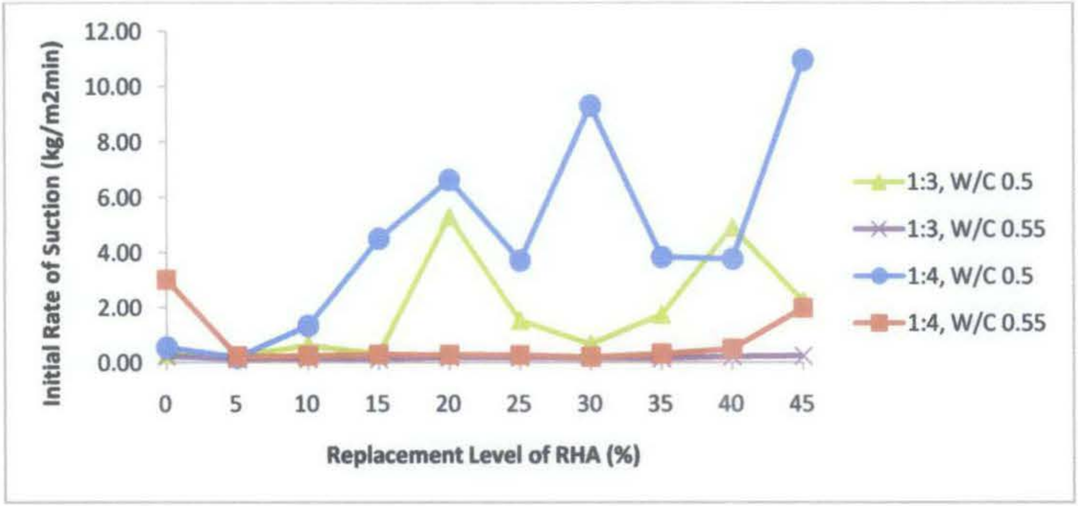


Figure 2.7: IRS Variation for Different Binder to Sand Ratio Mortars of Different W/C (Anwar, 2011)

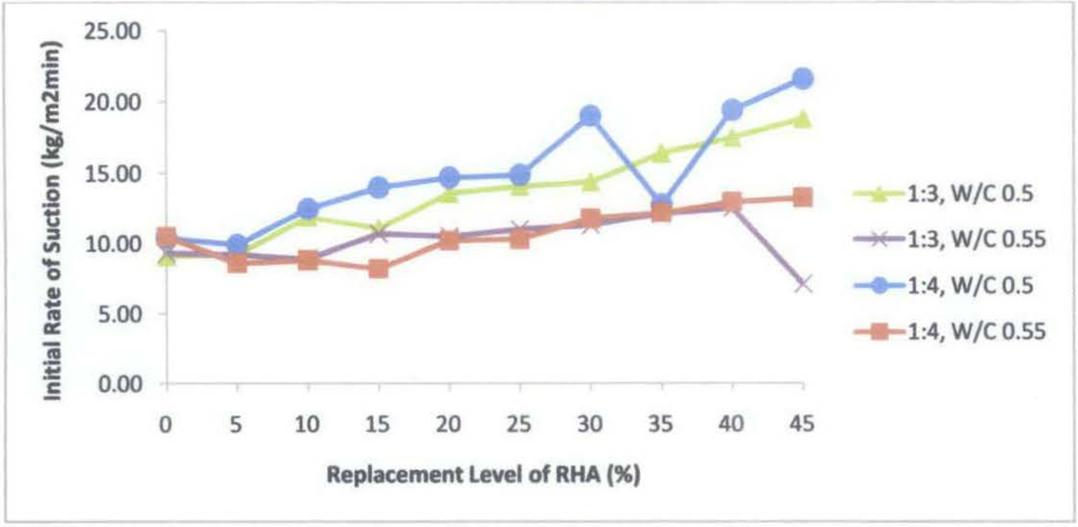


Figure 2.8: Water Absorption Variation for Different Binder to Sand Ratio Mortars of Different W/C (Anwar, 2011)

The experimental research that has been done before has analyzed the effects of mix composition on RHA mortars with w/c of 0.5 and 0.55. Thus, in order to further analyze the effects of mix composition on RHA mortars, this research will further analyze the properties of RHA mortars with water-cement ratio of 0.6 and 0.65. The analysis will be done by comparing the findings with previous results.

CHAPTER 3

METHODOLOGY

3.1 Project Activities

3.1.1 Literature Review/ Data Collection

The review of previous literature and researches of this topic is done to further understand the related knowledge and also to seek for recent founding. This is important in order to collect as much information as possible before proceed with laboratory work.

3.1.2 Laboratory Work

During the review of literature and data, laboratory work can be done. The preparation of the materials must be performed prior to the laboratory work so that the flow is going as per plan.

3.1.3 Analysis of Results

The results for every test performed during laboratory work will be gathered for analysis purposes. The effect of water-cement ratio on RHA mortar can be found through this analysis.

3.1.4 Final Report

Final report is completed based on the analysis and results that have been carried out throughout the duration of the research.

3.2 Research Methodology

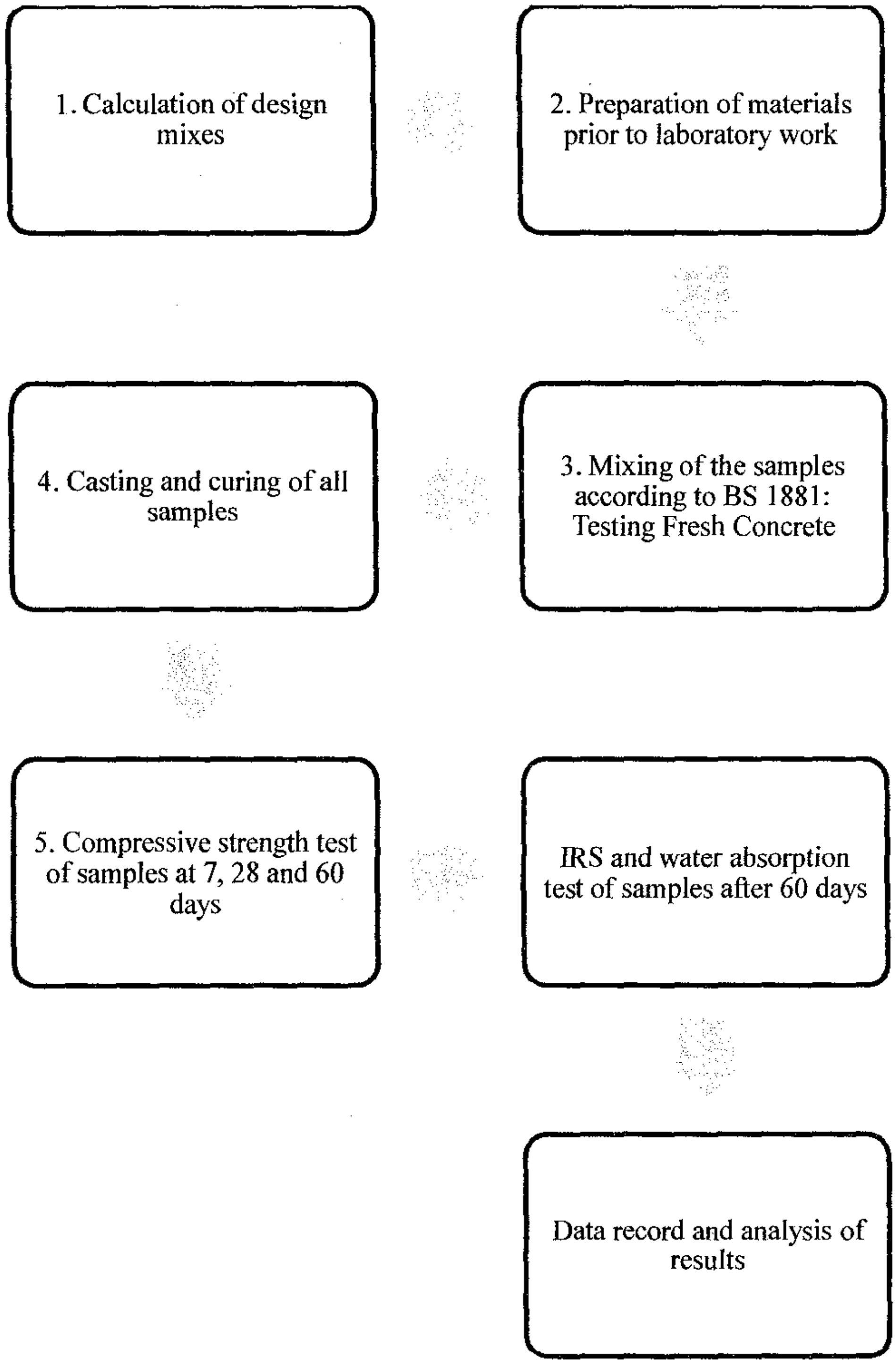


Figure 3.1: Flow Chart of Experimental Work

3.2.1 Calculation of Design Mixes

Various variables have been determined for this particular experimental research. With difference in binder to sand ratio, water-cement ratio and replacement level of OPC by RHA, the total of 28 different mixtures will be prepared for analysis purposes. After calculation of all mixtures has been done, the proportion for the design mixes is shown in Table 3.1 to Table 3.4.

Table 3.1: Mix Proportion for Cement:Sand=1:3 and W/C=0.60

Mix ID	**% RHA**	**RHA, kg**	**Cement, kg**	**Sand, kg**	**Water, kg**	**Total Mass, kg**
360-R0	0	0	0.978	2.935	0.587	4.5
360-R5	5	0.049	0.929	2.935	0.587	4.5
360-R10	10	0.098	0.880	2.935	0.587	4.5
360-R15	15	0.147	0.832	2.935	0.587	4.5
360-R20	20	0.196	0.783	2.935	0.587	4.5
360-R25	25	0.245	0.734	2.935	0.587	4.5
360-R30	30	0.293	0.685	2.935	0.587	4.5

Table 3.2: Mix Proportion for Cement:Sand=1:4 and W/C=0.60

Mix ID	**% RHA**	**RHA, kg**	**Cement, kg**	**Sand, kg**	**Water, kg**	**Total Mass, kg**
460-R0	0	0	0.804	3.214	0.482	4.5
460-R5	5	0.040	0.763	3.214	0.482	4.5
460-R10	10	0.080	0.723	3.214	0.482	4.5
460-R15	15	0.121	0.683	3.214	0.482	4.5
460-R20	20	0.161	0.643	3.214	0.482	4.5
460-R25	25	0.201	0.603	3.214	0.482	4.5
460-R30	30	0.241	0.563	3.214	0.482	4.5

Table 3.3: Mix Proportion for Cement:Sand=1:3 and W/C=0.65

Mix ID	% RHA	RHA, kg	Cement, kg	Sand, kg	Water, kg	Total Mass, kg
365-R0	0	0	0.968	2.903	0.629	4.5
365-R5	5	0.048	0.919	2.903	0.629	4.5
365-R10	10	0.097	0.871	2.903	0.629	4.5
365-R15	15	0.145	0.823	2.903	0.629	4.5
365-R20	20	0.194	0.774	2.903	0.629	4.5
365-R25	25	0.242	0.726	2.903	0.629	4.5
365-R30	30	0.290	0.677	2.903	0.629	4.5

Table 3.4: Mix Proportion for Cement:Sand=1:4 and W/C=0.65

Mix ID	% RHA	RHA, kg	Cement, kg	Sand, kg	Water, kg	Total Mass, kg
465-R0	0	0	0.796	3.186	0.518	4.5
465-R5	5	0.040	0.757	3.186	0.518	4.5
465-R10	10	0.080	0.717	3.186	0.518	4.5
465-R15	15	0.119	0.677	3.186	0.518	4.5
465-R20	20	0.159	0.637	3.186	0.518	4.5
465-R25	25	0.199	0.597	3.186	0.518	4.5
465-R30	30	0.239	0.558	3.186	0.518	4.5

3.2.2 Preparation of Materials Prior to Laboratory Work

Ordinary Portland Cement (OPC) Type-1 of Tasek brand will be used as a binder for mortar mixtures. According to BS EN 197-1: 2000, OPC Type-1 comprises of Portland cement and up to 5% of minor additional constituents. All samples will be mixed using only one type of cement in order to avoid inconsistency that can affect the properties of hardened mortar. This binder is provided in the UTP Concrete Laboratory. RHA is obtained from BERNAS's factory in Sungai Ranggam, Perak after the rice husks are burnt under open-burning condition and uncontrolled temperature. RHA is then grinded using Los Angeles Abrasion machine at UTP Highway Laboratory. This material must be prepared as early as possible before mixing day to avoid interruption in the planned schedule.

The fine aggregate that will be used is sand and it is also available at UTP Concrete Laboratory. The sand must be kept in the laboratory two days prior to mixing so that the sieving process can be done in an easier way. On the mixing day, the sand will be sieved to obtain the specified size of 2.36 mm and below. In addition, the water used for the mixing is the tap water and it must be clean.

3.2.3 Mixing of The Samples

Once all the materials are readily available at the UTP Concrete Laboratory, the mixing of 40 different mixtures will be done based on planned schedule. The materials must meet the requirement and standard. The procedures for mixing all the samples are stated in BS 1881: Part 125: 1986 – Methods for Mixing and Sampling Fresh Concrete and listed as follows;

1. The remaining fresh concrete from previous batch is cleaned off.
2. No free water shall remain in the mixer, but if it is too dry, the mixer must be wiped with a damp cloth.
3. The sands that have been poured into the mixer are mixed for 15 to 30 seconds.
4. In the next 15 seconds of mixing, half of the amount if water is added into the mixer.
5. After a mixing of 2 to 3 minutes, the mixtures are left covered for 5 to 15 minutes.
6. Cement and RHA are spread into the mixer in an even layer over the aggregate.
7. After restarting the mixer, the mixtures are mixed for 30 seconds.
8. After 30 seconds, the mixer is stopped and remaining material on the mixer blades must be cleaned off.
9. The remaining water is added for another 30 seconds of mixing.
10. After all materials have been added, the mixtures are mixed for at least 2 minutes but not more than 3 minutes.
11. The completed mix is mixed over the pan by using a hand tool to ensure homogeneity before sampling.

3.2.4 Casting and Curing of All Samples

After the mixing of particular design mixtures, the casting must be done immediately. 50 mm cubical mould will be used for each sample. A thin-layered of lubricant oil is applied onto the surface of the mould before the mould can be used for casting. This is important to avoid the mixtures from sticking onto the surface of the mould. In addition, this application on the mould will make the demoulding process of hardened mortar to be much easier. Once the step is done, the fresh mixtures are now poured into the 50mm cubical moulds according to needed number of samples. After 24 hours of mortar casting, the samples will be put into water curing tank for curing process according to different period and test. During cement hydration, the curing process controls the rate and extent of moisture loss from mortar. This process is also important as it is affecting the development of mortar's strength based on the duration of curing.

3.2.5 Compressive Strength Test of Samples at 7, 28 and 60 Days

At 7, 28 and 60 days of water curing, 3 samples from each mixture will be taken to measure their compressive strength using Digital Compression Testing Machine. Constant rate of load is applied on the area of samples' surface. The compressive strength for each sample is defined by the maximum load that the sample can resist before failure. The average between 3 samples is taken to increase the accuracy of data.

3.2.6 IRS and Water Absorption Test of Samples After 60 days

IRS of the samples is determined after 60 days of curing by measuring the amount of water absorbed through the bed face in 1 minute when immersed in 3 mm depth of water. According to ASTM C67-90a, the procedures are as follows;

1. The sample is dried in the oven (110 – 115°C) for not less than 24 hours.
2. The weight of the dry sample is recorded as m_1 in gm.
3. The sample is immersed in clean water at a depth of 3±1 mm for 1 min.
4. The weight of the sample is then recorded as m_2 in gm.
5. IRS is calculated as $m_1 - m_2$ in gm.

Water absorption test will also be conducted for all samples after 60 days of curing. Water absorption of a brick is defined as the weight of water in a brick expressed as a percentage of the brick's dry weight. For this research, the water absorption test will be conducted using 24-hour immersion test as specified in ASTM C67-90a. The procedures are shown below;

1. The sample is dried in the oven (110 – 115°C) for not less than 24 hours.
2. Then, it is cooled in a room temperature (24 ± 8°C) with 30 – 70% relative humidity.
3. The weight of the sample is recorded as W_d.
4. The sample is submerged in clean water at 15.5 - 30°C for 24 hours.
5. The sample is removed and wiped dry.
6. The weight of the sample is recorded as W_{sc}.
7. The absorption by immersion is calculated using the formula of $(W_{sc} - W_d)/W_d$

3.3 Gantt Chart

NO	ACTIVITIES	WEEK																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Project Topic Selection															Study Break	Final Examination		Semester Break
2	Preliminary Research Work																		
3	Submission of Extended Proposal																		
4	Laboratory Briefing																		
5	Material Preparation (RHA)																		
6	Mixing & Casting																		
7	Compressive Strength Test																		
8	Data Record & Analysis																		
9	Project/Proposal Defense																		
10	Submission of Interim Report																		

Figure 3.2: Gantt Chart for Final Year Project 1

NO	ACTIVITIES	WEEK														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Compressive Strength Test															
2	IRS & Water Absorption Test															
3	Data Record & Analysis															
4	Submission of Progress Report															
5	Pre-EDX Presentation															
6	Submission of Dissertation (Soft Bound)															
7	Submission of Technical Paper															
8	Oral Presentation															
9	Submission of Project Dissertation (Hard Bound)															

Figure 3.3: Gantt Chart for Final Year Project 2

CHAPTER 4

RESULTS & DISCUSSION

4.1 Compressive Strength

The compressive strength of mortar cubes is determined based on ASTM C109. The summarized compressive strength of mortar cubes with different proportion is shown in Table 4.1.

Table 4.1: Compressive Strength of Mixtures with Different Binder to Sand Ratio (1:3 and 1:4) and Water-Cement Ratio (0.6 and 0.65)

CEMENT: SAND	**COMPRESSIVE STRENGTH (MPa)**							
	0.6 W/C				**0.65 W/C**			
	MIX ID	**7-Day**	**28-Day**	**60-Day**	**MIX ID**	**7-Day**	**28-Day**	**60-Day**
1:3	**360-R0**	28.57	43.55	43.86	**365-R0**	26.75	43.28	47.07
	360-R5	22.25	40.85	53.56	**365-R5**	25.55	42.03	42.80
	360-R10	21.22	35.18	40.81	**365-R10**	18.65	30.28	36.15
	360-R15	13.34	21.82	25.54	**365-R15**	15.68	27.57	31.58
	360-R20	10.38	20.50	22.61	**365-R20**	13.28	24.67	27.65
	360-R25	10.38	14.11	20.54	**365-R25**	10.81	14.36	23.25
	360-R30	8.87	12.40	17.78	**365-R30**	9.85	14.16	19.90
1:4	**460-R0**	21.67	31.23	34.41	**465-R0**	19.31	28.17	34.06
	460-R5	22.17	29.86	37.88	**465-R5**	19.94	33.13	37.23
	460-R10	21.74	28.23	32.70	**465-R10**	16.88	26.94	32.00
	460-R15	9.88	14.68	16.15	**465-R15**	12.92	16.18	18.15
	460-R20	8.91	11.18	12.29	**465-R20**	8.85	13.26	13.51
	460-R25	7.14	9.24	10.76	**465-R25**	6.95	10.34	12.22
	460-R30	5.06	7.86	8.23	**465-R30**	5.45	7.58	8.65

For comparison purposes in term of water-cement ratio, the previous result from research that has been conducted before is used. The research used same methodology but the mixtures are having water-cement ratio of 0.5 and 0.55. Table 4.2 shows the compressive strength of 0.5 and 0.55 water-cement ratio mixtures that has been found by previous researcher.

Table 4.2: Compressive Strength of Mixtures with Different Binder to Sand Ratio (1:3 and 1:4) and Water-Cement Ratio (0.5 and 0.55) (Anwar, 2011)

CEMENT: SAND	**COMPRESSIVE STRENGTH (MPa)**							
	0.5 W/C				**0.55 W/C**			
	MIX ID	**7-Day**	**28-Day**	**60-Day**	**MIX ID**	**7-Day**	**28-Day**	**60-Day**
1:3	**350-R0**	27.20	29.70	44.70	**355-R0**	35.30	36.20	47.50
	350-R5	21.40	22.20	21.90	**355-R5**	25.50	35.30	24.20
	350-R10	10.00	12.20	20.30	**355-R10**	14.50	22.50	20.40
	350-R15	12.30	16.10	18.90	**355-R15**	17.40	26.40	19.00
	350-R20	21.10	23.80	30.10	**355-R20**	4.00	23.40	20.50
	350-R25	14.40	20.20	15.30	**355-R25**	4.20	13.60	11.80
	350-R30	9.50	19.00	17.30	**355-R30**	4.10	20.50	19.60
1:4	**450-R0**	20.60	24.40	26.50	**455-R0**	17.10	20.40	23.10
	450-R5	28.10	31.50	29.80	**455-R5**	20.60	32.10	22.60
	450-R10	22.90	22.40	23.00	**455-R10**	19.90	32.10	26.40
	450-R15	16.50	20.60	18.00	**455-R15**	16.50	21.10	15.90
	450-R20	18.00	18.00	17.70	**455-R20**	20.00	31.80	24.30
	450-R25	8.30	15.10	14.50	**455-R25**	18.50	29.80	29.10
	450-R30	7.10	15.10	14.20	**455-R30**	13.80	19.60	15.70

4.1.1 Compressive Strength for Mixtures with Water-Cement Ratio of 0.60 and 0.65

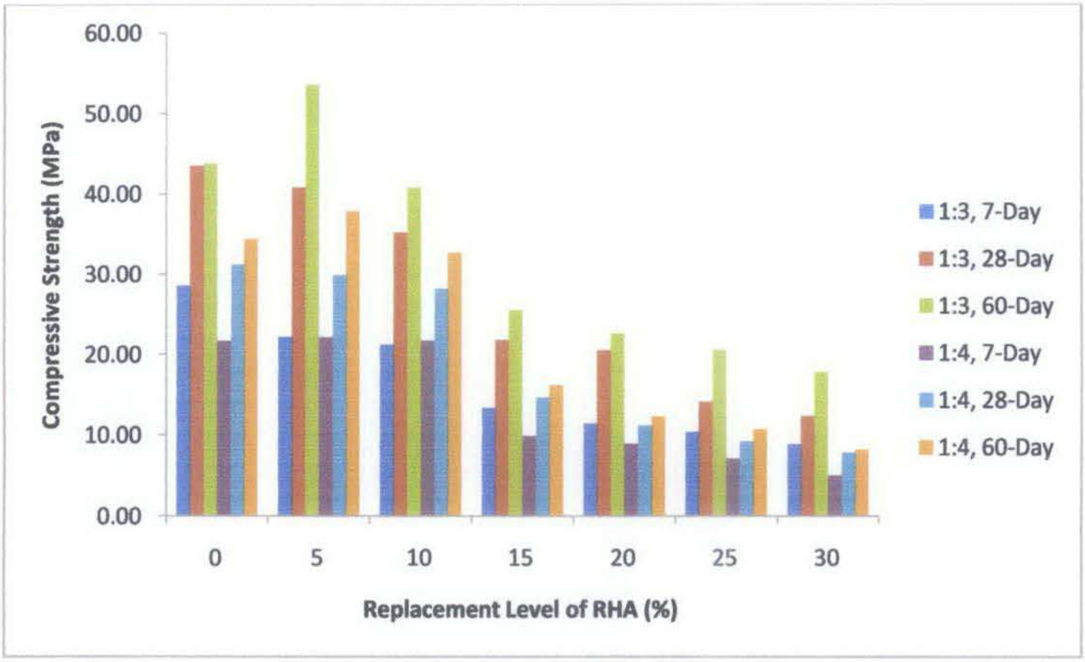


Figure 4.1: Compressive Strength Variation for 0.60 W/C Mortars of Different Binder to Sand Ratio at Different Days of Water Curing

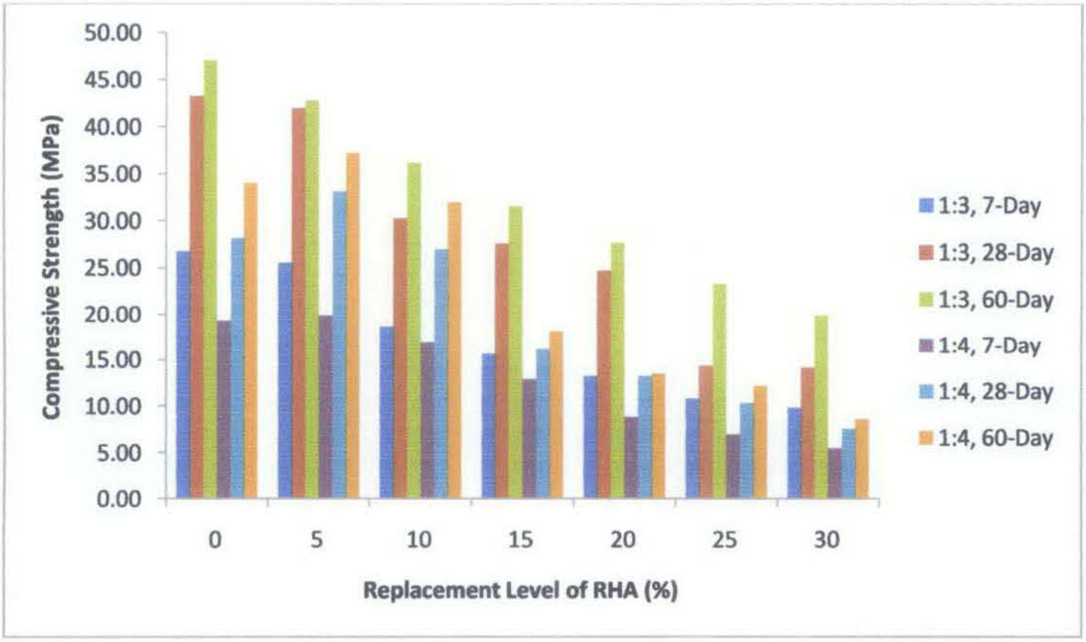


Figure 4.2: Compressive Strength Variation for 0.65 W/C Mortars of Different Binder to Sand Ratio at Different Days of Water Curing

Figure 4.1 and Figure 4.2 show the compressive strength variation for 0.6 and 0.65 w/c mortars of different binder to sand ratio at different days of water curing. As shown in the figures, the compressive strength for all RHA mortars increases as the water curing period increases. The RHA mortars hardened due to hydration process that will only occur with the presence of water and at suitable range of temperature. The hydration process of cement and RHA is the chemical reaction between grains of both cement and RHA with water to form the cement gel that can be laid down only in water-filled space. This process proceeds until all the cement and RHA reaches their maximum degree of hydration or until all the space available for the hydration product is filled by cement gel, whichever limit is reached first. In this investigation, all the samples are having proper hydration process over time as their compressive strength is increased after 7, 28 and 60-day of water curing.

It can be observed that the compressive strength of RHA mortars with 1:3 binder to sand ratio is relatively higher than 1:4 binder to sand ratio RHA mortars at all RHA replacement for both w/c of 0.6 and 0.65. This phenomenon is happened may be due to the properties of the binders which are the cement and RHA. The properties of both binders that have smaller grain sizes increase their capability to fill up the voids between the fines aggregate which is the sand and thus, increase the compressive strength.

The compressive strength for most of RHA mortars decreases as the RHA replacement increases. This happened as RHA that is used in this research have coarser grain size than cement. Therefore, the incorporation of higher percentage of RHA in the mixtures caused the mortars to contain more voids which reduce their compressive strength.

Although few RHA mortars do not have compressive strength greater than the control one, they still can be applied as construction materials according to requirements specified in the standard. For example, according to BS 6073, RHA mortars that have compressive strength greater than 8 MPa can be used as bricks. Moreover, in accordance to BS 6717, RHA mortars that have compressive strength greater than 49 MPa can be used as pavement blocks.

4.1.2 Compressive Strength for Mixtures with Binder to Sand Ratio of 1:3

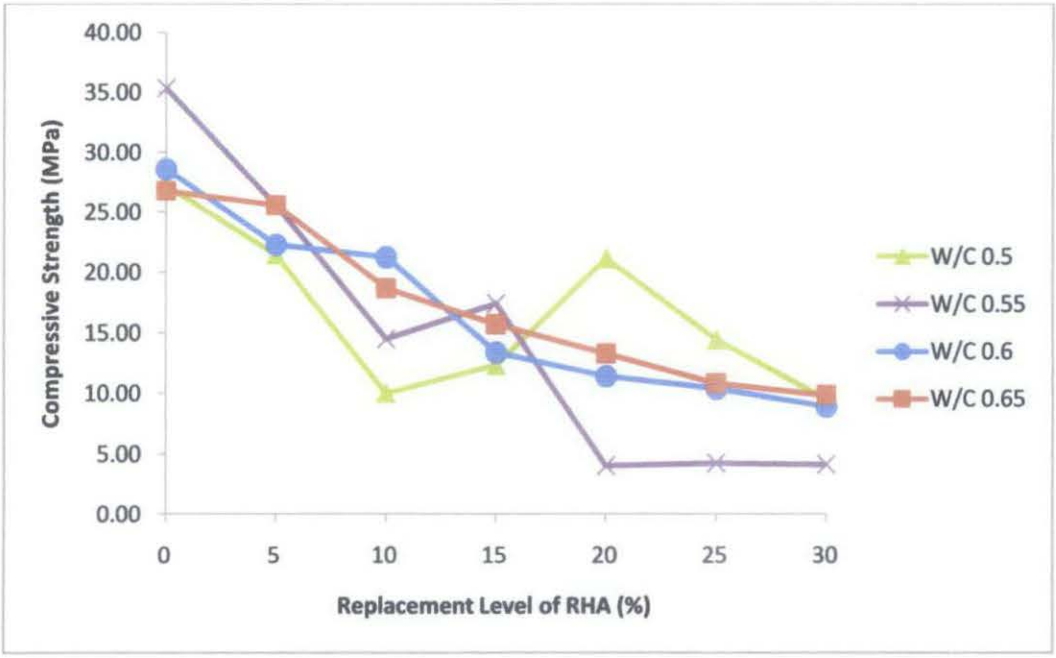


Figure 4.3: 7-Day Compressive Strength Variation for 1:3 Binder to Sand Ratio Mortar of Different W/C

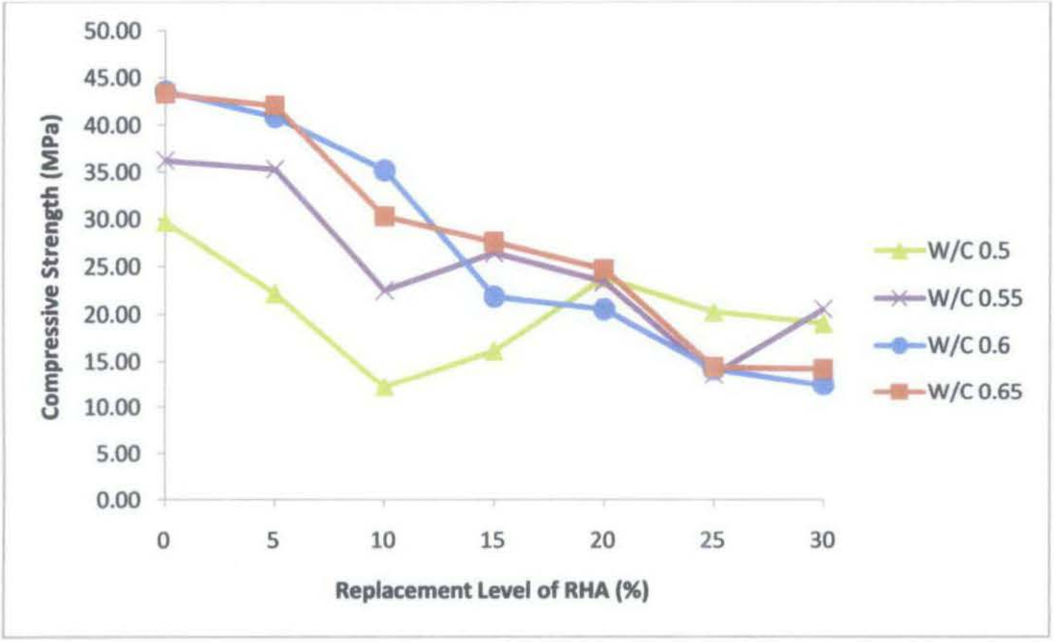


Figure 4.4: 28-Day Compressive Strength Variation for 1:3 Binder to Sand Ratio Mortar of Different W/C

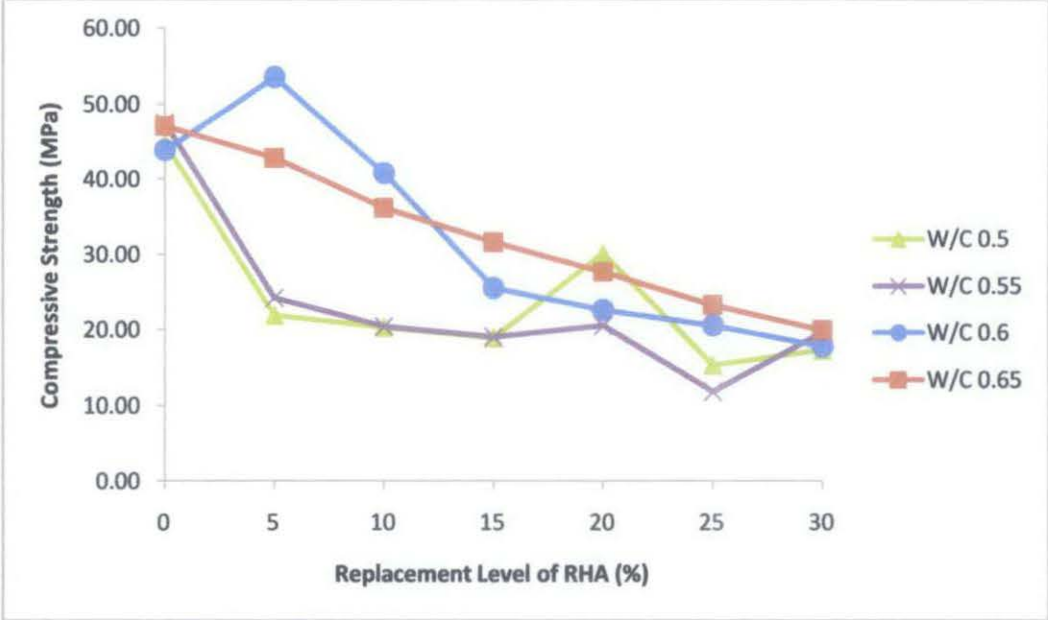


Figure 4.5: 60-Day Compressive Strength Variation for 1:3 Binder to Sand Ratio Mortar of Different W/C

7-day compressive strength for 1:3 binder to sand ratio RHA mortars is lower compare to the control mortar for all w/c at all RHA replacement as shown in figure 4.3. This preliminary result shows the decrement of compressive strength when the replacement level increases except for the fluctuated results for 0.5 and 0.55 w/c mortars. From this result, the addition of RHA at all replacement level does not give significant contribution towards the properties of RHA mortars in term of compressive strength. In addition, RHA mortar with 0.65 w/c at 5% RHA replacement shows the highest compressive strength at 7-day as compared to other RHA mortars.

28-day compressive strength result starts to show the trend for 1:3 binder to sand ratio RHA mortars as shown in figure 4.4. Like the 7-day compressive strength result, the RHA mortars have lower compressive strength compared to the control mortar for all w/c at all RHA replacement. It has been found out that 0.65 w/c RHA mortar with 5% RHA replacement has the highest compressive strength. This might happen due to the sufficient water content in the mixture that contribute towards hydration process of cement and RHA which provide better pore refinement in the sample. Thus, it contributes towards its high compressive strength compared to other RHA mortars. 28-day compressive strength result also indicates the decrement in compressive strength when the replacement level of RHA increases except for the 0.5 w/c which has fluctuating result.

Figure 4.5 shows the compressive strength of all samples after 60-day of water curing. RHA mortar with 0.6 w/c shows higher strength than control mortar at 5% RHA replacement. However, the other RHA mortars are having compressive strength lower than control mortar even after 60-day of water curing. As 28-day results are used in design, it can be concluded that for 1:3 binder to sand ratio RHA mortars, the addition of RHA into the mixtures does not give any significant contribution to the properties as the RHA mortars have lower compressive strength than control mortar for all w/c at all RHA replacement.

4.1.3 Compressive Strength for Mixtures with Binder to Sand Ratio of 1:4

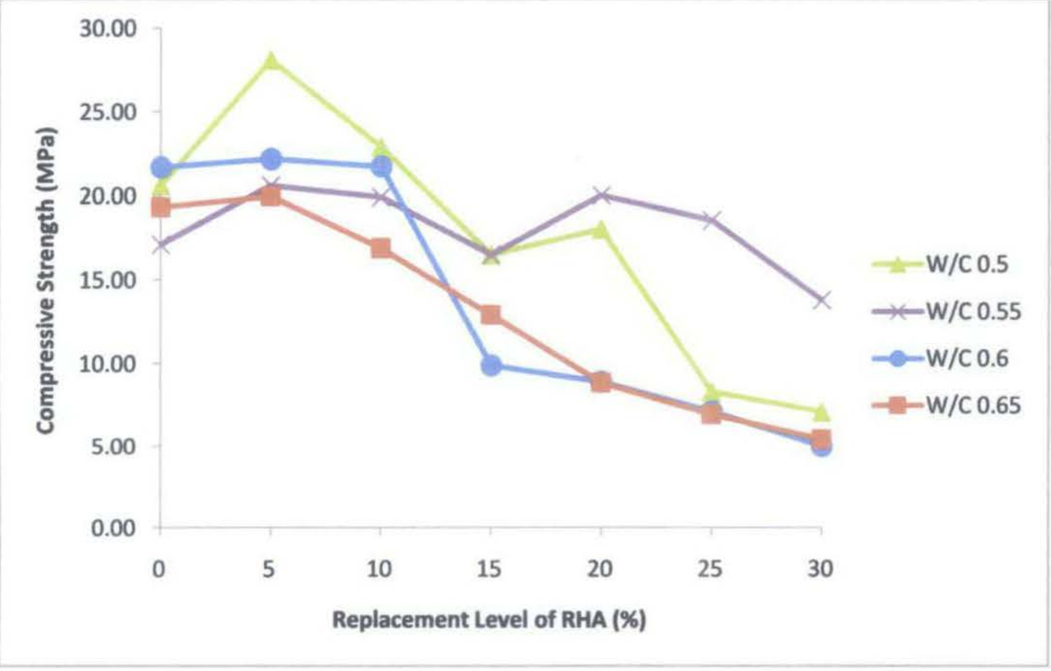


Figure 4.6: 7-Day Compressive Strength Variation for 1:4 Binder to Sand Ratio Mortar of Different W/C

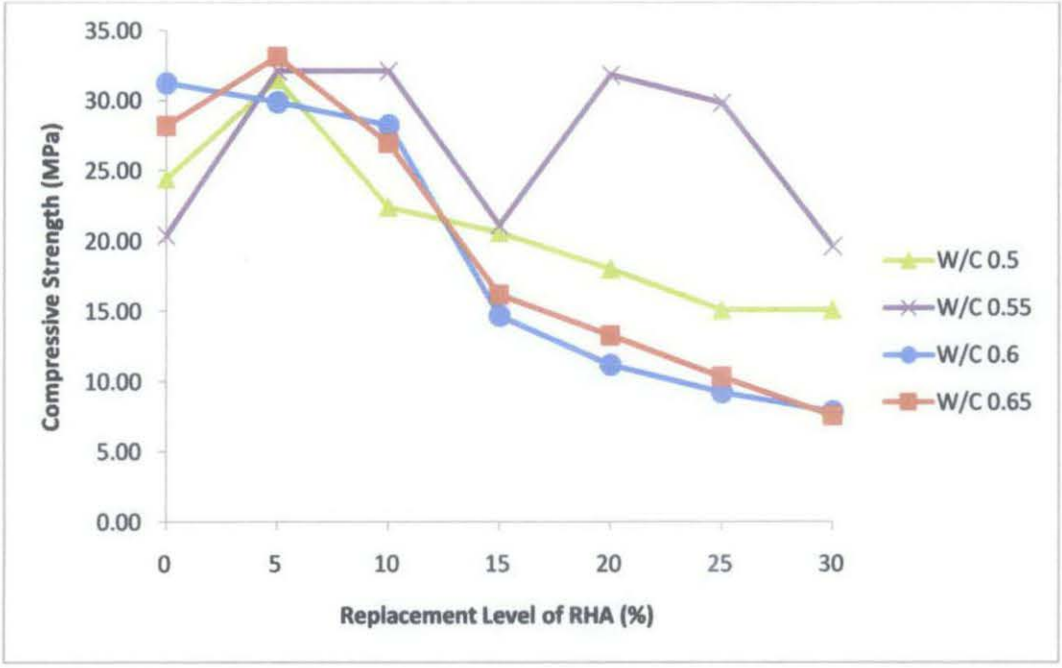


Figure 4.7: 28-Day Compressive Strength Variation for 1:4 Binder to Sand Ratio Mortar of Different W/C

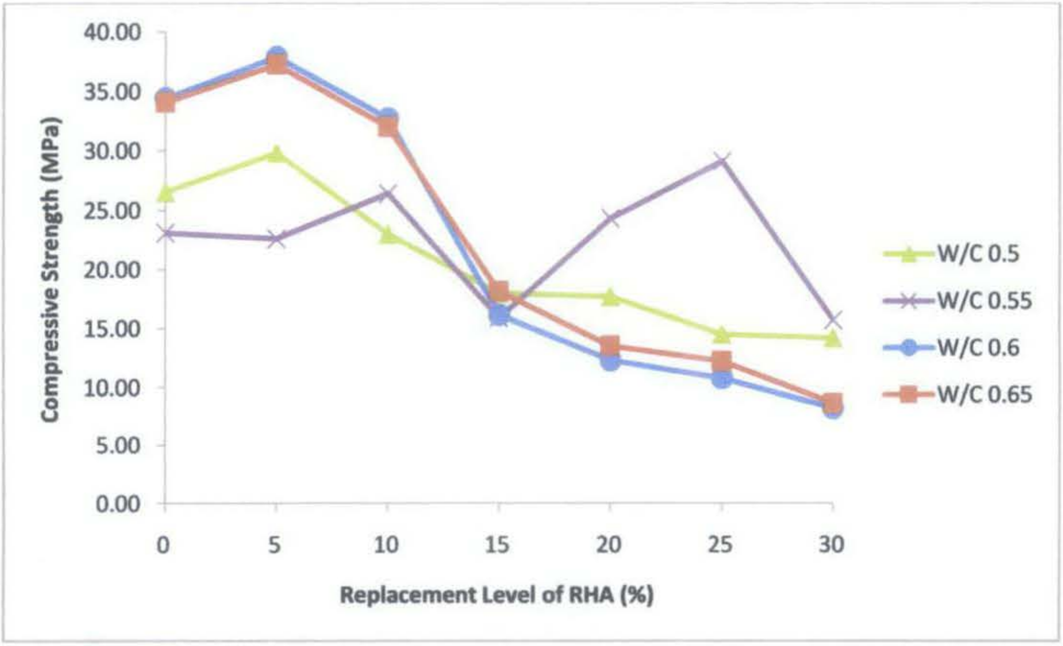


Figure 4.8: 60-Day Compressive Strength Variation for 1:4 Binder to Sand Ratio Mortar of Different W/C

Unlike 1:3 binder to sand RHA mortars, 1:4 RHA mortars show significant results as early as 7-day after water curing. As shown in Figure 4.6, the samples have highest compressive strength at 5% RHA replacement for all w/c. 0.5 w/c RHA mortar shows the highest compressive strength at 5% replacement level of RHA. The preliminary result indicates better contribution of RHA addition into mortar.

Figure 4.7 shows the 28-day compressive strength for 1:4 binder to sand ratio RHA mortars. All samples are having optimum value of compressive strength at 5% RHA replacement except for 0.6 w/c RHA mortars which have lower compressive strength compared to control mortar. In addition, 0.65 w/c RHA mortar at 5% RHA replacement has the highest value of compressive strength. This indicates that the incorporation of 5% RHA in the mortar mixtures with 0.65 w/c helps refining the pores between binders and sand. Thus, the pores refinement reduced the amount of voids in the mixtures which translated into higher compressive strength than other 1:4 binder to sand ratio mortars.

On the other hands, Figure 4.8 shows the 60-day compressive strength for 1:4 binder to sand ratio RHA mortars. 0.6 w/c RHA mortar at 5% RHA replacement has the highest compressive strength compared to control mortars and other RHA mortars. The trend shown in Figure 4.6 indicates that at 5% RHA replacement for 1:4 binder to sand ratio, the compressive strength is higher than respective control mortar except for 0.6 w/c RHA mortars.

Based on the analysis that has been done, the findings show that the incorporation of RHA significantly increased the compressive strength of mortars with 1:4 binder to sand ratio. However, the incorporation of RHA is only significant at 5% replacement level as the addition of RHA in the mixtures after 5% shows declining trend of compressive strength. Based on the 28-day results, the use of 0.65 w/c for the mixtures resulted in highest compressive strength for 1:4 binder to sand ratio mortars.

4.2 IRS & Water Absorption

The IRS of mortar cubes is determined based on BS 3921 Appendix H while the water absorption is determined based on ASTM C67-90a. The IRS and water absorption of RHA mortars are shown in Table 4.3 & 4.4.

Table 4.3: IRS and Water Absorption of Mixtures with Different Binder to Sand Ratio (1:3 and 1:4) and Water-Cement Ratio (0.6 and 0.65)

CEMENT: SAND	0.6 W/C			0.65 W/C		
	MIX ID	**IRS (kg/m^2.min)**	**Water Absorption (%)**	**MIX ID**	**IRS (kg/m^2.min)**	**Water Absorption (%)**
1:3	**360-R0**	0.53	4.52	**365-R0**	0.28	3.96
	360-R5	0.14	5.16	**365-R5**	0.25	5.42
	360-R10	0.37	5.42	**365-R10**	0.27	6.48
	360-R15	0.49	6.39	**365-R15**	0.22	6.53
	360-R20	0.38	6.47	**365-R20**	0.18	6.27
	360-R25	0.33	9.87	**365-R25**	0.28	10.95
	360-R30	0.30	9.70	**365-R30**	0.25	10.72
1:4	**460-R0**	0.28	4.20	**465-R0**	0.37	4.95
	460-R5	0.38	4.97	**465-R5**	0.42	5.43
	460-R10	0.27	5.13	**465-R10**	0.30	5.89
	460-R15	1.79	9.08	**465-R15**	0.32	8.20
	460-R20	0.69	10.01	**465-R20**	0.25	9.37
	460-R25	0.30	8.17	**465-R25**	1.18	10.23
	460-R30	1.47	11.90	**465-R30**	1.02	12.07

Table 4.4: IRS and Water Absorption of Mixtures with Different Binder to Sand Ratio (1:3 and 1:4) and Water-Cement Ratio (0.5 and 0.55) (Anwar, 2011)

CEMENT: SAND	0.6 W/C			0.65 W/C		
	MIX ID	**IRS (kg/m^2.min)**	**Water Absorption (%)**	**MIX ID**	**IRS (kg/m^2.min)**	**Water Absorption (%)**
1:3	**350-R0**	0.30	9.10	**355-R0**	0.22	9.30
	350-R5	0.24	9.20	**355-R5**	0.13	9.20
	350-R10	0.62	11.90	**355-R10**	0.14	8.90
	350-R15	0.31	11.10	**355-R15**	0.14	10.70
	350-R20	5.31	13.60	**355-R20**	0.19	10.50
	350-R25	1.52	14.10	**355-R25**	0.18	11.00
	350-R30	0.66	14.40	**355-R30**	0.17	11.30
1:4	**450-R0**	0.54	10.40	**455-R0**	3.01	10.50
	450-R5	0.19	9.90	**455-R5**	0.22	8.60
	450-R10	1.34	12.50	**455-R10**	0.24	8.80
	450-R15	4.51	14.00	**455-R15**	0.29	8.20
	450-R20	6.64	14.70	**455-R20**	0.27	10.20
	450-R25	3.71	14.90	**455-R25**	0.26	10.30
	450-R30	9.32	19.00	**455-R30**	0.20	11.80

4.2.1 Initial Rate of Suction (IRS)

IRS of mortars shows the amount of water sucked by the cubic mortar sample upon contact with mortar during laying. IRS affects the water tightness and durability of masonry as it can affect the bond strength between the brick and mortar. IRS must be ensuring to be within the specified limits as per standard so the optimum bond strength could be achieved. Thus, it is essential and important to measure IRS of mortar samples upon applying them to the masonry construction. BS 3921:1985 Appendix H specifies the test principle for measuring IRS of mortars by immersing the cubic sample in about 3 mm depth of water for duration of 1 minute.

Drysdale et al. (1994) established that bricks with IRS less than 0.25 kg/m^2.min can be considered as low suction bricks whilst bricks with IRS more than 1.5 kg/m^2.min can be regarded as high suction bricks. IRS values between 0.25 to 1.5 kg/m^2.min have the capability to produce good bond strength when used with the appropriate mortar proportions.

The mortar samples in this investigation have a mean IRS within the specified limit of 0.25 to 1.5 kg/m^2.min which is ideal to be used as brick. The results are shown in Figure 4.9 and Figure 4.10. These mortar samples have the capability to develop appropriate bond strength between the bricks and the mortar interface. High suction bricks with have IRS value more than 1.5 kg/m^2.min absorb water from the mortar upon contact during bricks layering. This property affects the impairing bond properties between the brick and mortar whereby the mortar to bond the bricks together will experience lesser water content for proper hydration of cement and thus, it affects the bond strength which also translates to lower durability of the construction. On the other hand, low suction bricks with IRS value less than 0.25 kg/m^2.min do not absorb water. Excess water from the mortar will float to its surface and it affects the bonding strength of the bricks and mortar.

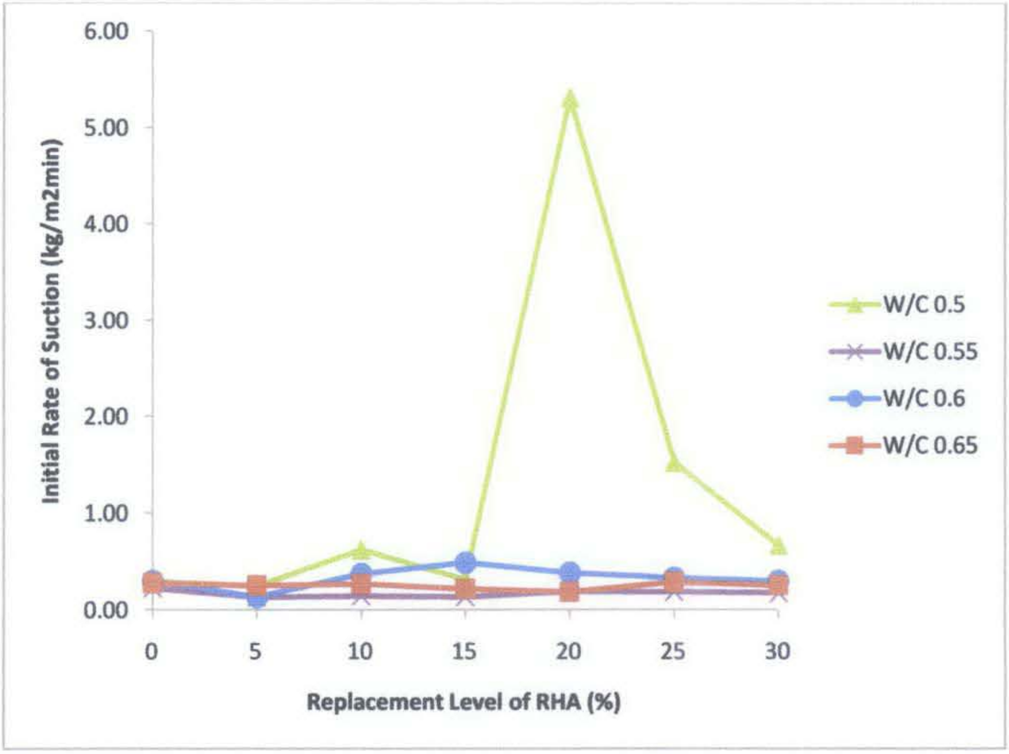


Figure 4.9: IRS Variation for 1:3 Binder to Sand Ratio Mortar of Different W/C

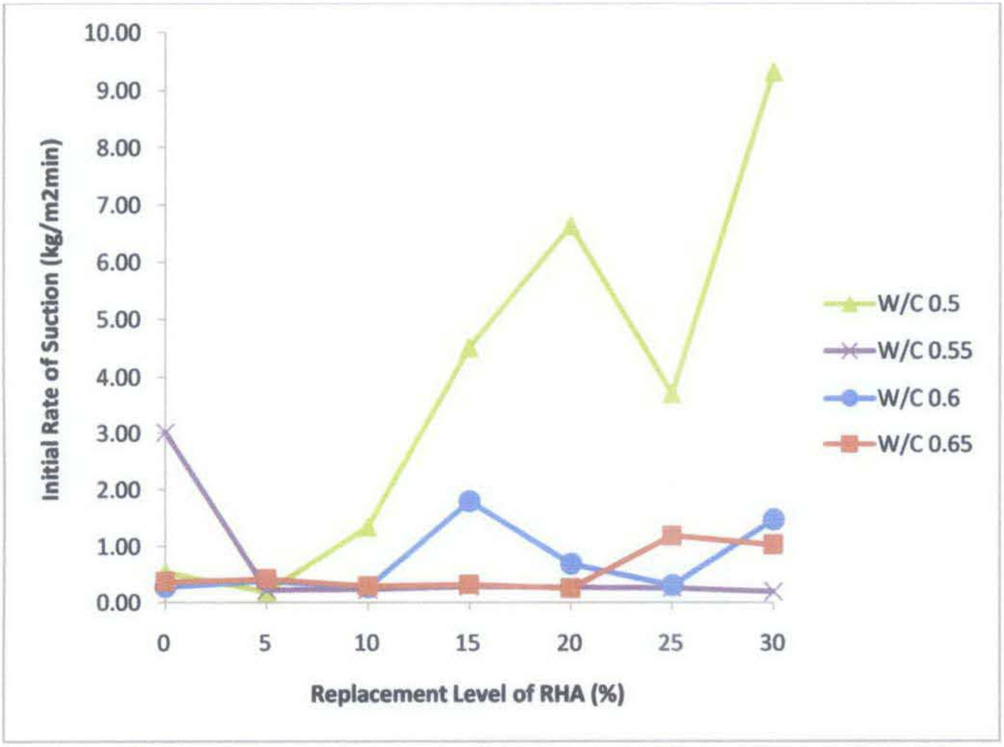


Figure 4.10: IRS Variation for 1:4 Binder to Sand Ratio Mortar of Different W/C

Figure 4.9 shows that the IRS values for 1:3 binder to sand ratio RHA mortars with varied w/c are within the acceptable limit of 0.25 to 1.5 kg/m^2.min as specified in the standard. However, the 0.5 w/c mortar with 20% RHA replacement has IRS value that exceeds the acceptable limit. It shows that at this replacement level, the RHA mortar has a high capacity of initial suction that will affect the bonding strength between RHA bricks and mortar in construction.

On the other hand, Figure 4.10 shows the IRS values for 1:4 binder to sand ratio RHA mortars with various w/c. The tabulated graph identified that most of RHA mortars in this investigation are having IRS values within the specified limit. However, 0.5 w/c RHA mortars have IRS values that exceeded the specified limit. This might happened due to porous surface of the samples. Lower w/c in the mixtures caused lower workability during the mixing as RHA absorbed more water quickly due to its high fineness surface. As the workability is decreasing when the RHA replacement increases, the IRS values for 0.5 w/c mortars increases with the addition of RHA.

For both 1:3 and 1:4 binder to sand ratio, most of the RHA mortars at various w/c are having acceptable value of IRS as specified in the standard. This represents the capability of these RHA mortars to be used as bricks as they contribute towards their bonding strength with the mortar. The appropriate bond strength can be achieved by these RHA bricks when they are used in the masonry construction. On the other hand, the low and high suction IRS values of RHA bricks will affect the bonding properties and thus, they are not suitable to be used as brick in the construction.

4.2.2 Water Absorption

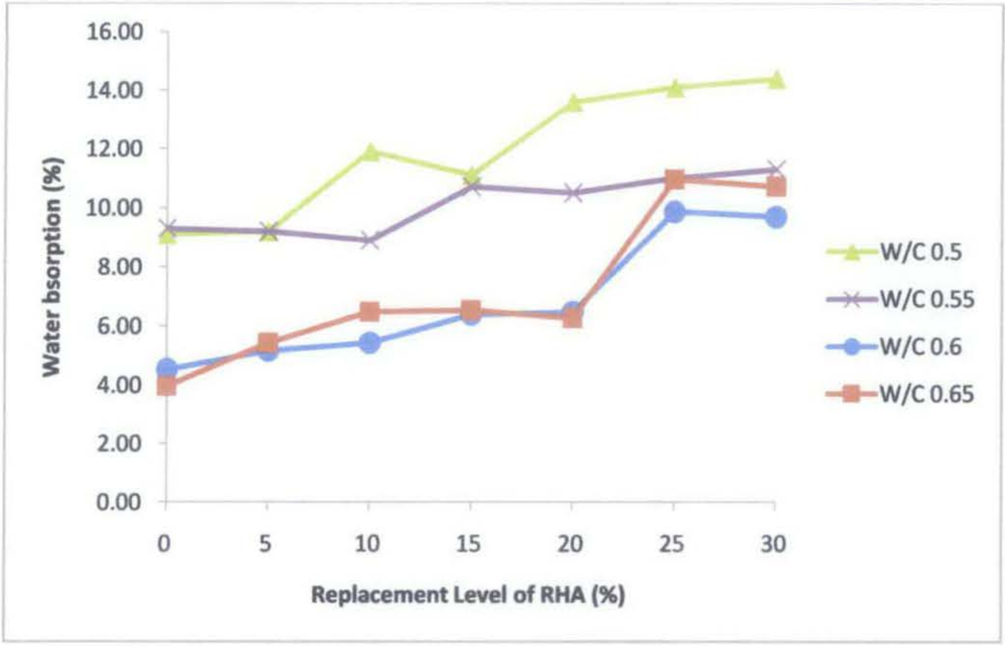


Figure 4.11: Water Absorption Variation for 1:3 Binder to Sand Ratio Mortar of Different W/C

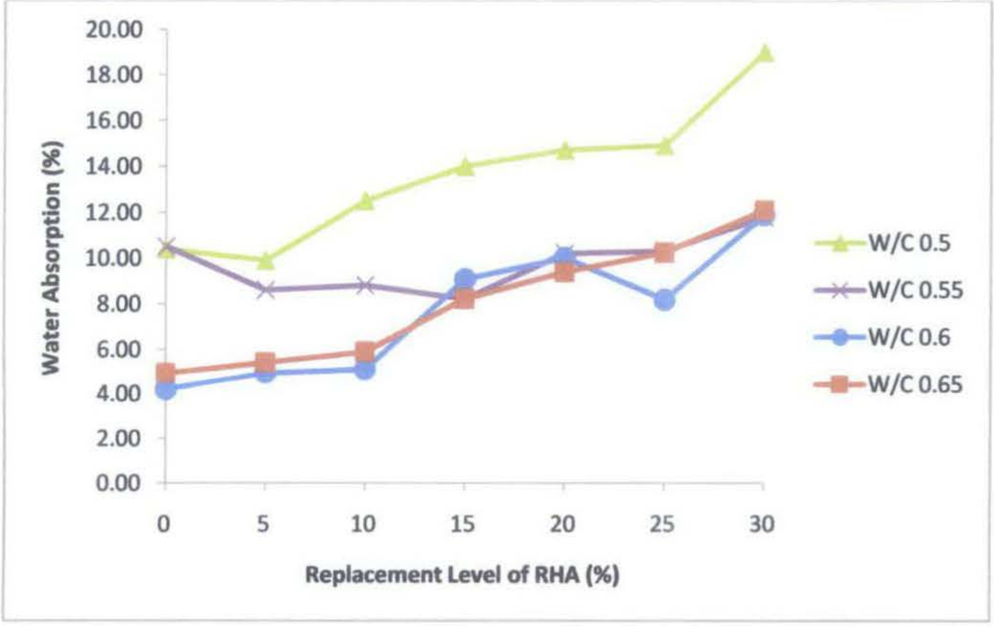


Figure 4.12: Water Absorption Variation for 1:4 Binder to Sand Ratio Mortar of Different W/C

From Figure 4.11 and 4.12, the graphs show that most of the water absorption values of varied w/c RHA mortars are higher than control mortar. This happened may be due to the permeability of the RHA mortars. During the mixing process to cast the cubic RHA mortars, it can be observed that the workability of RHA mixtures at same w/c was decreasing as the replacement level of OPC by RHA increased. The lower workability of RHA mortars when the RHA replacement increases happened as RHA absorbs more water which resulted in mixtures that have lower workability during mixing. On the other hands, RHA that is used in this research has coarser grain size than cement. Therefore, the incorporation of RHA in the mixtures in higher percentage causes the final products to contain more voids and increase their permeability to liquid. The increment in permeability causes the RHA mortars to absorb more water when the replacement level of RHA increases.

Previous researches that have been done agreed that the substitution of pozzolans for part of the cement reduces permeability and porosity in mortar. The pozzolanic materials can contribute to the filling and segmentation of the capillary voids as they produce more identical products of hydration compared to cement alone. Thus, the incorporation of pozzolanic materials in the mortar mixtures will help producing dense and impermeable mortar and also more durable mortar. However, the use of coarser RHA than cement might cause these mortars to have higher permeability in porosity than the mortars that used finer RHA.

The graphs also show that the water absorption is lower when the w/c is higher for both 1:3 and 1:4 binder to sand ratio RHA mortars. Higher w/c gives more and adequate water to the mixtures that helps the hydration process of the pozzolanic materials. The precipitation of cement gel products during hydration process is greater in the presence of pozzolanic materials. This process helps block the pores more effectively and thus reducing the permeability and porosity of the mortar. Thus, the RHA mortars with higher w/c tend to have lower water absorption value compared to RHA mortars with lower w/c.

4.3 Project Viability & Economic Benefit

4.3.1 Capital Cost

The cost of this research project is only involved the cost of cement since other materials are available at no cost.

Total OPC for 28 mixtures	=	23.913 kg (rounded to 50 kg for market selling)
Cost of OPC	=	RM 18.00 / 50 kg
Total cost of project	=	RM 18.00 / 50 kg x 50 kg
	=	RM 18.00

4.3.2 Business Element

RHA is abundantly available at rice mills at no cost involvement as it is a by-product of burning rice husks. The incorporation of RHA in the mortars that can be used as brick will definitely reduce the total cost of production as the amount of cement used is reduced. If RHA bricks are to be industrialized, several costs need to be taken into account which includes machinery, equipment and labor. However, the cost would not be as high as cement bricks as the incorporation of RHA in the mixtures reduces the need to use large amount of cement. On the other hands, the pollution of environment due to the cement production and dumped RHA can be reduced by reducing the demand for cement in construction industry while utilizing by-product of burning rice husks.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

The compressive strength of most RHA mortars decreased when the RHA replacement is increased. This is happened as the RHA used in this research has coarser grain size than the cement which produced porous surface and more voids inside the mixtures. These characteristics affected the compressive strength of RHA mortars.

For 1:3 binder to sand ratio RHA mortars, the compressive strength results show that the incorporation of RHA in varied w/c did not give significant contribution to the properties of the mortars. Based on 28-day results, all RHA mortars with 1:3 binder to sand ratio have compressive strength lower than the respective control mortars.

On the other hands, the addition of RHA in 1:4 binder to sand ratio mortars resulted in significant change in the properties of the mortars. At 5% RHA replacement, all samples have compressive strength higher than control mortars with 0.65 w/c RHA mortar is having the highest compressive strength which is 37.23 MPa. However, 0.6 w/c RHA mortar recorded lower compressive strength than control mortar at all RHA replacement. Although several mortar mixtures did not have compressive strength higher than control mortar, they can still be used as bricks or pavement blocks according to several standards.

In term of IRS, most of the samples showed IRS value that is between 0.25 to 1.5 kg/m^2.min which is the acceptable limit according to the standard. Mortars with IRS value that is lower than 0.25 kg/m^2.min and greater than 1.5 kg/m^2.min are not suitable to be used as brick as their properties will affect the bonding strength between bricks and mortar.

Most of RHA mortars in this research have higher water absorption value compared to control mortar and the value increases when the RHA replacement is increased. This is happened because the RHA is coarser than cement and its incorporation in the mortar mixtures produce more voids. Thus, the more the addition of RHA into the mixtures, the more voids are produced which translate into higher permeability mortars. In addition, the addition of RHA into mortars increases the water absorption due to the properties of this pozzolanic material to absorb more water for hydration process. Thus, insufficient w/c will affect the mixing process that has the possibility to cause greater amount of voids in the samples. It can also be concluded that as the w/c increases, the water absorption decreases until it reaches the optimum w/c which is 0.6 in this case.

For future work, there are few recommendations to improve the research's quality which includes;

1. The quality and condition of every materials used for casting must be maintained by using the same resources to avoid inaccuracy in the result.
2. The water must be ensure to be clean and clear from dirts.
3. The mixing procedures must follow the standard guidelines in order to obtain consistent result.
4. The temperature that is used to burn the rice husks in the rice mills must be ensure to be consistent.
5. The use of RHA with finer grain size than cement can be analyzed as it will further enhance the properties of the mixtures.
6. The use of additives in the RHA mortar can also be analyzed in the future in order to investigate the properties of RHA mortar especially in term of compressive strength.

In conclusion, the effects of mix composition on RHA mortars have been further analyzed through this research. The analysis that have been done can be useful for industrial application especially to utilize the rice husks from the rice mills while reducing the cement demand in the construction industry.

REFERENCES

Abdelalim, A., Abdelaziz, G.E., & Zahran, R. (2002). Fresh and mechanical properties of the cementitious materials containing rice husk ash. *Engineering Research Journal, Faculty of Engineering, Mataria, Helwan University, Cairo, Egypt, 84*, 15-28

Abu Bakar, B.H., Ramadhansyah, P., & Abdulaziz, H. (2009). Malaysian rice husk ash – improving the durability and corrosion resistance of concrete: Pre-review, *Concrete Research Letters, 1*(1), 6-13

Allen, G., Allen, J., Elton, N., Farey, M., Holmes, S., Livesey, P., & Radonjic, M. (2003). *Hydraulic lime mortar for stone, brick and block masonry*. Shaftesbury, Dorset: Donhead Publishing Ltd

Anwar, A. (2011). *Parametric Study on Effects of Water-Cement Ratio to Compressive Strength of RHA Mortar*. Unpublished thesis for bachelor's degree, Universiti Teknologi PETRONAS, Perak, Malaysia

Chindraprasirt, P., Jaturapitakkul, C., & Sinsiri, T. (2005). Effect of fly ash fineness on compressive strength and pore size of blended cement paste. *Cement and Concrete Composites. 27*(4), 425-428

Drysdale, R.G., Hamid, A.A. and Baker, L.R. (1994). *Masonry Structures: Behavior and Design*. Prentice Hall

Ismail, M.S., & Waliuddin, A.M. (1996). Effect of rice husk ash on high strength concrete. *Construction and Building Materials, 10*(7), 521-526

Kassim, K.A., & Chern, K.K. (2004). Lime stabilized Malaysian cohesive soils. *Civil Engineering National Journal, 16*(1), 13-23

Malhotra, V.M. (1993). Fly ash, slag, silica fume and rice husk ash in concrete: a review. Concrete International, 15(4), 23-28.

Mehta P.K. (1979). The chemistry and technology of cement made from rice husk ash. *In Proceedings of UNIDO/ESCAP/RCTT, Workshop on Rice-Husk Ash Cement*, Peshawar, Pakistan, 113-122

Mehta, P.K. (1992). Rice husk ash – a unique supplementary cementing material. *In Proceedings of the CANMET/ACI International Symposium on Advances in Concrete Technology, V.M. Malhotra,ed., Athens, Greece*, 407-430

Mehta, P.K. (2002). Method for producing a blended cementitious composition. *U.S. Patent 6451104 B2*

Nagataki, S. (1994). Mineral admixtures in concrete: state of the art and trends. *In Proceedings of V. Mohan Malhotra Symposium on Concrete Technology: Past, Present, and Future, ACI SP-144, P.K. Mehta, ed., American Concrete Institute, Farmington Hills, Michigan, USA,* 447-482

Naji Givi, A., Suraya, A.R., Farah, N.A.A, & Mohd Salleh, M.A. (2010). Contribution of rice husk ash to the properties of mortar and concrete: a review. *Journal of American Science, 6*(3), 157-165

Nehdi, M., Duquette, J., Damatty, A.E. (2003). Performance of rice husk ash produced using a new technology as a mineral admixture in concrete. *Cement and Concrete Research, 33*(8), 1203-1210

Nuruddin, M.F., Shafiq, N., & Mohd Kamal, N.L. (2008). Microwave incinerated rice husk ash (MIRHA) concrete: a new material in the construction industry. *UK Malaysia Engineering Conference 2008, UTP Institutional Repository*

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

Pitt, N. (1976). Process for preparation of siliceous ashes. *U.S. Patent 3959007*

Rai, D.C. (2010). *Masonry materials – mortar & grout* [Lecture notes]. Kanpur, India: Indian Institute of Technology Kanpur, Department of Civil Engineering

Rashid, M.H., Ali Molla, M.K., & Ahmed, T.U. (2010a). Long term effect of rice husk ash on strength of mortar. *World Economy of Science, Engineering and Technology, 67,* 740–743

Rashid, M.H., Ali Molla, M.K., & Ahmed, T.U. (2010b). Durability of mortar in presence of rice husk ash. *World Economy of Science, Engineering and Technology, 67,* 736-739

Rashid, M.H., Ali Molla, M.K., & Ahmed, T.U. (2010c). Mortar incorporating rice husk ash: strength and porosity. *European Journal of Scientific Research, 40* (3), 471-477

Rice Trade. (2010). *World rice production 2009-2010.* Retrieved June 15, 2011, from http://www.rice-trade.com/articles/rice-production.html

Rodriguez, G.S. (2006). Strength development of concrete with rice-husk ash. *Cement and Concrete Composites. 28*(2), 158-160

Rukzon, S., & Chindarprasirt, P. (2006). Strength of tenary blended cement mortar containing portland cement, rice husk ash and fly ash. *J. Eng. Inst. Thailand, 17,* 33

Safiuddin, M., West, J.S., & Soudki, K.A. (2008). *Self-consolidating high performance concrete with rice husk ash – components, properties, and mixture design.* Deutschland: VDM Verlag Dr. Muller Aktiengesellschaft & Co. KG

Saraswathy, V., and Ha-Won, S. (2007). Corrosion performance of rice husk ash blended concrete. *Construction and Building Materials. 21*(8), 1779-1784

Sumrerng, R., Chindarprasirt, P., & Mahachai, R. (2009). Effect of grinding on chemical and physical properties of rice husk ash. *International Journal of Minerals, Metallurgy and Materials, 116*(2), 242-247

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*, 778-786

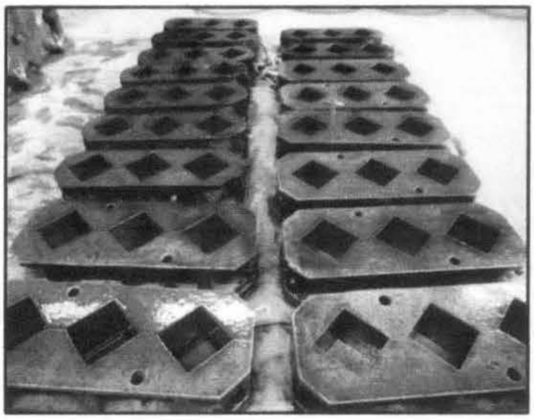
Zhang, M.H., Lastra, R., & Malhotra, V.M. (1996). Rice-husk ash paste and concrete: some aspects of hydration and the microstructure of the interfacial zone between aggregate and paste. *Cement and Concrete Research, 26*(6), 963-977

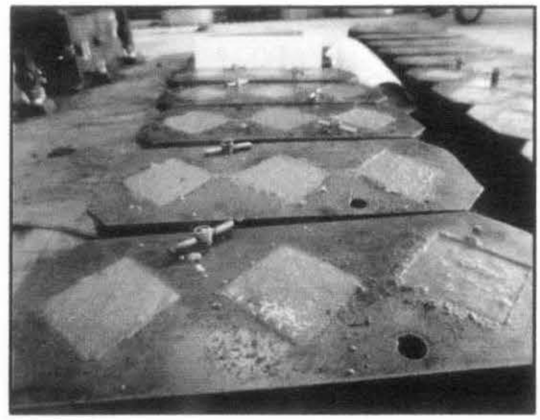
Zhang, M.H., & Malhotra, V.M. (1996). High-performance concrete incorporating rice husk ash as a supplementary cementing materials. *ACI Materials Journal, 93*(6), 629-636

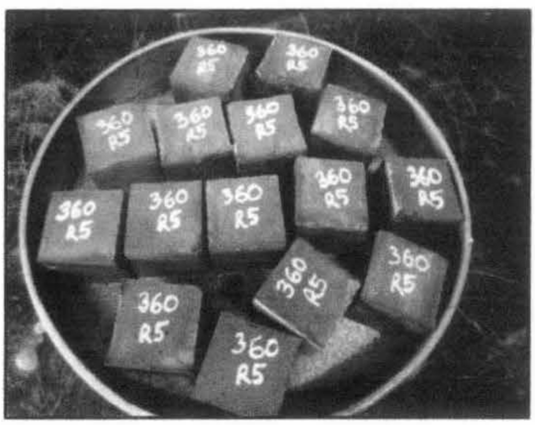
APPENDICES

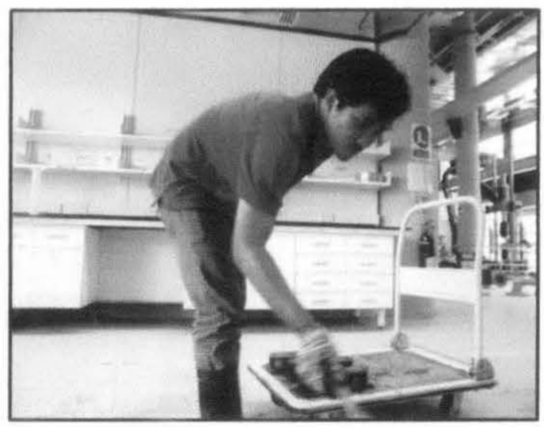
APPENDIX I: Preparation of Materials Prior to Laboratory Work

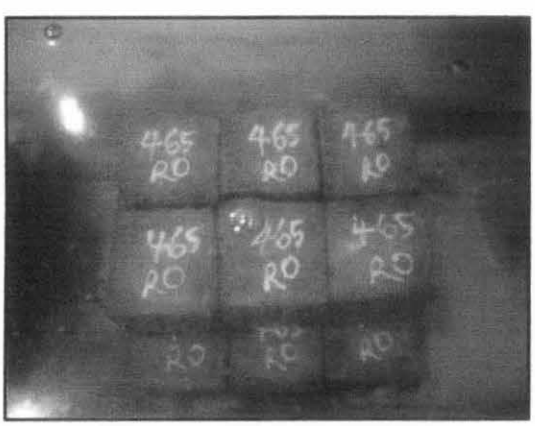
APPENDIX II: Mixing, Casting and Curing of All Samples

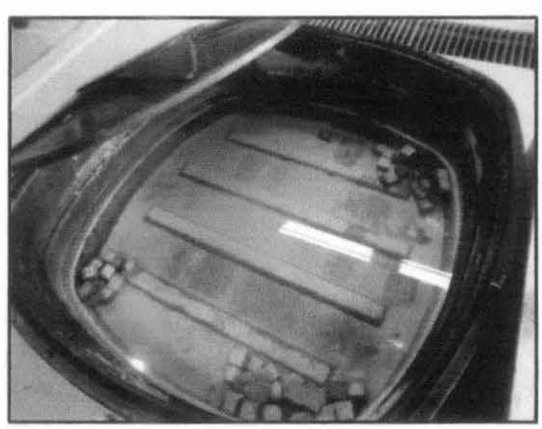




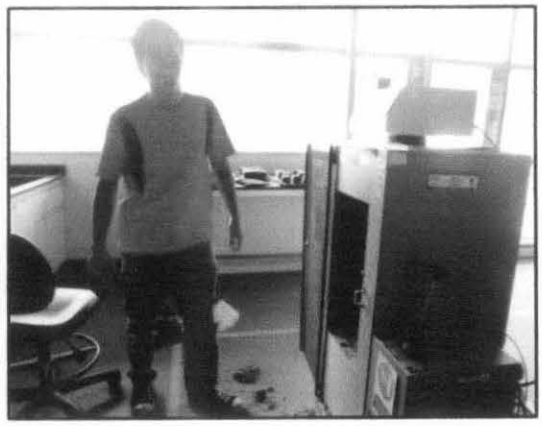


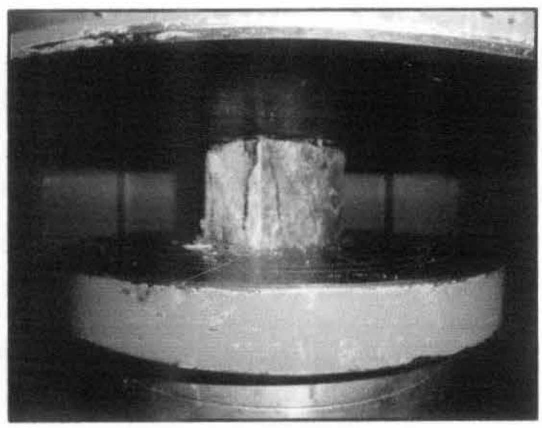






APPENDIX III: Compressive Strength Test of Samples at 7, 28 and 60 Days





APPENDIX IV: IRS and Water Absorption Test of Samples after 60 Days