Effects of Mix Composition on Microwave Incinerated Rice Husk Ash (MIRHA) Mortar

by

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CERTIFICATION OF APPROVAL

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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 NASUHA BIN ALIAS)

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ABSTRACT

There are many cement replacement materials (CRM) have been commercialized in the industry. Microwave Incinerated Rice Husk Ash (MIRHA) is a new material that can be used as CRM in the industry. The used of MIRHA in concrete has been extremely studied in Universiti Teknologi PETRONAS (UTP). The study on use of MIRHA in mortar has not been studied. The objectives of this project were to obtain optimum water cement ratio for MIRHA mortar mix, to obtain the suitable mix composition and to obtain the optimum cement replacement by MIRHA in MIRHA mortar. Various water cement ratios (0.60 and 0.65), binder aggregate ratios (1:3 and 1:4) and different percentages of cement replacement by MIRHA (0%, 5%, 10%, 15%, 20%, 25% and 30%) were used to cast mortar cubes. The sample preparation follows BS 1881 and compressive strength (7, 28 and 60 days after curing), water absorption (60 days after curing) and initial rate of suction (IRS) (60 days after curing) values were determined. The highest result for 28-day compressive strength test for all samples is 46.17MPa from sample 5M360 which contains 5% of cement replacement by MIRHA, binder to sand ratio of 1:3 and water cement ratio of 0.60. Whereas for IRS test, almost all IRS values of all samples fall between accepted range within between 0.25 to 1.5 kg/m^2.min. For water absorption, almost all samples were under maximum water absorption value for bricks which is 18% water absorption.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

In concrete production, the most important element that must be in the constituents is the binder, which is cement. Portland Cement, or Ordinary Portland Cement is the main type of cement that is used globally. Its crystalline silicate available on its chemical structure makes OPC suitable for binding material. However, the source of OPC is reducing world widely due to the mining and mass use of OPC as the main construction material. The need to find new renewable source to replace or to reduce the use of OPC in the concrete industry is needed to be commercialised.

There are many cement replacement material that have been commercialised in today's world, but in this proposal, the cement replacement material (CRM) will be focussed on Microwave Incinerated Rice Husk Ash (MIRHA) which is the new material that can be used as CRM. MIRHA is made of rice husk with a controlled burning method to reduce carbon emissions, thus making the concrete environmental friendly (Nuruddin, Shafiq and Mohd Kamal 2008).

The source of rice husk can be taken from rice milling industries which it produce 22% weight of husk and the other 78% weight of rice, broken rice and bran. This husk contains about 75% organic volatile matter and the balance 25 % of the weight of this husk can be converted into MIRHA by burning the rice husk in the incinerator with temperature of 800°C. Latest research found that by replacing 10% of RHA in cement, it can increase the compressive strength by 30% (Ou, Xi and Corotis 2007).

Green Concrete as the name suggests is eco friendly and saves the environment by using products generated by industries in various form like rice husk ash, micro silica and etc. to make resource-saving concrete structure. Use of green concrete is very often also cheap to produce as it uses production of per unit of cement (Nuruddin, Shafiq and Mohd Kamal 2008).

1.2 Problem Statement

1.2.1 Problem Identification

Production of Portland Cement (PC) is resulting in two major issues that are needed to be considered before it is too late to find out the solution. Firstly, manufacturing of PC is emitting 5% of the global CO_2 into the atmosphere causing global warming (Worrell, et al. 2001). Secondly, PC utilizes limestone and clay that are depleting day by day causing environmental degradation. To produce 1 ton of PC, 1.6 tons of raw materials are needed and the extraction of raw materials from the earth is 20% faster than the earth replenish it (Nuruddin, et al. 2010) , so in near future there will be a shortage of these raw materials for the production of PC; i.e. expected to rise by 4.7% globally to 3.5 billion metric ton in 2012 according to the recent World Cement Research report.

The rice production in Malaysia up to 2007 based on International Rice Research Institute is about 2.2 million tonnes (International Rice Research Institute 2008) raw rice produced in Malaysia. There are at least 484 thousand tonnes of husk produced every year and only 121 thousand tonnes of the husk becomes RHA. The huge amount of renewable material must be not wasted and it should be used in order to promote Green Concrete by applying the material into something that used the most in construction field. The disposal problems of RHA (Jha and Gill 2006) is the main reason that this kind of scheme promote the green way not to disposed but to recycle the waste produced.

1.2.2 Significance of the Project

The use of CRM to form mortar will reduce the use of cement since mortar consists of cement, fine aggregate (sand) and water. The use of CRM will apply the concept of Green Concrete which mortar too falls in the group. The application of mortar; bricks is commonly used in building construction, road pavement and etc. For road pavement application (Singh 2007), the technology has been used since 5000 years ago, brick pavements for highways were commonly used, as can be seen in the old ruins in the West Asian Region, which was earlier known as Mesopotamia. The use of bricks as road pavement nowadays is also become an option to risen up the aesthetics value of building design.

By replacing the OPC with CRM in the bricks, the project promotes reduction of CO_2 in the atmosphere; since currently the cement industry contributes about 7% - 10% of carbon emission worldwide (Mcleod 2005). The use of the eco-friendly bricks may not be as cheap as the common bricks price, since the addition procedure to make the bricks. The different of price between normal cement bricks and green bricks will be effected by the percentage of CRM used in the green bricks. The higher the replacement, the higher the price since production of MIRHA can be expensive although the source is free. However, the choice is available for the industry either to use the common type of bricks or to use the eco-friendly brick.

As for the water-cement ratio element in this project, the purpose of having it is to verify the minimum strength that is relevant to the formation of mortar. By having the measure, tests can be conducted to measure the mortar strength and to fulfil the objective of the project. The compressive strength decreases with a higher water-cement ratio but is not influenced much by the cement content (Schulze 1999).

1.3 Objective

The main objectives of this project are;

1. To obtain the optimum water-cement ratio of MIRHA mortar.
2. To obtain the optimum percentage of MIRHA as cement replacement material of MIRHA mortar.
3. To obtain the best binder to sand ratio of MIRHA mortar.

1.4 Scope of Study

The scope of study for this project are:

1. To prepare MIRHA cement mixture samples with standard procedure as in BS 1881: Testing Fresh Concrete.
2. To prepare MIRHA in the highway engineering laboratory. MIRHA was available in the university and were grinded using LA (Los Angeles) equipment before applying into the experiments.
3. To vary the percentage of MIRHA content as cement replacement, starting with 0% (control specimen), 5%, 10%, 15%, 20%, 25% and 30%.

4. To vary the binder-aggregate proportion by 1:3 and 1:4.
5. To vary the water-cement ratio value by 0.6 and 0.65.

1.5 The Relevancy of the Project

The experimental based research in this project to obtain the optimum water-cement ratio of MIRHA mortar and to obtain the optimum percentage of MIRHA needed in the MIRHA mortar is pertinent due to the various types of bricks application in the construction field. The choice offered to the industry to use the waste based type of material in the construction which offers admirable outcome to the environment in the future. Greening of the building industry cannot be complete until the materials used for construction are also green (Mehta 2002). The project introduces the green material that is used in the construction industry by using waste as CRM to reduce the use of OPC in the bricks.

1.6 Feasibility of the Project within the Scope and Time Frame

The following are the aims to be achieved for the project during the first four months (FYP 1) period;

1. Review literatures related to the topic.
2. Perform preliminary the lab works to get used to the lab instruments.
3. Perform lab works to prepare the samples.

In the remaining four months of the project (FYP 2), following are the aims have been achieved;

1. Perform lab works to prepare the samples.
2. Perform compression strength test 7 days, 28 days, and 60 days.

Basically, the project is feasible within the scope and time frame if proper planning is done. Every laboratory and testing works have been successfully done during the two semester without having a long break.

CHAPTER 2

LITERATURE REVIEW

This section discussed about published information and researches about related topics to the project. The topics are as follows;

1. Bricks and mortar
2. MIRHA
3. Water-cement ratio

The details will be discussed further.

2.1 Bricks and Mortar

Based on Concise Oxford Dictionary 10^{th} edition, brick is 'a small rectangular block of fired or sun-dried clay used in a building'. Nowadays, brick have developed not only either present in clay or mud forms, but it also present in mortar form, whereas mortar, based on the Concise Oxford Dictionary 10^{th} edition, is a mixture of lime with cement, sand and water, used to bind bricks and stones. However, brick in form of mortar is also known as cement brick in the industry.

2.1.1 History of Brick

Sun-dried mud brick is conceivable on the Nile, Euphrates, or Tigris rivers, for long time and the technology has been spreading to the valley. However, the problems with sun-dried brick is, the brick cracked, and formed cakes that could be reshaped into crude building units. The first true arch of sun-baked brick was made about 4000 BC in the ancient city of Ur, in Mesopotamia. The arch itself has not survived, but a description of it includes the first known reference to mortars other than mud. Bitumen slime was used to bind the bricks together (Lee & Mason, 2006).

In Ur, the potters found the new way to form bricks by using heat. They discovered the principle of closed kiln, in which the heat could be controlled. The steps of sun-dried brick-making then were replaced completely during 1500 BC by burned bricks.

The technology spreads from the Middle East to the west where the Roman's built the Pantheon, and to the east where the Chinese built the Great Wall of China (Lee & Mason, 2006).

2.1.2 Brick Properties

Raw material composition and the manufacturing process will affect properties of bricks. To achieve the desired properties of the raw materials and of the fired brick, manufacturers blend different clays, this application somehow improves the overall quality of the finished product. The quality control during the manufacturing process permits the manufacturer to limit variations due to processing and to produce a more uniform product (The Brick Industry Association 2006).

The most important properties of brick are;

1) Durability

The durability of a brick depends on the ability to withstand incipient fire and partial vitrification during firing. The durability of a brick is predicted using compressive strength and absorption values because of the values are related to the firing temperatures.

2) Colour

The brick's colour depends on the chemical composition of the clay used, the firing temperature and method of firing control. The red colour of brick is due to the present iron particle inside the clay.

3) Texture

The smooth and sand-finished textures produced by the dies or moulds used in forming. The kind of surface is also called die skin, resulted from pressure exerted from steel die as the clay passes through it during extrusion process. Most of the manufacturers have the die skin removed to change into rough texture. The reason of changing the texture is to make the plastering process become possible. The plaster could not stick on to die skin brick.

4) Size Variation

The bricks will shrink during the drying and firing process. To obtain a desired size of brick, adjustment can be made within following ranges;

a) Drying shrinkage : 2% to 4%

b) Firing shrinkage : 2.5% to 4%

5) Compressive Strength and Absorption

The properties of raw materials are the key of having high compressive strength and low absorption values. Although the firing methods and manufacturing method can control the compressive strength and absorption values, but the properties of raw materials holds the maximum the optimum value.

2.1.3 Use of Recycled Aggregate in Moulded Concrete Bricks and Blocks

Huge quantity of constructions and demolitions (C&D) waste produced every year makes the disposal of those C&D become a severe social and environmental problem in Hong Kong (Poon, Kou and Lam 2002). The recycled materials has been used in large amount in non-structural concretes or used as road bases, its use in structural concrete is limited. The research studies show that little effect on properties of concrete is noticed when crushed concrete are used to replace 20% by weight of the natural aggregate. On the other hand, with higher level of replacement, high water absorption ability is observed thus creates higher total of water demands.

The problems of high water demand by using recycled aggregates can be avoided in concrete mixtures for mechanized moulded concrete bricks and blocks since mechanized moulding machine mixed materials and moulded under a combined vibrating and compacting action. Therefore, minimal amount of water is needed to make the mixes workable to be fed into the mould.

The research is to fulfil the requirement for masonry bricks that all the mixes satisfy the requirements of BS 6073, for compressive strength (≥ 8MPa), transverse strength (≥0.65MPa) and shrinkage (≤0.06%). For paving blocks, the result of the tests must be according to the requirement of BS 6717, which expected to achieve 28-day compressive strength of 49MPa. The results are as follows;

Table 2.1: The Results for Masonry Bricks (Poon, Kou and Lam 2002)

Mix Notation	Compressive Strength (MPa)	Transverse Strength (MPa)	Drying Shrinkage (%)	Density (kg/m^3)
BR-Control	16.2	1.76	0.040	2210
BR-TKOL-25	15.9	1.80	0.042	2195
BR-TKOL-50	16.7	1.87	0.044	2150
BR-TKOL-75	15.0	1.95	0.046	2120
BR-TKOL-100	11.8	1.99	0.052	2060
BR-TKOF-100	12.9	1.92	0.050	2070
BR-KTF-100	11.4	1.94	0.051	2054

Table 2.2: The Results of Paving Blocks without Fly Ash (Poon, Kou and Lam 2002)

Mix Notation	Compressive Strength (MPa)	Transverse Strength (MPa)	Drying Shrinkage (%)	Density (kg/m^3)
BL-Control	58.6	3.31	0.027	2328
BL-TKOF-50	62.1	3.74	0.030	2281
BL-TKOF-100	51.2	3.81	0.038	2258
BL-KTF-50	60.4	3.79	0.032	2244
BL-KTF-100	50.9	3.89	0.039	2215

Table 2.3: The Results of Paving Blocks with Fly Ash (Poon, Kou and Lam 2002)

Mix Notation	Compressive Strength (MPa)	Transverse Strength (MPa)	Drying Shrinkage (%)	Density (kg/m^3)
BLF-Control	46.6	3.30	0.026	2285
BLF-TKOF-25	44.7	3.30	0.026	2257
BLF-TKOF-50	46.5	3.32	0.029	2245
BLF-TKOF-75	45.4	3.53	0.034	2193
BLF-TKOF-100	40.1	3.63	0.036	2167
BLF-KTF-25	45.3	3.32	0.028	2250
BLF-KTF-50	47.5	3.47	0.030	2231
BLF-KTF-75	42.5	3.56	0.035	2170
BLF-KTF-100	41.0	3.68	0.037	2136

The results show that for masonry bricks and paving rocks without fly ash fulfil the requirement of BS 6073 and BS 6717. However, for paving blocks with fly ash did not fulfil the BS 6717 requirement. Fortunately, Hong Kong standards stated that compressive strength of 30MPa is the minimum strength needed for paving block for footway. The bricks still can be used in Hong Kong using the standards.

2.1.4 Fabrication of Bricks from Paper Sludge and Palm Oil Fuel Ash

The increment of disposed paper sludge and palm oil fuel ash (POFA) has attracted concern for an alternative environmentally sustainable development (Ismail, et al. 2010). There has been a research on using POFA to fabricate six types of mixtures to made brick specimens. Curing periods of 7-day, 28-day and 84-days were applied followed by compressive strength test. Finally, paper sludge-POFA brick made with 60% cement, 20% paper sludge and 20% POFA satisfies the strength requirements of BS 6073.

Since the minimum requirement of BS 6073 are compressive strength (≥ 7MPa), transverse strength (≥0.65MPa) and shrinkage (≤0.06%), the 60-20-20 mix is just slightly fulfil the requirement, it is chosen to be the ideal mix for paper sludge-POFA bricks. The result of the research was portrayed by the figure 2.1.

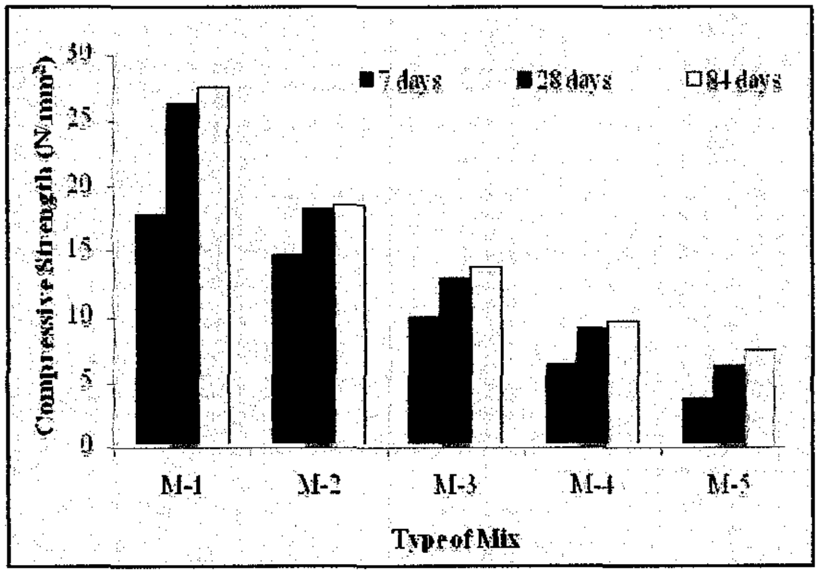


Figure 2.1: Compressive Strength of Mixes (Ismail, et al. 2010)

2.2 Microwave Incinerated Rice Husk Ash (MIRHA)

Based on research done by Nuruddin et al (2008) stated that, a proper burning method of rice husk ash (RHA) will result to a high proportion of SiO_2 content. The burning procedure shall not exceed 800°C longer than one hour because it tends to cause sintering effect and is indicated by a dramatic reduction in the specific surface.

Laboratory study on the effect of MIRHA on the compressive strength of concrete is done to measure the performance of concrete mixes with ordinary concrete mixes.

The results show that MIRHA mixtures clearly enhance concrete strength performance. MIRHA concrete has higher compressive strength at early curing days stated that pozzolanic reaction started to occur during early ages. MIRHA does not follow normal pozzolanic attributes which has low strength at early stage as it is more like silica fume where the samples gain high compressive strength at early stage as shown in figure 2.2 and continue to gain strength by the time.

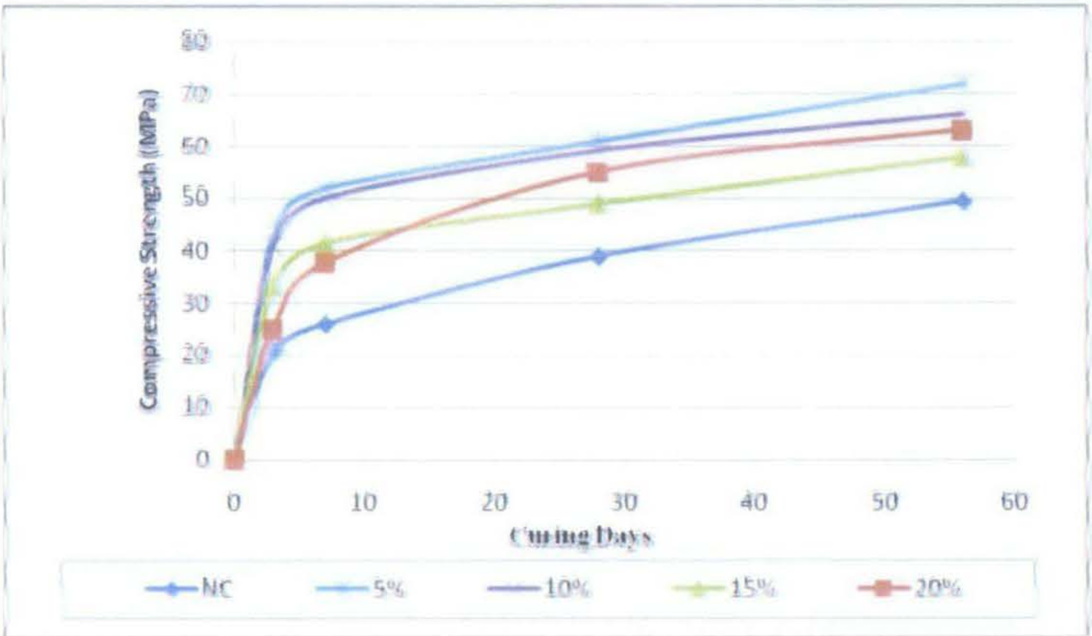


Figure 2.2: Compressive Strength Development of Concrete Sample with MIRHA at 800°C (Nuruddin, Shafiq and Mohd Kamal 2008)

From the research, it concluded that MIRHA is a new material that can be used as cement replacement material (CRM). MIRHA concrete offers higher in term of strength compared to normal concrete. MIRHA enhance concrete performance at early curing days also long term performance according to the results which shows the 56-day compressive strength test that the value of compressive strength are higher than normal concrete.

2.3 Water – Cement Ratio

The water-cement ratio (w/c) of the mixture has the most control over the final properties of the concrete. The water-cement ratio is the relative weight of the water to the cement in the mixture. Selection of a w/c ratio gives control over two opposing, yet desirable properties: strength and workability (Hover 2011). A mixture with a high w-c will be more workable than a mixture with a low w-c: it will flow easier. But the less workable the mixture, the stronger the concrete will be. The engineer must decide what ratio will give the best result for the given situation. This is not an entirely free choice because the water-cement ratio needs to be about 0.25 to complete the hydration reaction. Typical values of w-c are between 0.35 and 0.40 because they give a good amount of workability without sacrificing a lot of strength.

2.4 Parametric Study on Effects of Water-Cement Ratio to Compressive Strength of MIRHA Mortar

Yusoff (2011) had conduct a similar project to this research with water cement ratio of 0.50 and 0.55. Based on his thesis, the objectives of his project are;

1. To determine the most suitable composition of water cement ratio in mortar.
2. To find out the optimum percentage of MIRHA to cement in order to produce the best quality of MIRHA mortar.

The scope of study of the project was to vary the water cement ratio from 0.50 and 0.55, binder to aggregate ratio of 1:3 and 1:4 and to include MIRHA as CRM in the mortar (5, 10, 15, 20, 25, 30, 35, 40 and 45%).

The results of compressive strength are as figure 2.3 and 2.4.

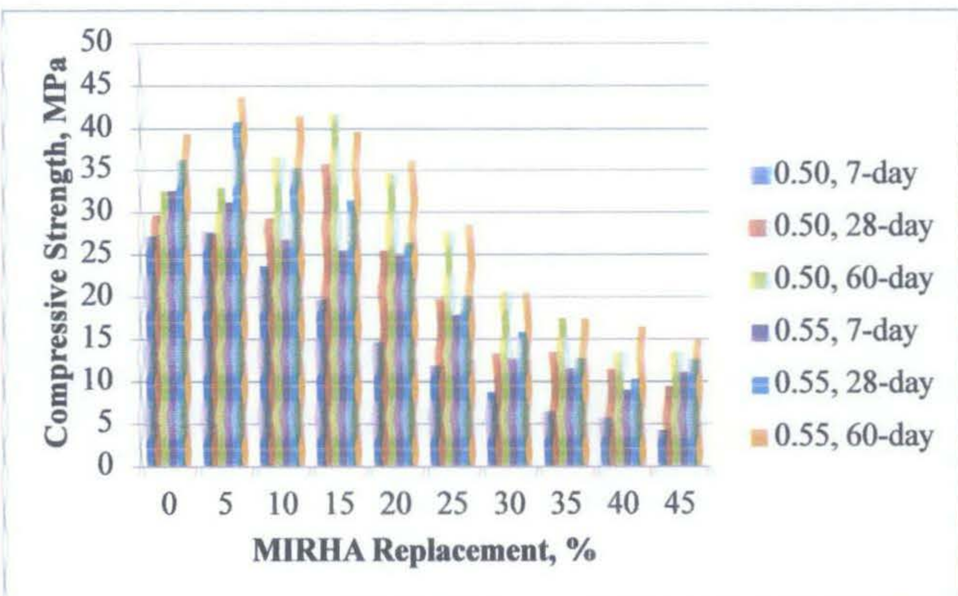


Figure 2.3: Compressive strength result of binder to sand ratio of 1:3 (Yusoff, 2011)

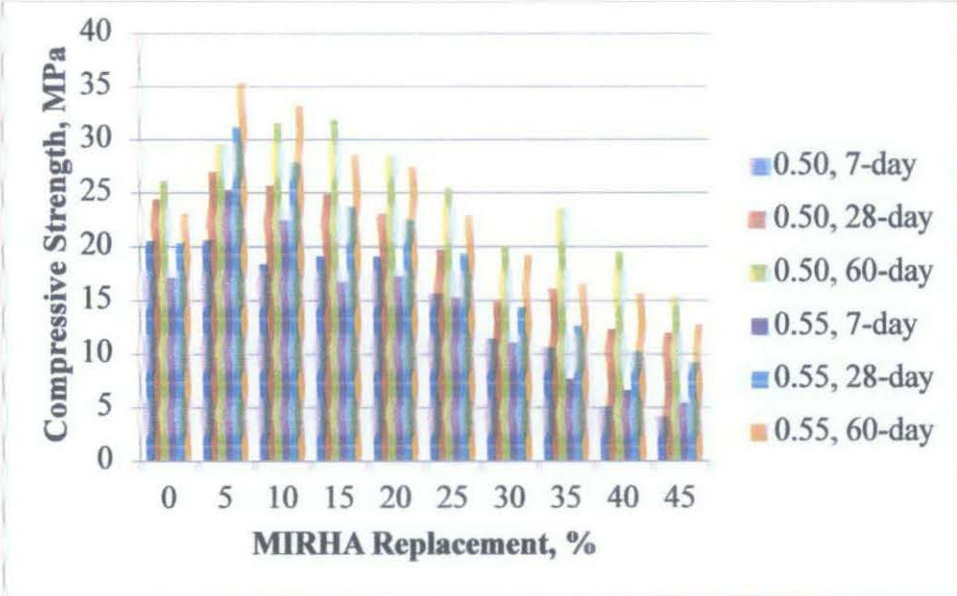


Figure 2.4: Compressive strength result of binder to sand ratio of 1:4 (Yusoff, 2011)

Based on compressive strength results, it was proved that water cement ratio of 0.55 is better than 0.50 in term of improving mortar strength. At 28-day compressive strength, the highest compressive strength of mortar recorded is 43.76 MPa with binder to sand ratio of 1:3 whereas, for binder to sand ratio of 1:4, the highest compressive strength recorded is 35.34 MPa.

The thesis proved that the increase of water cement ratio in MIRHA mortar, from 0.50 to 0.55, the compressive strength increased.

For water absorption of MIRHA mortar, the trend can be seen in figure 2.5.

Figure 2.5: Water Absorption of MIRHA Mortar (Yusoff, 2011)

The increase of MIRHA replacement increase the water absorption of MIRHA mortar due to the ability of MIRHA in absorbing water is better than cement. Ranges of water absorption that achieve are varies from 8% to 21%.

Similar to water absorption, result of initial rate of suction for MIRHA mortar also increase with higher cement replacement by MIRHA. The results are as per figure 2.6.

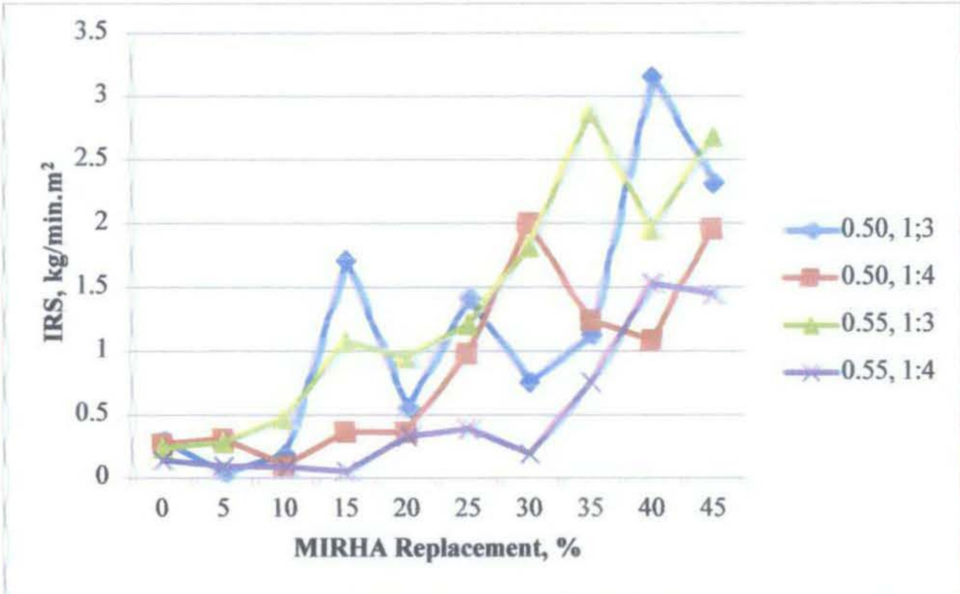


Figure 2.6: Initial Rate of Suction of MIRHA Mortar (Yusoff, 2011)

Although the result of IRS increases, most of the samples are in the accepted range of IRS for brick application which is within 0.25 kg/min.m^2 – 1.5 kg/min.m^2. Bricks beyond the range are considered high suction bricks which need to be watered before brick layering process because it is feared that the bricks will suck too much water from mortar during brick layering process and gives low bonding strength between bricks.

Final diameter of cement and MIRHA is the same based on Yusoff (2011) after sieving and hydrometer test is conducted to sand, cement and MIRHA. The earlier result, based on sieving analysis, MIRHA size shown is bigger than cement and as aspected, sand has the largest diameter compared to cement and MIRHA.

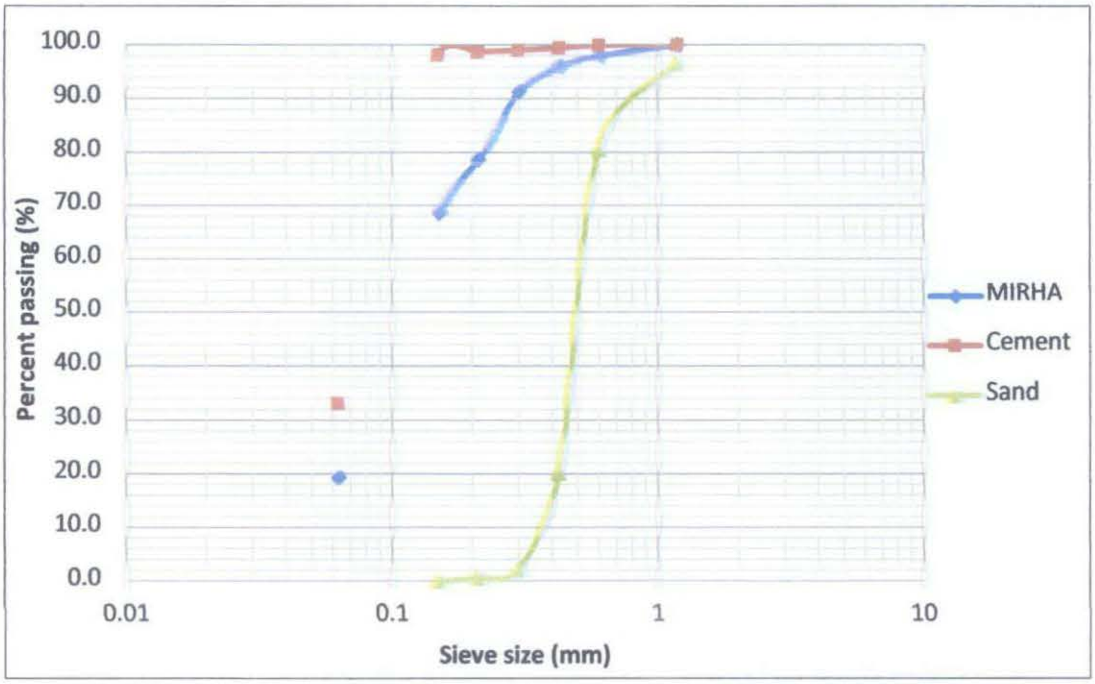


Figure 2.7: Results of Sieving Analysis (Yusoff, 2011)

2.5 The Importance of the Research

Less research done on MIRHA mortar induced the selection of this project to further the past Final Year Project on MIRHA mortar. In order to relate the past project result and this project, same testing method, material used and procedure are followed to come out with a solid conclusion on MIRHA mortar. By varying the water to cement ratio, this project can be considered as the continuation of study on MIRHA mortar in order to develop varieties of research done towards the new CRM in the cement industry which is MIRHA.

CHAPTER 3

METHODOLOGY

3.1 Main Process

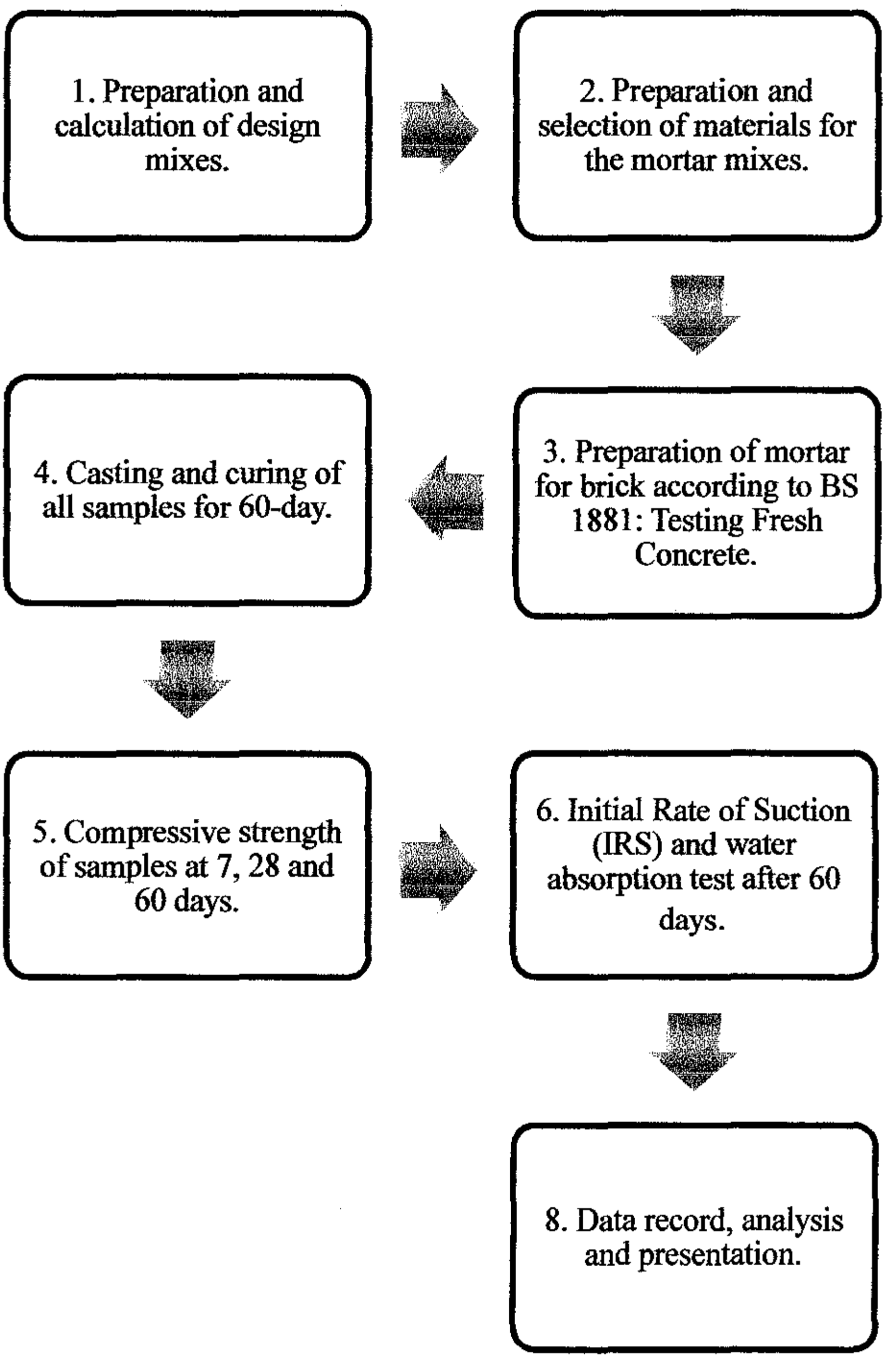


Figure 3.1: Project Activities

The experimental work will be conducted as per flow chart in figure 3.1. The purpose of having the flow chart is to highlight the main activities need to be conducted during the project.

3.2 Materials

The main materials needed to conduct this project are; cement (OPC), sand, tap water and MIRHA.

3.2.1 Cement

The cement used in this project is Ordinary Portland Cement (OPC) type 1 since the mass use in the industry. The cement comprised of cement and up to 5% of minor additional constituents, according to BS EN 197-1: 2000. The samples are casted using the same brand of OPC to avoid any effect with the compressive strength of the samples in the future.

3.2.2 Sand

Sand is obtained from UTP Concrete Laboratory. The preparation of sand one day before mixing needed to be done to make sure the aggregate is dry before any mixing activity is done. The purpose of preparing the sand before mixing activities one day ahead is to make the sand easier during sieving procedure. The sands are sieved to obtain the specified size of 2.36 mm and below.

3.2.3 Water

The water is taken from laboratory tap water. The water ratio used in the experiment is 0.6 and 0.65. The purpose of having different water ratio is to obtain the minimum strength of brick required in BS 6073 and BS 6717.

3.2.4 Microwave Incinerated Rice Husk Ash (MIRHA)

MIRHA can be obtained from UTP Concrete Lab. In order to get MIRHA, rice husk is needed to be burnt at 800°C in the UTP Microwave Incinerator in UTP Highway Laboratory. The purpose of burning the rice husk with high temperature is to maximize the amount of silica in MIRHA.

The portion of MIRHA varies in each sample. It starts with 0%, 5%, 10%, 15%, 20%, 25% and 30%. The rationale of varying the percentage replacement of cement in the samples is to obtain the minimum strength needed of brick based on BS 6073 and BS 6717.

3.3 Mix Design Proportioning

In this project, there are 28 different samples that need to be made. Each sample has different properties. Mix ID for samples is named by 4 sections, 1st is for percentage of MIRHA addition, 2nd the type of CRM used (in this projecth is MIRHA), 3rd the binders to sand ratio and 4th the water ratio. For example, 0M360, it stands for 0% of MIRHA addition, using MIRHA as CRM, binders to sand ratio of 1:3 and water to cement ratio of 0.60. For total, there are 420 cubes need to be prepared during this project. The following are the mix proportioning for the mixes;

Table 3.1: W-C Ratio= 0.6, Binder : Aggregate = 1 : 3

Mix ID	MIRHA %	Water (kg)	MIRHA (kg)	Cement (kg)	Sand (kg)	Total Mass(kg)
0M360	0	0.5870	0.0	0.9783	2.9348	4.5
5M360	5	0.5870	0.0489	0.9293	2.9348	4.5
10M360	10	0.5870	0.0978	0.8804	2.9348	4.5
15M360	15	0.5870	0.1467	0.8315	2.9348	4.5
20M360	20	0.5870	0.1957	0.7826	2.9348	4.5
25M360	25	0.5870	0.2446	0.7337	2.9348	4.5
30M360	30	0.5870	0.2935	0.6848	2.9348	4.5

Table 3.2: W-C Ratio= 0.6, Binder : Aggregate = 1 : 4

Mix ID	MIRHA %	Water (kg)	MIRHA (kg)	Cement (kg)	Sand (kg)	Total Mass(kg)
0M460	0	0.4821	0.0	0.8036	3.2143	4.5
5M460	5	0.4821	0.0402	0.7634	3.2143	4.5
10M460	10	0.4821	0.0804	0.7232	3.2143	4.5
15M460	15	0.4821	0.1205	0.6830	3.2143	4.5
20M460	20	0.4821	0.1607	0.6429	3.2143	4.5
25M460	25	0.4821	0.2009	0.6027	3.2143	4.5
30M460	30	0.4821	0.2411	0.5625	3.2143	4.5

Table 3.3: W-C Ratio= 0.65, Binder : Aggregate = 1 : 3

Mix ID	MIRHA %	Water (kg)	MIRHA (kg)	Cement (kg)	Sand (kg)	Total Mass(kg)
0M365	0	0.6290	0.0000	0.9677	2.9032	4.5
5M365	5	0.6290	0.0484	0.9194	2.9032	4.5
10M365	10	0.6290	0.0968	0.8710	2.9032	4.5
15M365	15	0.6290	0.1452	0.8226	2.9032	4.5
20M365	20	0.6290	0.1935	0.7742	2.9032	4.5
25M365	25	0.6290	0.2419	0.7258	2.9032	4.5
30M365	30	0.6290	0.2903	0.6774	2.9032	4.5

Table 3.4: W-C Ratio= 0.65, Binder : Aggregate = 1 : 4

Mix ID	MIRHA %	Water (kg)	MIRHA (kg)	Cement (kg)	Sand (kg)	Total Mass(kg)
0M460	0	0.5177	0.0000	0.7965	3.1858	4.5
5M460	5	0.5177	0.0398	0.7566	3.1858	4.5
10M460	10	0.5177	0.0796	0.7168	3.1858	4.5
15M460	15	0.5177	0.1195	0.6770	3.1858	4.5
20M460	20	0.5177	0.1593	0.6372	3.1858	4.5
25M460	25	0.5177	0.1991	0.5973	3.1858	4.5
30M460	30	0.5177	0.2389	0.5575	3.1858	4.5

3.4 Design Specification

The moulds that being used in this project have dimensions of 50mm X 50mm X 50mm. The quantity of mortar cube that each sample need are fifteen mortar cubes (9 cubes for compressive strength test 7-day, 28-day and 60-day, 3 cubes for water absorption test and 3 cubes for initial rate of suction test). The average results for all samples are shown in the result section.

3.5 Mixing of Samples

The mixing procedures in this project follow the standard in BS 1881: Part 125: 1986 – Methods for Mixing and Sampling Fresh Concrete in the Laboratory. The mixing procedures are describes as follows;

1) The mixer is wetted with water before mixing starts.
2) Sand is poured into the mixer for about 25 seconds.
3) Half of the water is poured into the mixer. Mix water and sand for about 1 minute.
4) The mixture of water and sand is left for 8 minutes.
5) Pour cement into the mixer. Mix for about 1 minute.
6) Pour the remaining water.mix for the other 1 minute.
7) Use hand mixing to ensure the homogeneity of the mixture.

3.6 Casting and Curing

Before the mixes are poured into the moulds, the moulds first need to be brush with lubricants. The purpose of brushing the moulds with lubricants before casting the samples is to make demoulding process will be easier. The lubricants will make the sample not to stick to the moulds, thus making demoulding become much easier.

The next day, demoulding process needed to be done. The samples will be stored in a curing tank in UTP Concrete Laboratory. Curing process is done to make the process of mixtures hydration and cracking due to temperature fluctuation is reduce, thus make the samples is able to achieve its high strength.

3.7 Proposed Tests for the Project

There are several tests that are relevant for this project. They are; compressive strength test, water absorption test and internal rate of suction test (IRS).

3.7.1 Compressive Strength Test

The test will be conducted using Digital Compressive Testing Machine that present in UTP Concrete Laboratory. The test will be conducted on 7-day, 28-day and 60-day from the samples' casting date. Three cubes of the same sample will be tested. The compressive strength is measured using the average value of the crushed cubes.

The purpose of this test is to measure the strength of the samples. In order to propose the project to be relevant for brick, the test will show the strength of the mortar produced.

3.7.2 Water Absorption Test

Weight of water in a brick expressed in the percentage of dry brick is water absorption in a brick is all about. The value of absorption varies from 4.5% to 21% due to the different of raw materials used in the manufacturing company and the procedure of bricks manufacturing.

The procedure of conducting water absorption test for this project is based on ASTM C67-60a. The procedures are as follows;

1. The samples are oven-dried in the oven for 110°C - 115°C for 24 hours.
2. After oven-dried, samples are cooled in room temperature (24±8°C) with 30% to 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 $(W_{sc} - W_d)/W_d$

3.7.3 Initial Rate of Suction Test

IRS denotes the amount of water sucked by the brick upon contact with mortar during layering. Resulting from the presence of capillary mechanism of the small pores in the bricks, the IRS is an important property in masonry construction since it affects the bond strength between the brick and the mortar. The IRS also affects water tightness and durability of masonry.

IRS is determined by the amount of water absorbed through the bed face when immersed in 3mm depth of water for a period of 1 minute.IRS is recognised as crucial requirement for highly stressed masonry by the British Standard and a test method to determine IRS is given in BS 3921:1985, the procedures are as follows;

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

3.8 Gant Chart FYP1

Table 3.5: Proposed Gant Chart for FYP1

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 (MIRHA)																		
6	Mixing & Casting (Control Mortar)																		
7	Mixing & Casting (Remaining Samples)																		
8	Compressive Strength Test (7-Day)																		
9	Compressive Strength Test (28-Day)																		
10	Data Record & Analysis																		
11	Project/Proposal Defense																		
12	IRS & Water Absorption Test																		
13	Submission of Interim Draft Report																		
14	Submission of Interim Report																		

Table 3.6: Gant Chart for FYP2

NO	ACTIVITIES	WEEK														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Compressive Strength Test (60-Day)	■	■	■	■											
2	Data Record & Analysis	■	■	■	■	■	■	■	■	■	■	■				
3	Submission of Progress Report								■							
4	Submission of Draft Report												■			
5	Submission of Dissertation (Soft Bound)													■		
6	Submission of Technical Paper													■		
7	Oral Presentation														■	
8	Submission of Project Dissertation (Hard Bound)															■

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter will discuss about results of several tests that have been done for all of the samples which are Compressive Strength test (7, 28 and 60 days), Water Absorption test (60 days) and Initial Rate of Suction test (IRS) (60 days).

4.1 Results

4.1.1 Compressive Strength

For 1:3 binders to sand ratio with 0.6, and 0.65 water cement ratio, all mixes have been completed. The results are as table 4.1 and 4.2.

Table 4.1: Compressive Strength Test Results for 1:3 binder to sand ratio and 0.6 and 0.65 water cement ratio

MIX ID	7-days strength (MPa)	28-days strength (MPa)	60-day strength (Mpa)	MIX ID	7-days strength (MPa)	28-days strength (MPa)	60-days strength (MPa)
0M360	24.58	43.55	45.21	0M365	28.67	44.92	47.07
5M360	23.54	46.17	49.29	5M365	23.56	39.46	41.82
10M360	17.08	38.58	47.07	10M365	18.59	33.00	36.79
15M360	14.78	33.45	39.99	15M365	25.45	32.72	34.17
20M360	17.08	24.57	35.22	20M365	22.28	34.12	34.59
25M360	12.69	21.53	28.85	25M365	19.24	34.22	35.00
30M360	17.29	23.25	30.64	30M365	18.96	25.93	27.43

Table 4.2: Compressive Strength Test Results for 1:4 binder to sand ratio and 0.6 and 0.65 water cement ratio

MIX ID	7-days strength (MPa)	28-days strength (MPa)	60-days strength (MPa)	MIX ID	7-days strength (MPa)	28-days strength (MPa)	60-days strength (MPa)
0M460	21.17	32.55	34.41	0M465	16.94	34.06	39.98
5M460	23.96	37.14	37.40	5M465	24.11	34.01	37.44
10M460	20.17	32.21	32.48	10M465	24.17	29.78	30.81
15M460	19.46	32.15	33.01	15M465	21.68	30.85	32.42
20M460	20.68	27.58	29.32	20M465	18.27	27.23	29.75

25M460	18.05	23.53	26.71	25M465	13.15	22.04	25.98
30M460	14.97	19.81	23.25	30M465	12.47	20.89	24.07

4.1.2 Water Absorption and Initial Rate of Suction

The results of water cement ratio of 0.50 and 0.55 are taken from the previous final year project student's result (Yusoff, 2011). The purpose of comparing the result with Yusoff's (2010) results is to show the relationship between this project and his project where this project is the continuation of his project in order to obtain the optimum water cement ratio of MIRHA mortar.

Table 4.3: Water Absorption Test Results of Different WC ratio and Binder to Sand ratio

1:3					1:4				
MIRHA (%)	**Water Cement Ratio**				**MIRHA (%)**	**Water Cement Ratio**			
	0.5	**0.55**	**0.6**	**0.65**		**0.5**	**0.55**	**0.6**	**0.65**
	Water Absorption, %					**Water Absorption, %**			
0	9.1	9.3	4.34	5.27	**0**	10.4	10.5	4.20	5.05
5	12.2	8.1	4.27	5.46	**5**	8.3	9.5	4.51	5.12
10	12.4	9.1	4.57	5.97	**10**	8.8	10.8	4.78	5.13
15	11.4	12.4	5.16	8.91	**15**	9.8	10.4	8.84	8.23
20	11.2	12.8	5.23	9.08	**20**	11.3	10.1	8.62	9.38
25	15.9	16.7	5.38	8.13	**25**	14	11.6	10.93	7.39
30	17	18.2	5.42	10.96	**30**	15.3	14.6	10.24	9.58

Table 4.4: Initial Rate of Suction Test Results of Different WC ratio and Binder to Sand ratio

1:3					1:4				
MIRHA (%)	**Water Cement Ratio**				**MIRHA (%)**	**Water Cement Ratio**			
	0.5	**0.55**	**0.6**	**0.65**		**0.5**	**0.55**	**0.6**	**0.65**
	IRS, kg/min.m²					**IRS, kg/min.m²**			
0	0.30	0.27	0.37	0.31	**0**	0.24	0.14	0.35	0.35
5	0.04	0.31	0.45	0.51	**5**	0.28	0.09	0.50	0.30
10	0.19	0.10	0.32	0.14	**10**	0.47	0.09	0.99	0.22
15	1.71	0.37	0.41	0.33	**15**	1.08	0.05	0.29	0.27
20	0.56	0.36	0.25	0.39	**20**	0.95	0.33	0.42	0.36
25	1.42	0.98	0.55	0.36	**25**	1.21	0.39	1.99	0.42
30	0.76	2.00	0.44	0.57	**30**	1.82	0.19	1.45	1.09

4.2 Discussions

4.2.1 Compressive Strength

The purpose of compressive strength test is to measure the strength of the samples can undergo and to find which type of sample have the highest strength. The result is shown in MPa.

The comparisons of compressive strength of water cement ratio 0.5 and 0.55 will be shown in the graphs below. The results are taken from the previous final year project student who was doing the same research on water cement ratio of 0.50, and 0.55 with binder to sand ratio of 1:3 and 1:4. The results for binder to sand ratio of 1:3 are as per figure 4.1.

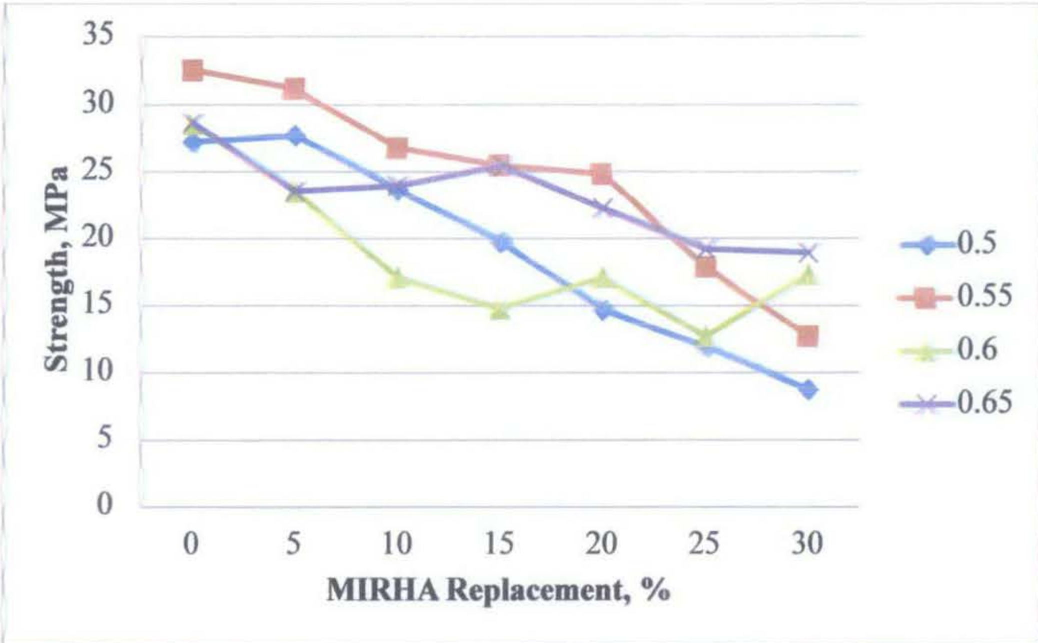


Figure 4.1: 7-Day Compressive Strength Results of Binder to Sand ratio of 1:3

The compressive strength of 0.60 water cement ratio mortars were not fully developed as shown in the graph with the lowest strength compared to the other water cement ratio mortars. However, for water cement ratio of 0.55, the result shows consistent trend of compressive strength which almost all of its MIRHA replacement, it has the highest strength on the 7-days test.

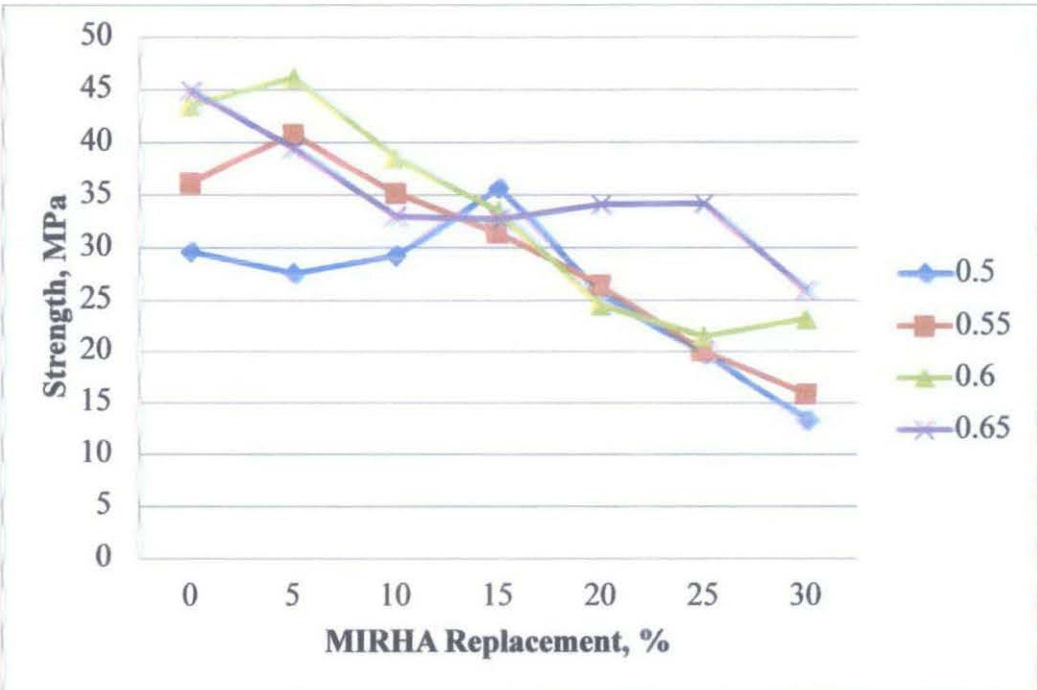


Figure 4.2: 28-Day Compressive Strength Results of Binder to Sand ratio of 1:3

For 28-days compressive strength test result, the high increment of strength developed by 0.60 water cement ratio mortar with 5% MIRHA replacement reached the highest strength compared to mortars of other water cement ratios. The trend can be observed in the graph which shows the trend of higher strength developed at 5% MIRHA replacement and the strength of mortar decrease with higher MIRHA replacement. This is exactly follow the past research on MIRHA which stated that, the optimum strength of MIRHA concrete is within 5% replacement of MIRHA in the mix (Nuruddin et. al, 2008).

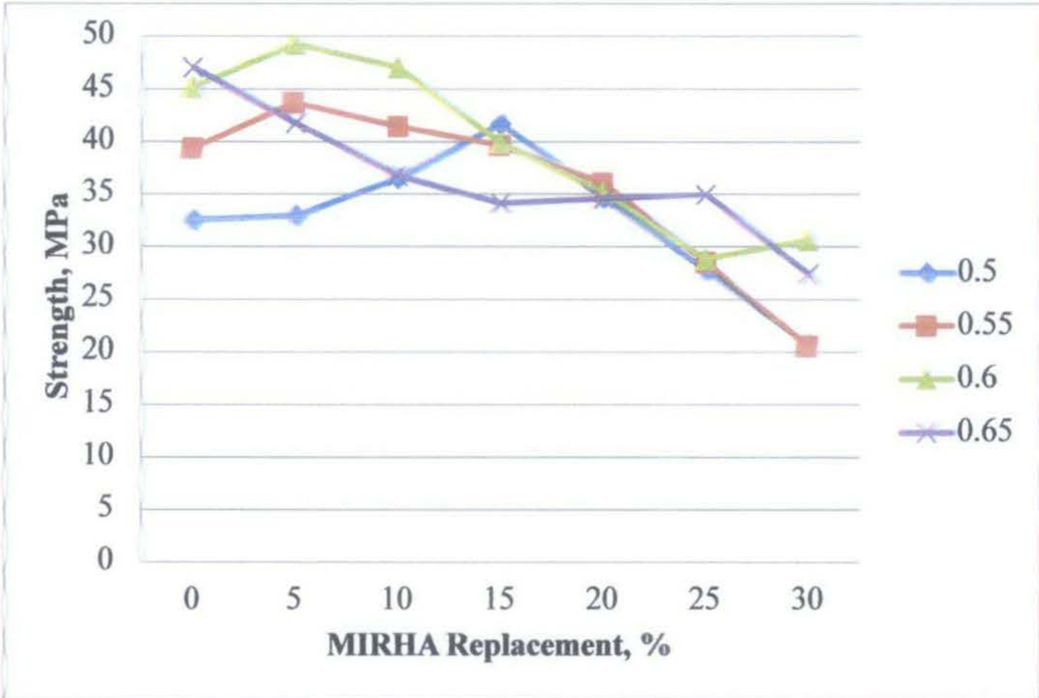


Figure 4.3: 60-Day Compressive Strength Results of Binder to Sand ratio of 1:3

From the 60-days results, conclusion can be made for binder to sand ratio of 1:3; the optimum strength of mortar is 49.29MPa of 5% MIRHA replacement. The decreasing trend of 0.65 water cement ratio samples compared to 0.60 water cement samples also can be concluded as the optimum water cement ratio of MIRHA mortar for binder to sand ratio of 1:3 is 0.60 water cement ratio. The conclusion made based on the increasing trend of strength from 0.50 until 0.60 and decrease at 0.65 water cement ratio. It is also has the possibility of the highest water cement ratio is between 0.60 and 0.65 water cement ratio.

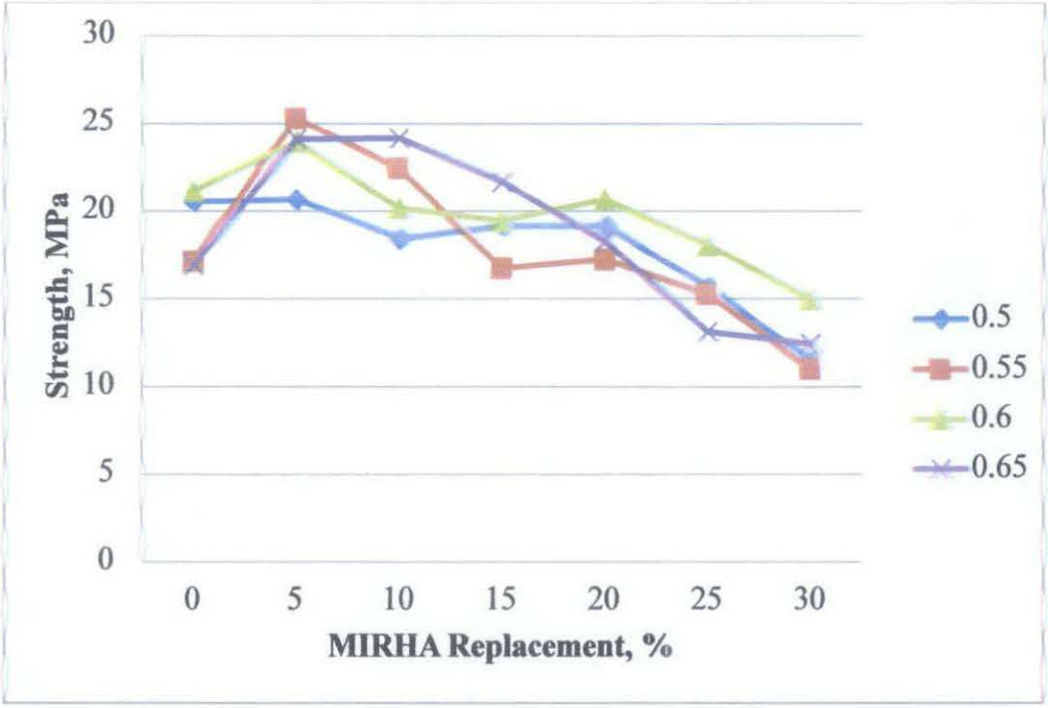


Figure 4.4: 7-Day Compressive Strength Results of Binder to Sand ratio of 1:4

The 7-days compressive strength test of binder to sand ratio of 1:4 shows increment of compressive strength on mortar with 5% MIRHA replacement to control. The highest 7-days compressive strength of mortar sample for binder to sand ratio of 1:4 samples is sample with 5% MIRHA replacement of 0.55 water cement ratio with compressive strength of 25.3MPa.

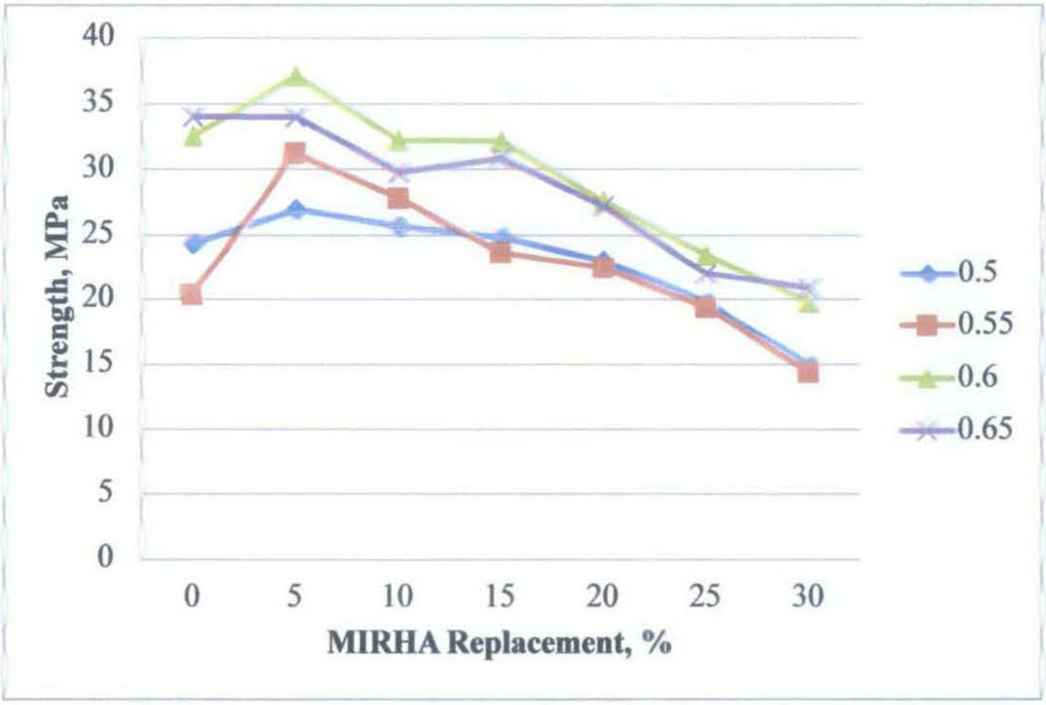


Figure 4.5: 28-Day Compressive Strength Results of Binder to Sand ratio of 1:4

Similar to the samples of binder to sand ratio of 1:3, the samples with water cement ratio of 0.60 have high result of 28-days compressive strength test with the highest compressive strength test value of 37.14MPa. The decreasing strength of samples at water cement ratio 0.60 and 0.65 can be seen in the graph. Therefore, we can conclude that the optimum strength of mortar samples in 28-days is the sample with 5% MIRHA replacement and water cement ratio of 0.60.

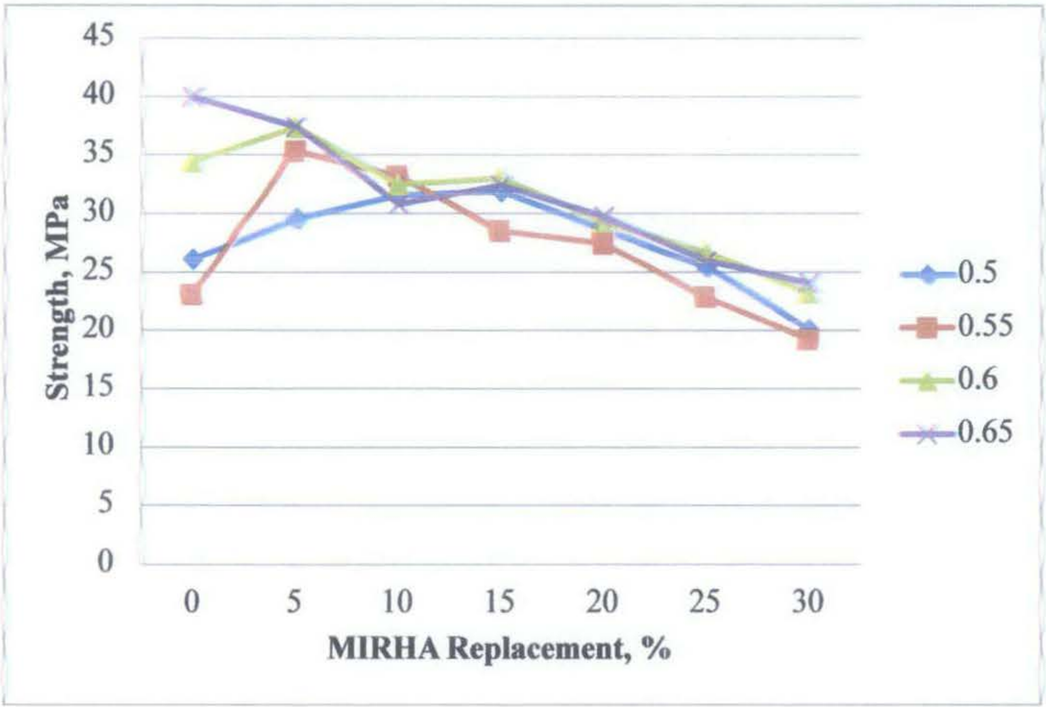


Figure 4.6: 60-Day Compressive Strength Results of Binder to Sand ratio of 1:4

However, based on 60-days compressive strength test results, the optimum strength of mortar is shared between water cement ratio of 0.60 and 0.65 with the compressive strength value of 37.44 MPa. The result of 0.65 water cement ratio mortar is decreasing compared to the control mortar. This result can be interpret as the water cement ratio increase until it reaches the optimum value for MIRHA mortar, the excess water in the mortar will result to decrease of compressive strength of the mortar itself. Based on the result, generalization on higher water cement ratio the lower the strength of samples after the optimum water cement ratio of sample is obtained can be made.

The comparison of binder to sand ratio can be observed in the graphs below. The purpose of comparing the strength of samples of the same water cement ratio is to compare which binder to sand ratio is better for this research.

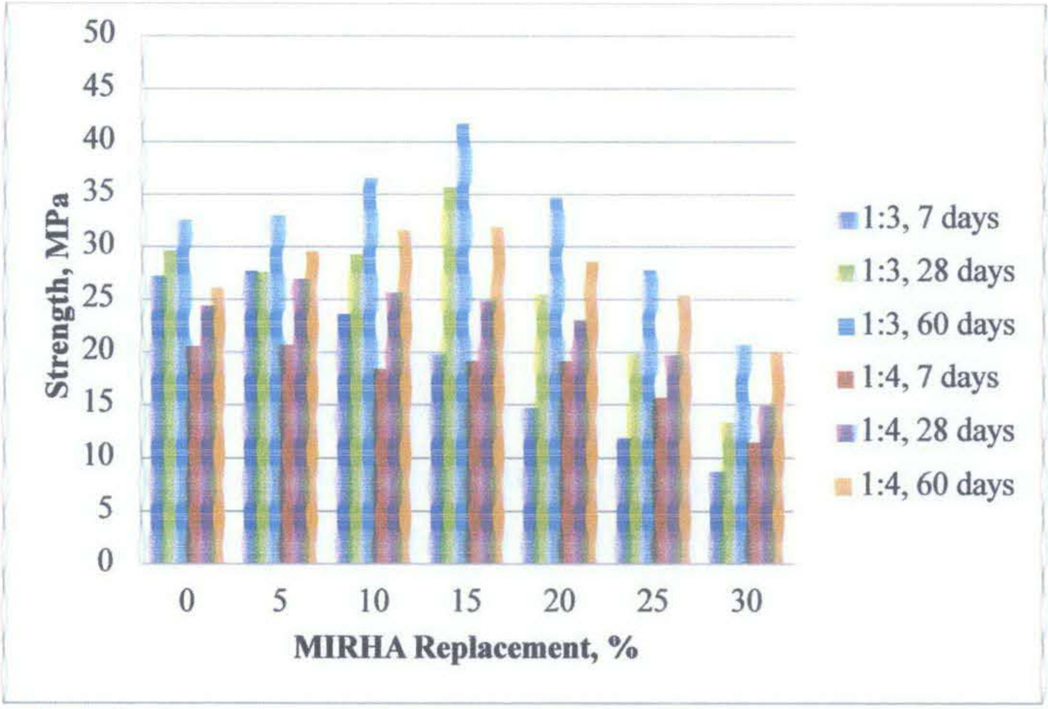


Figure 4.7: Compressive Strength Results of WC ratio of 0.50 (Yusoff, 2011)

Since the project is focused on the long term strength of samples, observation can be made that on 60-days compressive strength values of binder to sand ratio of 1:3 samples are better than the results of binder to sand ratio of 1:4 samples. Although the research is focused on long term strength of samples, the characteristic strength of samples at 28-day compressive strength test have already shown the strength of samples for binder to sand ratio of 1:3 is better than 1:4. Thus, we can say, for MIRHA mortar, the best binder to sand ratio is 1:3.

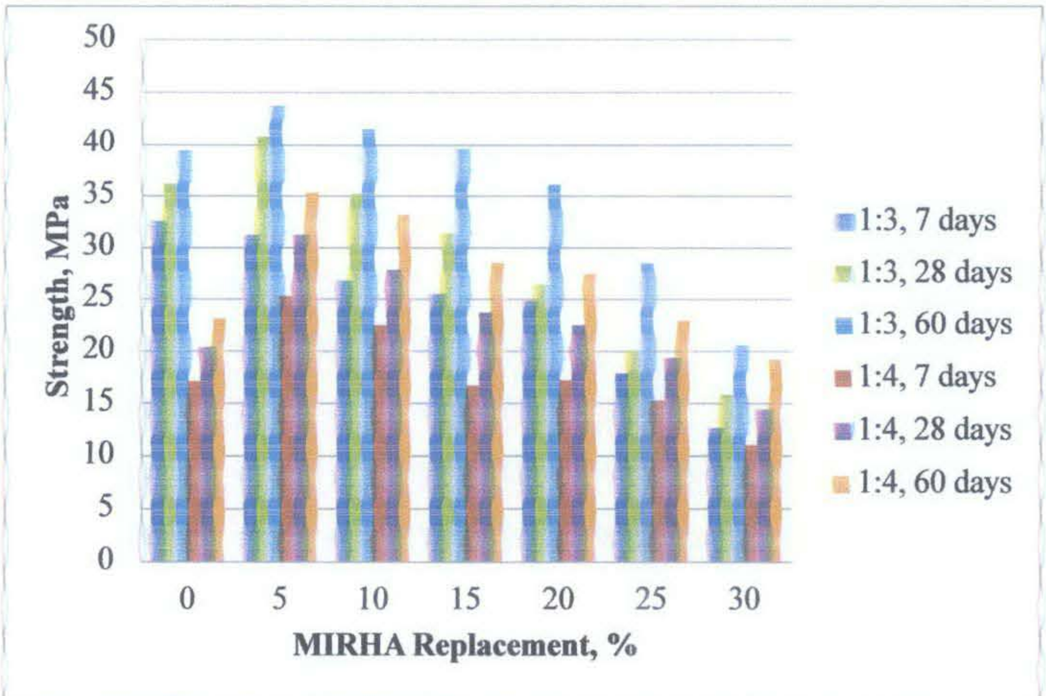


Figure 4.8: Compressive Strength Tests Results of WC ratio of 0.55 (Yusoff, 2011)

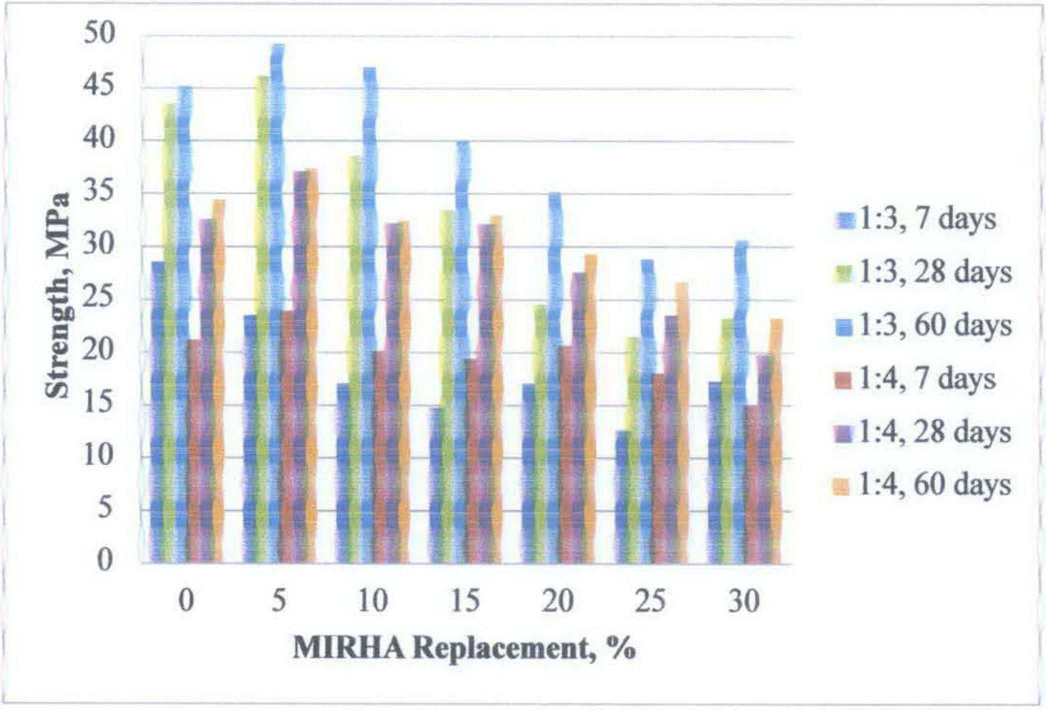


Figure 4.9: Compressive Strength Tests Results of WC ratio of 0.60

In this research, it is obtained that the highest compressive strength value for 60-day test of mortar is 49.29 MPa of 5% MIRHA replacement, water cement ratio of 0.60 and binder to sand ratio of 1:3.

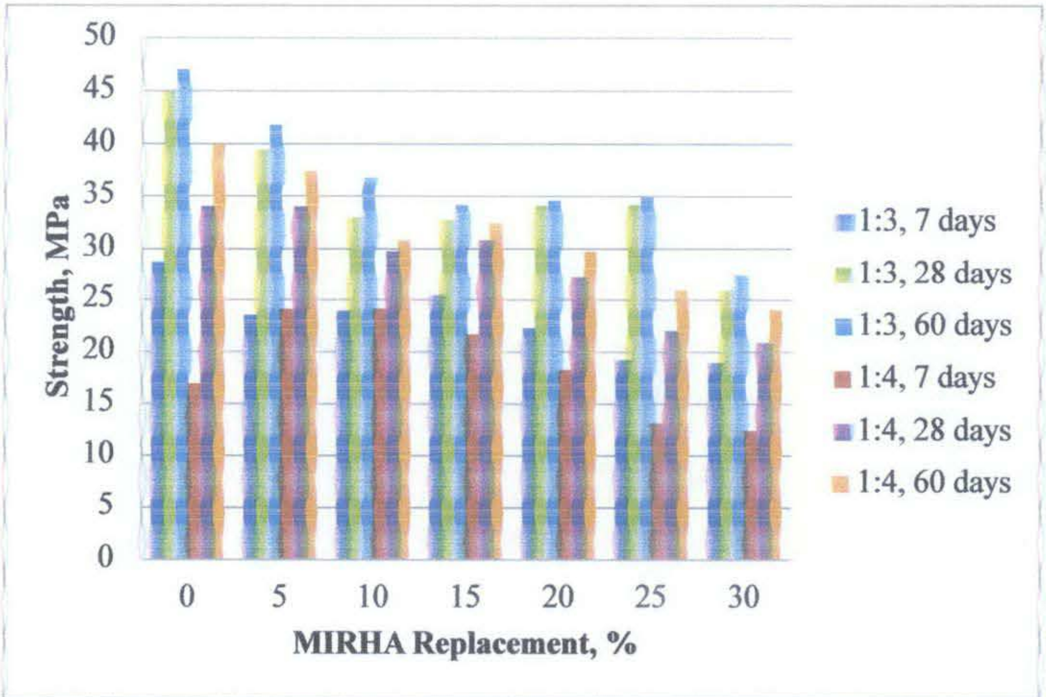


Figure 4.10: Compressive Strength Tests Results of WC ratio of 0.65

The decrease of strength in the samples of 0.65 water cement ratio shows the addition of water is irrelevant for more than 0.60 water cement ratio. It is because of the probability of the MIRHA mortar has reach its optimum water cement ratio, thus, the addition of water cement ratio is no longer improve the mortar strength.

The reason of strength variation of samples with 1:3 and 1:4 binders to sand ratio can be concluded that the different amount of binders in the samples affects the compressive strength test results of the samples. The trend can be observed in the compressive strength results of the samples at 7-days, 28-days and 60-days test. The values of 1:3 binders to sand ratio samples are higher than 1:4 binders to sand ratio samples. The high amount of binders, in this research refers to cement and MIRHA, will results to higher strength of mortar samples with proportion of 1:3 binders to sand ratio.

For control mortars, highest compressive strength test value recorded is at 0.65 water cement ratio and 1:3 binders to sand ratio with 47.01MPa. High values of compressive strength test may be results from high water ratio used in the mixes.

The observation has been made during mixing the samples that the mix of 0.6 and 0.65 water to cement ratio of 1:4 binders to sand ratio that the mixes are quite dried and hard to cast. The effect of using lower water cement ratio will result to drier mixes and hard to cast. Thus, the compressive strength results will be lower than what it supposed to be. However, use of plasticiser on mix of samples has not being done. There is possibility that by using plasticiser, the workability of mortar mix can be improved thus make casting process easier and may results to higher compressive strength test with lower water cement ratio.

To compare the results with BS6073, British Standard for masonry bricks which the minimum values of compressive strength of a brick must be at least 8MPa, all the samples passed the requirement at 7-days compressive strength test. This can be concluded that, masonry bricks can be fabricated using every proportion of the samples that have been done. The recommended proportion so far is to use the minimum strength that complies with the BS6073 is 25M360 which have the compressive strength of 12.69MPa.

Besides, to compare the results with BS6717, British Standard for pavement blocks requirement which the minimum value of compressive strength of a pavement block must be at least 49MPa during 28-days compressive strength test, no samples meet the requirement so far. The highest value recorded is 46.17MPa of 5M360 sample.

Based on previous research done, although the pavement block standard of BS6717 is not achieved, Hong Kong standard of pavement block on 28-days compressive strength test is achieved with the compressive strength test value must not be less than 30MPa (Poon, Kou and Lam 2002). The samples can still be used to be the pavement block for footway according to Hong Kong standard.

4.2.2 Water Absorption Test

The purpose of doing water absorption test is to observe the ability of mortar to absorb water for a long period of time. If the mortar absorbs too much water, it will result to less durability of mortar for a long time. Thus, the less it absorbs, the better the mortar mixes.

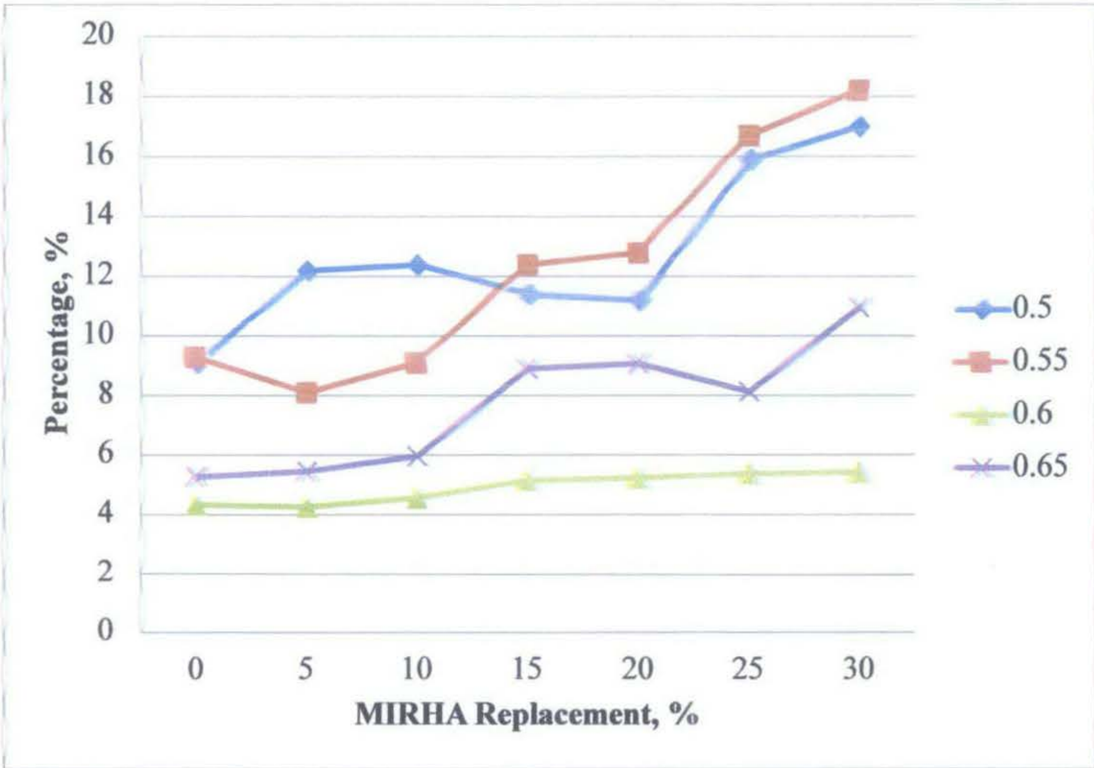


Figure 4.11: Water Absorption Tests Results of 1:3 Binders to Sand ratio

Based on the graph, it can be concluded that samples of 0.60 and 0.65 have less pores than samples of 0.50 and 0.55 water cement ratio. The reason of higher values of water absorption tests are due to pores in samples of 0.50 and 0.55. Less workability of samples during casting were the main reasons of pores in the sample developed. Based on observation during mixing and casting the samples of 0.60 and

0.65 water cement ratio, the workability of the mixes are hard to handle. Thus, for lower water cement ratio will results to lower workability of mixes and develop large number of pores inside the mixes.

However, for 0.65 water cement ratio, the samples show higher water absorption than sample of 0.60 water cement ratio. Since the samples have to be oven dried for more than 24 hours, at temperature of 110°C, the water inside the samples have already dried. Thus, the pores inside the mortars depend on the water cement ratio of the mixes. Since 0.65 is higher than 0.60, the pores inside 0.65 water cement ratio sample are suppose to be higher.

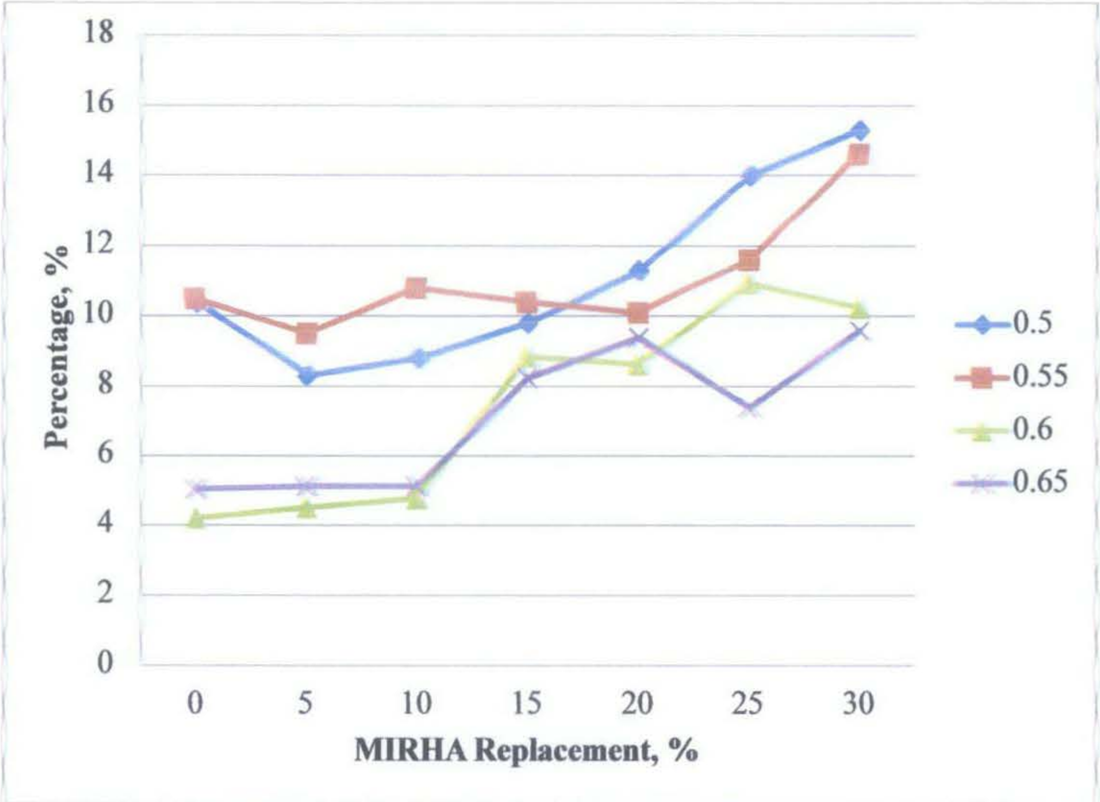


Figure 4.12: Water Absorption Tests Results of 1:4 Binders to Sand ratio

Similar conditions of results appear for the samples of 1:4 binders to sand ratio. The MIRHA inside the mortar also have fully reacted and due to its small sizes, it filled up gap inside the mixes. Therefore, fewer pores appear in the samples of 0.6 and 0.65 water cement ratio. MIRHA is also proved to be pozzolanic materials that fill the segmentation and capillary voids in the mortar. Although the mix of water cement ratio 0.50 and 0.55 also have MIRHA, but less workability of mixes during casting contribute otherwise results.

Possibility of not-reacted MIRHA inside the mortar is also considered to be the reason of high water absorption in samples of 0.50 and 0.55 water cement ratio. The MIRHA somehow able to react after all water is removed from the samples during submersion of samples in clean water in 24 hours. However, there is no solid evidence about the reaction occurrence since the samples are already cured for 60-days, which the access of water should be more than enough for the MIRHA to react.

Therefore, base on observation on the results, 0.60 water cement ratio produces good workability of mortar during mixing and reduces pores compared to samples of 0.50 and 0.55 water cement ratio mixes.

4.2.3 Initial Rates of Suction Test (IRS)

Initial rate of suction or IRS is defined as the number of grams of water absorbed in one minute over area (Wyoming n.d.). The IRS is measured with kg/m^2.min based on BS3921.

The purpose of measuring the IRS is to identify whether the mortar samples have high suction properties or not. If the mortar samples have high suction properties, during the application of mortar as bricks, the bricks will suck the water from mortar during brick layering. This will result to rapid suction of water from the mortar and result to less strength of mortar that bond the bricks. Therefore, if the bricks have high suction properties, the bricks have to be wetted before layering occurs. However, if the bricks are too wet, the water inside the bricks will be absorb by mortar which also can reduce the strength because designated water ratio is changed.

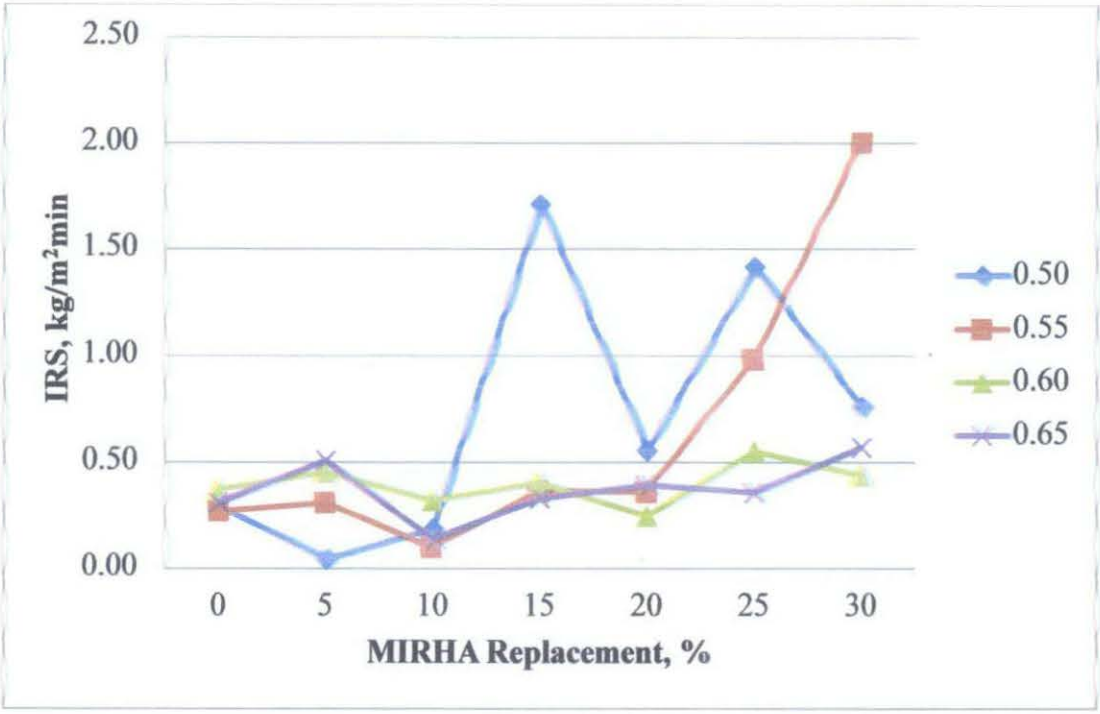


Figure 4.13: Initial Rates of Suction Tests (IRS) Results of 1:3 Binders to Sand ratio

The initial rate of suction for the bricks ranged from 1.4 to 2.0 kg/min.m^2 indicating high suction property thus implying the necessity of wetting bricks before bricks layering (Ali 2005). Based on the initial rates of suction for bricks, the mortar samples of 0.60 and 0.65 water cement ratio are all classified as low suction property which is good for application as bricks.

Figure 4.14: Initial Rates of Suction Tests (IRS) Results of 1:4 Binders to Sand ratio

As per figure 4.14, almost all samples were under the value 1.4 kg/min.m^2 which indicating acceptable value for IRS test. Based on observation during conducting the test, the surface of sample also affects the value of IRS. It was observed that, with the increase value of MIRHA replacement, the workability of mixes become lower and effect casting process. Therefore, it is concluded higher the pores, the higher IRS value.

However, for 0.65 water cement ratio samples, the workability of all mix during mixing were high for all samples which indicating high access of water in the samples. Less pores at the surface of samples 0.65 compared to samples 0.60 water cement ratio. Furthermore, those samples were 1:4 binders to aggregate samples. The workability of samples is very low due to the extra presence of sand and low amount of binders.

4.2.4 Project Viability and Economic Benefit

The project is conducted with available materials in the university. Most of material can be taken from the laboratory except for cement (OPC). Therefore, the cost needed for the project is only the cost for OPC. The mass of OPC used in the project that had been pre calculated before the project starts with every sample have extra 2 mortar cubes is around 24 kg.

The cost of this project can be calculated as:

Mass of OPC/Packet = 50 kg

Price OPC/Packet = RM 18.00

Total cost of project = 24/50 x 18

= RM 8.64

However, the cement is needed to be purchase by packet; therefore the cost of project is RM 18.00.

For commercialization purposes, it is proposed that sample from Yusoff (2011) is used. The suitable sample for brick commercialization based on the thesis consists of 45% cement replacement by MIRHA, water cement ratio of 0.55 and binder to aggregate ratio of 1:4.

By using the value, the amount of cement can be reduced is up to 45% which can be saved from cost of purchasing cement. To see in a clearer view, rough calculation on 10m^3 of mortar will be calculated further.

During this project, it is assumed that density of mortar is equal to the density of concrete, thus the calculation is based on density of concrete which is $24kN/m^3$. The mass of water, cement, MIRHA and sand for the proportion stated earlier are as follows;

The total mass of $10m^3$ mortar is 24, 000 kg.

Sand	Cement	MIRHA	Water
17, 963 kg	2, 023 kg	1, 647 kg	2, 379 kg

Based on the calculation, the amount of cement can be reduced is more than 1 tonne. The cost of cement per bag is RM 18.00, thus for this project, we can save the cost of cement for RM 729.00.

The cost of rice husk is free since it is abundantly available at the environment. Thus the price of MIRHA is based on transportation, labour and electric cost for preparing MIRHA.

Based on observation of MIRHA preparation during the project, it is estimated that 50 kg of rice husk will produce 5 kg of MIRHA which is about 1:10 ratio. Thus, for commercialization purposes, 1 647 kg of MIRHA would need 16, 470 kg of rice husk to be prepared. By assuming MIRHA can be produce for 2 tonnes amount per preparation, the cost should be considered is 2 trips of 10 tonnes lorry to the MIRHA production area.

Assuming the MIRHA production area is very near to a rice factory, the cost of transportation is estimated as RM 200.00 per trip.

The electric cost for the incinerator in UTP is 63kW. MIRHA preparation for 800°C need 1 hour burning process. Assume the power needed by the equivalent incinerator is the same with the one in UTP. The cost of electricity needed for converting rice husk into MIRHA can be calculated by multiplying electric tariff rate from Tenaga Nasional Berhad (TNB) with the power used by the incinerator.

Cost of electricity is;

63kWh X RM 0.22 = RM 13.86

Therefore, cost of MIRHA production for $10m^3$ MIRHA mortar is about RM 415.00 whereas cost of cement reduced is about RM 730.00. This concluded that use of MIRHA safe about 24% cost of cement purchasing.

It is assumed other cost, aside from cement is similar to the cost of cement bricks. Thus, the cost of MIRHA brick is manipulated solely by the cost of MIRHA.

To compare with other bricks available in the industry, the cost of MIRHA brick is estimated to be the lowest. The cost per brick is estimated around RM 0.20 with other cost that is unforeseen; the cost of MIRHA bricks is estimated to be RM 0.25 to RM 0.30 per brick which is cheap compared to available brick in the nearest brick manufacturers near UTP. Table 4.5 summarize the cost of brick available in the industry with MIRHA bricks.

Table 4.5: Types of Brick and Discount Comparison to MIRHA Brick

Types of Brick	MIRHA	Clay	Cement
Cost per brick (RM)	0.25-0.30	0.45 – 0.60	0.30 – 0.35
Local Supplier	-	Hiap Lee Clay Pavers. Sdn. Bhd.	Bricks Sdn. Bhd.
Discount Comparison (%)	Minimum	44	17
	Maximum	58	29

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Compressive Strength

During 7-days compressive strength test, highest compressive strength achieve were mix of 1:3 binders to sand ratio and 0.55 water to cement ratio.

During 28-days compressive strength test, highest compressive strength test measured is sample 5M360 with 1:3 binders to sand ratio and 0.60 water to cement ratio with 46.17MPa.

During 60-days compressive strength test, the highest strength mortar is sample 5M360. The compressive strength value is 49.29MPa.

For mortar samples of 1:4 binders to sand ratio, trend of increment at 5% of MIRHA addition is observed during 7-days compressive strength test.

High amount of binders affect the strength of the mortar samples with 1:3 binders to sand ratio gives higher compressive strength results than mortar samples 1:4 binders to sand ratio.

Highest compressive strength test value recorded for control mortar is 44.92MPa of 0M360 sample with 0% of MIRHA addition, 1:3 binders to sand ratio and 0.65 water to cement ratio.

For 1:4 binders to sand ratio samples, the water demand is high so the use of plasticiser to improve workability of samples to ease casting is recommended.

It is also recommended that, use of plasticiser to ease mixing and casting after 15% replacement of MIRHA and above. It is because, mixing using more than 15% replacement of MIRHA is observed to be quite dry and hard to handle during mixing.

All mortar samples in this research comply with BS6073 of masonry brick requirement that bricks must at least have 8MPa test on 28-days compressive strength test.

The mortar samples in the research have not complied with BS6717 of pavement blocks requirement that requires 28-days compressive strength test must at least 49MPa.

Only sample 5M360 reaches the strength of more than 49 MPa. However, the result is obtained after 60-days of curing.

All mortar samples on this research so far complied with Hong Kong standard of pavement blocks that requires 30MPa compressive strength test at 28-days.

It is recommended to use 5% replacement of cement by MIRHA, water cement ratio of 0.6 and 1:3 binders to sand ratio for brick pavement as further research.

It is also recommended that commercialization of MIRHA bricks with 30% cement replacement, binder to sand ratio of 1:4 and water cement ratio of 0.65 as masonry brick as the 28-day compressive strength result is higher than 8 MPa based on BS 8073.

Water Absorption and Initial Rates of Suction (IRS)

Current results shows the samples of 0.60 and 0.65 water cement ratio has low water absorption which is good for brick characteristic.

Low IRS test results shows good quality bricks can be fabricate with this research proportion.

Almost every sample is suitable as bricks application and only 1 sample has the possibility to be made as pavement block.

REFERENCES

Ali, Z. A. (2005). *Properties of Malaysian Fired Clay Bricks and their Evaluation with International Masonry Specifications – A Case Study.* Johor, Malaysia: Universiti Teknologi Malaysia.

Hover, K. C. (2011). The influence of water on the performance of concrete. *Construction and Building Materials*, 3003–3013.

International Rice Research Institute, I. (2008). *Table 1. Paddy rice production (000 t), by country and geographical region, 1961-2007. (FAO).* Retrieved 6 29, 2011, from http://beta.irri.org/solutions/images/stories/wrs/wrs_jun09_2009_table01_usda_prod.xls

Ismail, M., Ismail, M., Lau, S., Muhammad, B., & Majid, Z. (2010). Fabrication of Bricks From Paper Sludge. *Concrete Research Letters, Vol. 1(2) 2010*.

Jha, J., & Gill, K. (2006). Effect of Rice Husk Ash on Lime Stabilization. *Journal of the Institution of Engineers (India) Volume 87*, 33-39.

Khalaf, F. M., & DeVenny, A. S. (2002). New Tests for Porosity and Water. *Journal of Material in Civil Engineering*.

Lee, J. A., & Mason, T. O. (2006). *Bricks and Tiles.* Retrieved 6 30, 2011, from http://www.britannica.com/EBchecked/topic/79195/brick-and-tile

Mcleod, R. S. (2005). Ordinary Portland Cement: with extraordinarily CO2 emissions. What Can be done to reduce them? *BFF Autumn*.

Mehta, P. K. (2002, July). Greening of the Concrete Industry for Sustainable Development. *Concrete International*, pp. 23-28.

Nuruddin, M. F., Shafiq, N., & Mohd Kamal, N. L. (2008). Microwave Incenerated Rice Husk Ash (MIRHA) Concrete: A New Material In Concrete Industry. *UK Malaysia Engineering Conference 2008, UTP Institutional Repository*.

Nuruddin, M., Qazi, S., Shafiq, N., & Kusbiantoro, A. (2010). Polymeric Concrete: Complete Elimination of Cement for Sustainable Futures. *ICSBI 2010 KL Conference*
.

Ou, E., Xi, Y., & Corotis, R. (2007). The Effect of Rice Husk Ash On Mechanical Properties Of Concrete Under High Tempratures, 18th Engineering Mechanics Division Conference. *M. ASCE (EMD2007)* .

Poon, C. S., Kou, S. C., & Lam, L. (2002). Use of Recycled Aggregates in Moulded Concrete Bricks and Blocks. *Construction and Building Materials (Volume 16)* , 281-289.

Schulze, J. (1999). Influence of Water-Cement Ratio and Cement Content on the Properties of Polymer-Modified Mortars. *Cement and Concrete Research 29* , 909–915.

Singh, B. (2007, September). Concrete Block Pavements for Roads. *New Building Material and Construction World* .

The Brick Industry Association, T. (2006, December). Manufacturing of Brick. *Technical Note on Bricks Construction* .

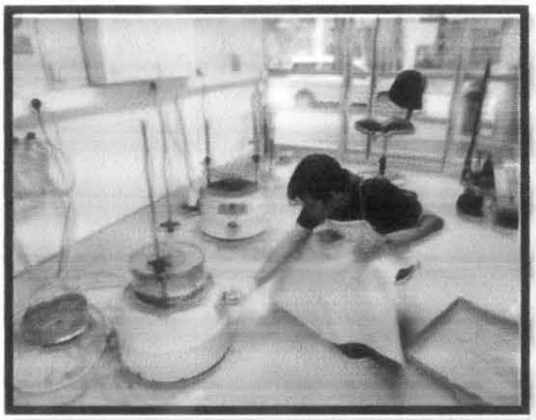
Worrell, E., Price, L., Hendricks, C., & Meida, L. O. (2001). *Annual Review of Energy and Environment, Vol 26, 2001.* INDUSTRIAL ENERGY ANALYSIS, LBNL-49097.

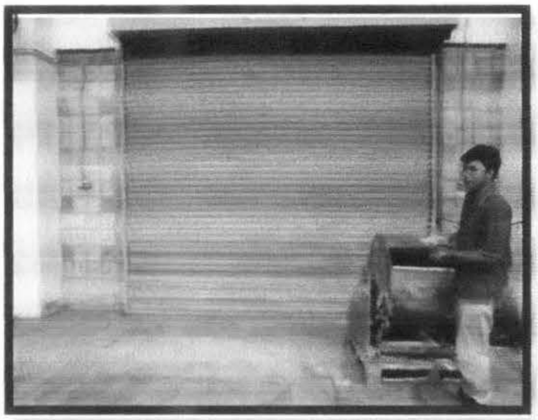
Wyoming, U. o. (n.d.). *Laboratory Website.* Retrieved November 18, 2011, from To Advance The Knowledge of Masonry: http://www.masonrysociety.org/Masonry%20Lab/Lab%201/Lab-1-IRA.html

Yusoff, M. F. (2011). *Parametric Study on Effects of Water Cement Ratio to Compressive Strength of MIRHA Mortar.* Universiti Teknologi PETRONAS.

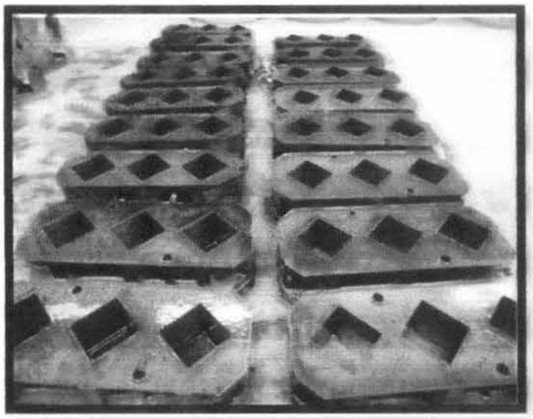
APPENDICES

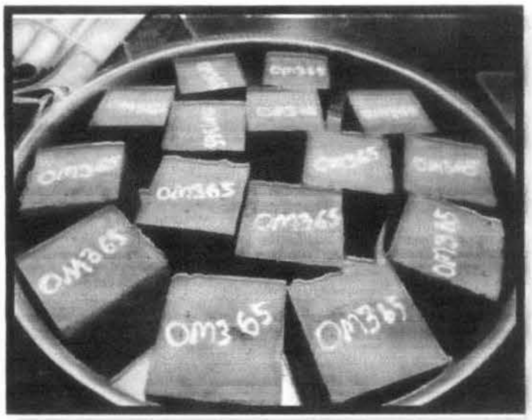
APPENDIX I: Preparation of Materials Prior to Laboratory Work

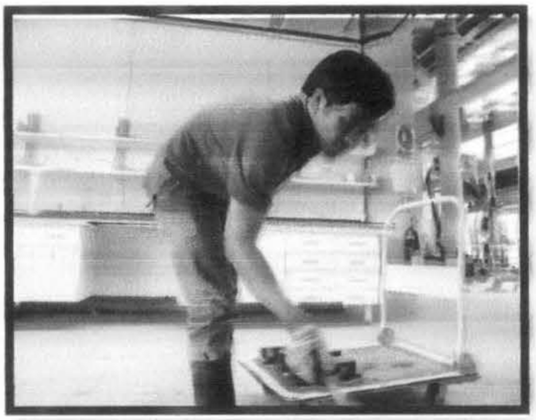


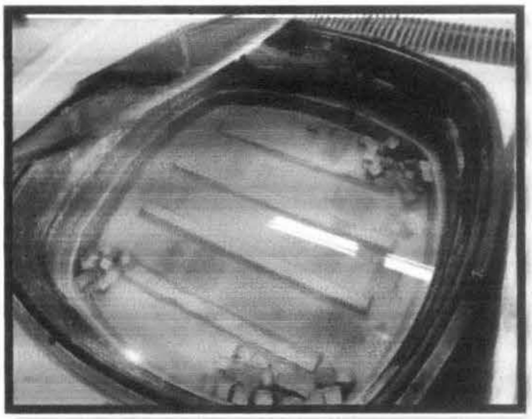


APPENDIX II: Mixing, Casting and Curing of All Samples

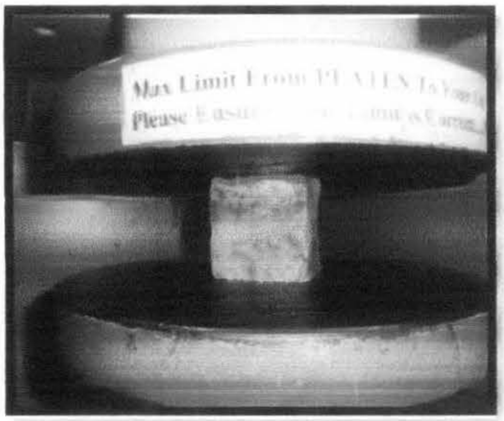
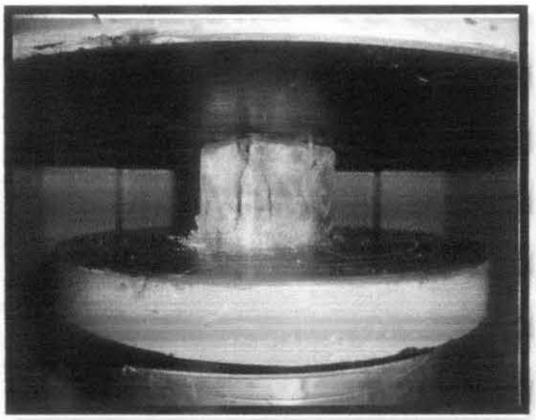


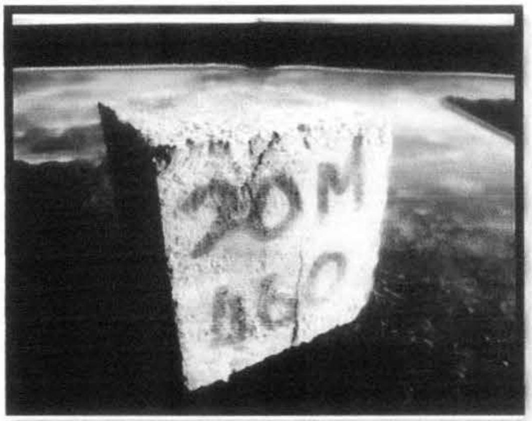






APPENDIX III: Compressive Strength Test of Samples at 7, 28 and 60 Days




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