MICROWAVE INCINERATED RICE HUSK ASH (MIRHA) AND PULVERIZED FUEL ASH (PFA) AS A MULTIPLE BINDER IN CONCRETE

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by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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TRONOH, PERAK

JANUARY 2009

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 HAFIZEE BIN HARON

ABSTRACT

The study deliberates on the incorporation of Microwave Incinerator Rice Husk Ash (MIRHA) and Pulverized Fuel Ash (PFA) as a multiple binders to produce concrete. The project was conducted to identify the optimum concrete mix proportion of binders containing Microwave Incinerated Rice Husk Ash (MIRHA) and Pulverized Fuel Ash as concrete replacement material. The optimum mix proportion of multiple binders to strengthen the concrete had been observed from the results. Concrete produce by using these materials will reduce the content of cement up to 15%, with increasing of the concrete strength until 40-50%. The importance of the new replacement materials lies mostly in the fact that superior qualities are achieved without having to increase the cement content. Thus it is also possible to reduce the amount of cement without affecting the required strength. The use of ternary blend Silica Fume, MIRHA and PFA is very effective in enhancing the compressive strength, tensile strength, integrity and surface hardness.

ACKNOWLEDGEMENT

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INTRODUCTION

1.1 BACKGROUND OF STUDY

Studies on fly ash (FA) started in 1966 by a Japanese name Kokubu during the 6th international symposium on the chemistry of cement held in Tokyo. The studies cover ash characteristics, testing pozzolanic reactivity, and influences of FA (physical and chemical) on properties of concrete. Then, since 1980s many researchers focus their study on the performance of concrete with the addition of fly ash as a supplementary cementing material due to the increasing concern about durability of concrete structures.

FA or pulverized fly ash (PFA), is a residue derived from the combustion of pulverized coal in furnaces of thermal power plant. The characteristics of FA vary according to the combustion operation system as well as the coal composition. Research studies revealed that FA, which is pozzolanic material, significantly improves the material transport properties of concrete, and the effect of pozzolanic materials is even greater than the effect of water-to-cement ratio.

Other than FA, rice husk ash (RHA) is also one of pozzolonic materials that has been studied to be incorporated into concrete as a cement replacement material. Rice husk (RH) is a by-product of rice paddy milling industries. For rice growing countries, RH has attracted more attention due to environmental pollution and an increasing interest in conservation of energy and resources. About 20% of dried rice paddy is made up of the RH. For developing countries where rice production is abundant, disposal of RH has become a challenging problem. It is recognized that only cement and concrete industries can consume such large quantities of solid pozzolanic wastes.

1.2 PROBLEM STATEMENT

Cement is a main composition in concrete. In the world, cement is widely used especially in construction field instead it was used in highway construction as filler. Previously, cement composition has no other addition or replacement of material until the research of pulverized fly ash (PFA) shown that the PFA contribute to improve some characteristics in concrete. In fact, the PFA in concrete prevent the heat evolved during the hydration process that will result of cracking to the concrete soon. PFA in cement was used in percentage of nearly 20% as a replacement material. So the use of PFA was established in the construction industry.

Another research also shown that the use of rice husk ash (RHA) in concrete also gives some improvement to the strength of concrete. It is because the composition of RHA has higher percentage of active silica that behaves as a pozzolanic material. For PFA and microwave incinerated rice husk ash (MIRHA) blended in cement, there still has no research developed. There has no chart or table that shows the proportions of both binders to use in concrete like PFA.

PFA-MIRHA blended cement has some informal research shows that the use of these by product can produce the higher strength and more durable concrete since both material is very fine material. Besides, in early 1960's, one established research has been done and found that the production of cement contributed to the air pollution. It exerts a large amount of carbon dioxide onto the air, where one ton of cement production emits nearly 900kg of carbon dioxide to the environment. By replacing partially the use of cement in concrete, it slightly helps to prevent from major pollution.

1.3 OBJECTIVE

The main objectives of this research are:

- To establish the effects of pulverized fly ash (PFA) and microwave incinerated rice husk ash (MIRHA) on concrete properties in term of its compressive strength, tensile strength, surface hardness and integrity.
- To identify the probable multiple binder mix proportion containing MIRHA and PFA in concrete.

1.4 SCOPE OF STUDY

The scope of this study covers the analysis of the properties of concrete that contains pulverized fly ash (PFA) and microwave incinerated rice husk ash (MIRHA). Tests conducted are:

- Compressive strength test
- Tensile strength test
- Surface hardness test
- Integrity test

For compressive strength test, the sample covers the shape of cube which dimension is 150mm X 150mm X150mm. This test conducted in every 3, 7 and 28 days after every cube has been cast. 3 samples is taken for each day and the result is from the average value. But for the 28th days testing, two non-destructive tests should be conducted before it been compressed, which is rebound hammer test (surface hardness) and ultrasonic pulse velocity test (integrity test).

Next, for tensile strength test, the sample covers the shape of cylinder which dimension is 300mm in height and 150mm in diameter. This test conducted in every 28 days after the sample has been cast.

For every casting, the slump test is conducted as a testing for workability. Then, after been cast and placed, all the sample is soaked into the water tank for curing process takes place until the day for those above tests is conducted.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is made up of three basic components: water, aggregate (rock, sand, or gravel) and Portland cement. Cement, usually in powder form, acts as a binding agent when mixed with water and aggregates. This combination, or concrete mix, will be poured and harden into the durable material with which we are all familiar.

There are three basic ingredients in the concrete mix:

1. Portland cement.

   The cement and water form a paste that coats the aggregate and sand in the mix. The paste hardens and binds the aggregates and sand together.

2. Water

   Water is needed to chemically react with the cement (hydration) and too provide workability with the concrete. The amount of water in the mix in pounds compared with the amount of cement is called the water/cement (w/c) ratio. The lower the w/c ratio, the stronger the concrete. (Higher strength, less permeability)

3. Aggregates

   Sand is the fine aggregate. Gravel or crushed stone is the coarse aggregate in mo[illegible] mixes.

2.1.1 Pozzolan

A pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "cement extender") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete, and in some cases reduce the material cost of concrete. Pozzolans are primarily vitreous siliceous materials which react with calcium hydroxide to form calcium silicates; other cementitious materials may also be formed depending on the constituents of the pozzolan.

The pozzolanic reaction may be slower than the rest of the reactions that occur during cement hydration, and thus the short-term strength of concrete made with pozzolans may not be as high as concrete made with purely cementitious materials. On the other hand, highly reactive pozzolans, such as silica fume and high reactivity metakaolin can produce "high early strength" concrete that increase the rate at which concrete gains strength.

The first known pozzolan was pozzolana, a volcanic ash, for which the category of materials was named. The most commonly used pozzolan today is fly ash, though silica fume, high-reactivity metakaolin, ground granulated blast furnace slag, and other materials are also used as pozzolans.

Many pozzolans available for use in construction today were previously seen as waste products, often ending up in landfills. Use of pozzolans can permit a decrease in the use of Portland cement when producing concrete, this is more environmentally friendly than limiting cementitiuos materials to Portland cement. As experience with using pozzolans has increased over the past 15 years, current practice may permit up to a 40 percent reduction of Portland cement used in the concrete mix when replaced with a carefully designed combination of approved pozzolans. When the mix is designed properly, concrete can utilize pozzolans without significantly reducing the final compressive strength or other performance characteristics.

2.1.2 Pozzolanic reaction

At the basis of the Pozzolanic reaction stands a simple acid-base reaction between calcium hydroxide, also known as Portlandite, or ($Ca(OH)_2$), and silicic acid (H_4SiO_4, or $Si(OH)_4$). For simplifying, this reaction can be schematically represented as following:

$$Ca(OH)_2 + H_4SiO_4 \longrightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \longrightarrow CaH_2SiO_4 \cdot 2\ H_2O$$

or summarized in abbreviated notation of cement chemists:

$$CH + SH \longrightarrow CSH$$

The product of general formula ($CaH_2SiO_4 \cdot 2\ H_2O$) formed is a calcium silicate hydrate, also abbreviated as CSH in cement chemist notation.

2.2 CEMENT REPLACEMENT MATERIALS

There are many cement replacement materials in the market nowadays such an example silica fume, fly ash and ground granulated blast furnace slag (GGBFS). The widely use of cement was contributed in pollute our environment as our discussion before; this will contribute to global warming and green house effect. Furthermore, since this replacement materials is residue or by product from other industry, it indirectly help to save our environment in term of land space.

2.2.1 Rice Husk Ash (RHA) and microwave incinerated rice husk ash (MIRHA)

Rice husk ash (RHA) was obtained by burning rice husk (RH) in a furnace with a controlled temperature in order to establish the optimum burning temperature and burning time. Grinding of RHA aims to achieve the best specific surface area. It was found that the most convenient and economical temperature required for conversion of the RH into ash was 600°C for 3 hours (El-Karmouty 2000). The RHA that was used had a specific surface area of $5.6 \times 10^6\ mm^2/g$, and the unit weight was $2.06 \times 10^3\ kg/m^3$.

MIRHA is burnt in the Modern incinerator to avoid environmental problem caused by open burning. In University Technology Petronas, rice husk is burned in the microwave incinerator. Microwave incinerator as one of the modern incinerators is proposed to produce amorphous RHA with high pozzolanic reactivity as a result this can significantly enhance the concrete properties.

The advantages of using microwave incinerator to burn RH is the produce ash contains best quality of MIRHA and high reactivity of silica.

- open burning (such as deliberately setting fire to piles of dumped husk),
- Enclosed burning (typically a chamber made from fire resistant bricks with openings to allow air to enter and flue gases to leave).

The chemical composition of RHA shows in Table 1.

Table 1: Chemical composition of RHA

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO,	MgO	K_2O
Percentage (%)	87.0	1.75	2.5	2.5	2.3	2.5

The silica content of the ash was derived from the amorphous silica present in the cellular structure of the husks. X-ray diffraction of the RHA showed that the RHA contained mainly amorphous materials with a very small amount of crystallized quartz. (El-Karmouty 2000)

2.2.1.1 Analysis of the quality of RHA

The quality of RHA actually depends on the method of ash incineration and the degree of grinding. It also depends upon the preservation of cellular structure and the extent of amorphous material within the structure.

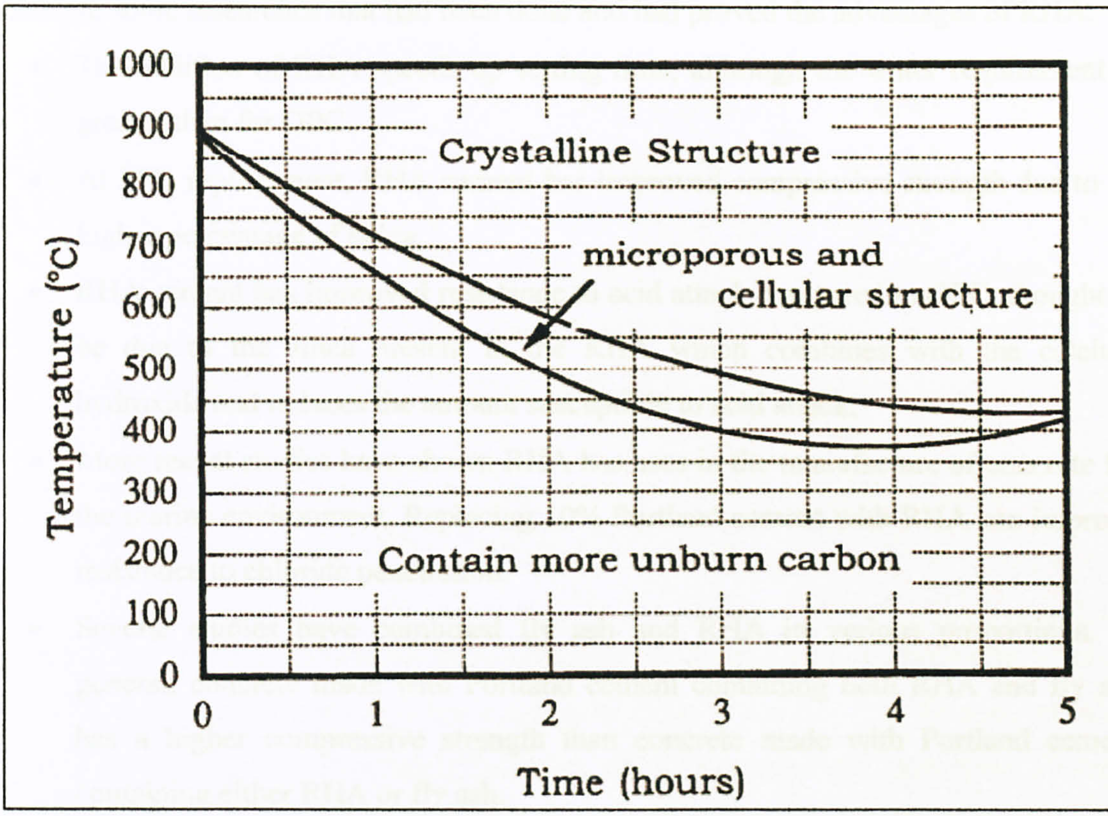

Figure 1: The optimum incineration condition curve for obtaining reactive cellular RHA.

Rice Husk Ash (RHA) is a strong choice for concrete strengthening. Recently, most research had used high cementations materials content that can give a desired properties to the concrete. Most mixtures contain one or more materials such as fly ash, ground granulated blast furnace slag, silica fume, metakolin or natural pozzolanic materials.

There are two main uses of RHA; as an insulator in the steel industry and as a pozzolan in the cement industry. Substantial research has been carried out on the use of amorphous silica in the manufacture of concrete. There are two areas for which RHA are used; in the manufacture of low cost building blocks and in the production of high quality cement. Ordinary Portland Cement (OPC) is expensive and unaffordable to a large portion of the world's population. Since OPC is typically the most expensive constituent of concrete, the replacement of a proportion of it with RHA offers improved concrete affordability, particularly for low-cost housing in developing countries.

There are some researches that had been done and had proved the advantages of RHA:

- The addition of RHA speeds up setting time, although the water requirement is greater than for OPC.
- At 35% replacement, RHA cement has improved compressive strength due to its higher percentage of silica.
- RHA cement has improved resistance to acid attack compared to OPC, thought to be due to the silica present in the RHA which combines with the calcium hydroxide and reduces the amount susceptible to acid attack.
- More recent studies have shown RHA has uses in the manufacture of concrete for the marine environment. Replacing 10% Portland cement with RHA can improve resistance to chloride penetration.
- Several studies have combined fly ash and RHA in various proportions. In general, concrete made with Portland cement containing both RHA and fly ash has a higher compressive strength than concrete made with Portland cement containing either RHA or fly ash.

2.2.2 Pulverized Fuel Ash

Fly ash, or pulverized fuel ash, is a residue derived from the combustion of pulverized coal in furnaces of thermal power plant. The characteristic of fly ash varies according to the combustion operation system as well as the coal composition. Various suspension-firing systems, e.g. vertical firing and horizontal firing, etc., have been widely used, which afford a high steam-generation capacity and quick response to load changes. The combustion temperature is high (approximately 1200°C) and the ash, in finely divided form (usually less than 100 pm in size) is carried along in the air stream, collected by electrical or mechanical precipitators (dry process) while it is quickly cooled. In some power stations, the old wet collection process is still in use.

Fly ash collected by a dry process is usually rather homogenous in particle size; whereas that collected by a wet process is more segregated due to the fact that the sedimentation speed is lower for smaller or lighter particles, and it contains large quantities of water. The coarser portion of the coal ash (~15-20% by mass) is heavy and falls to the bottom of the furnace and thus is called bottom ash. Residue of combustion consists of about 85% fly ash and 15% bottom ash.

In general, for high strength concrete applications, fly ash is used at dosage rates of about 15% of the cement content. Because of the variability of the fly ash produced even from a single plant, however, quality control is particularly important. The chemical composition of RHA shows in Table 2.

Table 2: Chemical composition of PFA

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO,	MgO	K_2O	TiO_2
Percentage (%)	55.4	25.5	7.8	4.1	1.0	1.1	1.7

2.2.2.1 Particle Size and Density of Fly Ash

Fly ash, as it comes from the combustion of pulverized coal is a powder with particle sizes similar to that of cement. Generally, more than 70% of an ash can pass through a 45 μm sieve, and a fraction of particles are smaller than 3 μm, as shown by Joshi and Lohtia. Unburned coal particles are usually larger than 100 μm. The Blaine Fineness of typical Class F fly ash is in the range of 300 - 400 m^2/kg.

During the combustion-cooling process, smaller fly ash particles may cool more rapidly and remain more glassy and thus, have a higher reactivity. Because of the glassy nature of smaller fly ash particles, the surface is the most reactive part. Rehsi shows the lime reactivity of fly ashes is higher for the percent of ash with particle sizes < 45 μm, which appears to be the only parameter (compared with silica content, silica-alumina content, and the Blaine specific surface) that has significant relation to the reactivity.

According to ASTM C 6 18, fly ashes used in concrete should possess no more than 34% of particles retained by the 45 μm sieve. Butler and Mearing, in reviewing the use of fly ash fractions for different purposes, consider that particles in the range of 10 to 50 μm mainly act as void fillers in concrete, whereas the particles smaller than 10 μm are more reasonably classified as "pozzolanic reactive". It should be noted that this effect is largely physical, because for a unique mass, the smaller the particles, the higher the specific surface which provides a larger interface available for reaction. As an evidence of this point, Carles-Gibergues and Aitcin showed that there is no significant differences in chemical or mineralogical compositions for a Class F fly ash separated by an air classifier.

2.3 EFFECTS OF RHA OR MIRHA TO THE CONCRETE

2.3.1 Water absorption

The water absorption is shown in table 2 and figure 2 below. The results reveal that higher substitution amounts results in lower water absorption values, its occur due to the RHA is finer than cement. Adding 10% of RHA to the concrete, a reduction of 38.7% in water absorption is observed when compared to mixture D.

Table 3 : Water absorption test (%)

Sample	Mixture of Cement (kg/m3)	7 days	28 days
D	490.0 (control item)	2.67	1.76
E	465.5 (5 % of RHA)	2.64	1.64
F	441.0 (10 % of RHA)	2.35	1.38

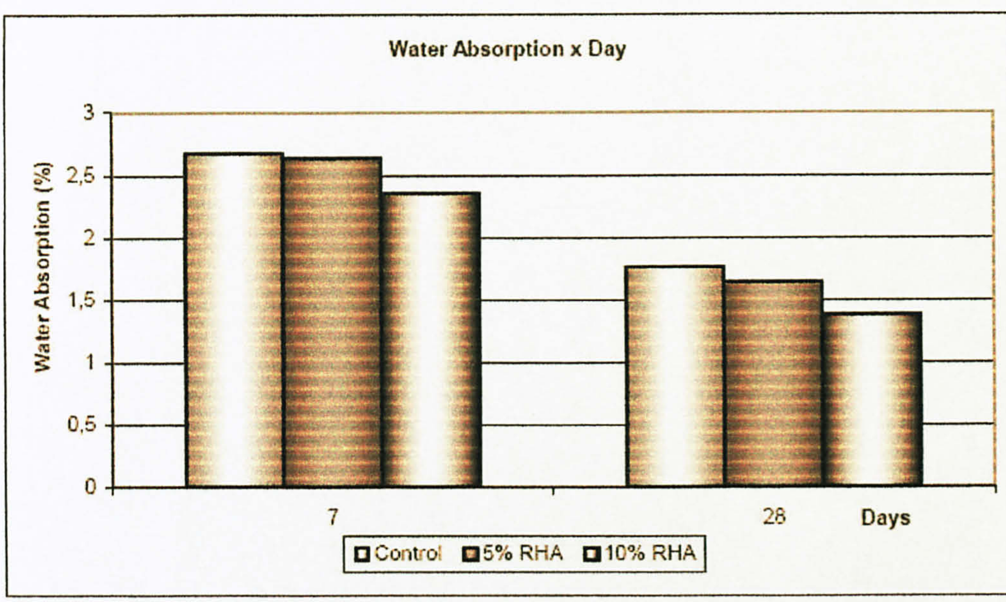

Figure 2 : Result of water absorption test

From the table and figure above it shows that higher substitution amounts results in lower water absorption because RHA is finer that cement.

2.3.2 Compressive strength test

The compressive strength is shown in table 3 and figure 3 below. The addition of RHA causesan increment in the compressive strength due to the capacity of the pozolan, of fixing the calcium hidroxide, generated during the reactions of hydrate of cement. All the replacement degrees of RHA increased the compressive strength. For a 5% of RHA, 25% of increment is verified when compared with mixture D.

Table 4: Compressive strength test (MPa)

Sample	7 days	28 days
D	45.9	48.1
E	52.9	60.4
F	45.8	54.2

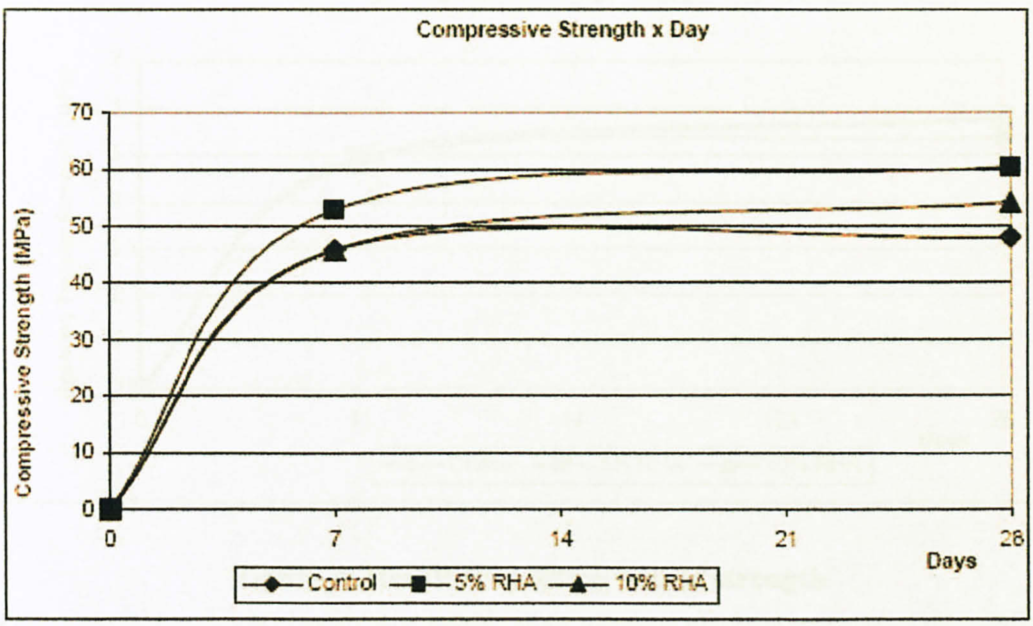

Figure 3 : Result of Compressive strength test

The result from the table shows that the addition of RHA causes an increment in the compressive strength due to the capacity of the pozzolan, of fixing the calcium hydroxide, generated during the reactions of hydrate of cement.

2.3.3 Splitting Tensile test

The results of splitting tensile strength are shown in table 4 and figure 4 below. All the replacement degrees of RHA researched, achieve similar results in splitting tensile strength. According to the results, may be realized that there is no interference of adding RHA in the splitting tensile strength.

Table 5: Splitting tensile strength (MPa)

Sample	7 days	28 days
D	4.85	5.37
E	4.94	5.79
F	4.82	5.78

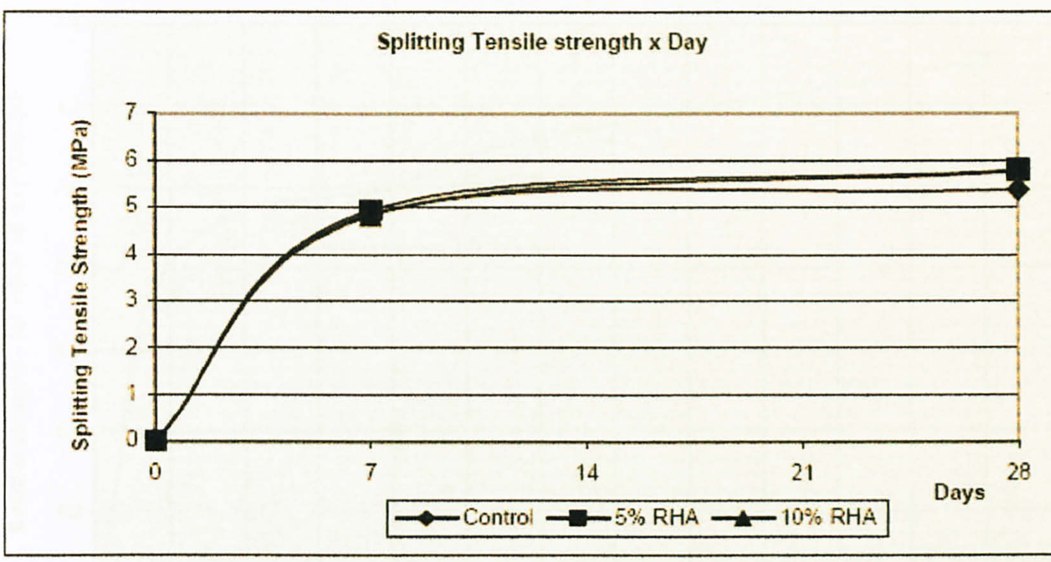

Figure 4: Result of splitting tensile strength

From the result, it approved that there was no interference of adding RHA in the splitting tensile strength.

As the conclusion from the research by Mauro M. Tashima, Carlos A. R. Da Silva, Jorge Akasaki and Michele Beniti Barbosa on the possibility of adding the Rice Husk Ash

(RHA) to the concrete, it can give an effect on several properties such as water absorption and compressive strength.

2.4 EFFECTS OF PFA TO THE CONCRETE

2.4.1 Strength development

The typical strength development of concrete containing PFA is illustrated in figure 5, where both mixes have been designed for equal 28 day strength. There may be a marginal decrease in early strength development up to 7 days, which can be exacerbated in cold weather, depending on admixtures used. However after 28 days, the PFA continues to increase in strength due to the pozzolanic properties of pfa. External temperatures can affect strength gain, as illustrated in figure 6.

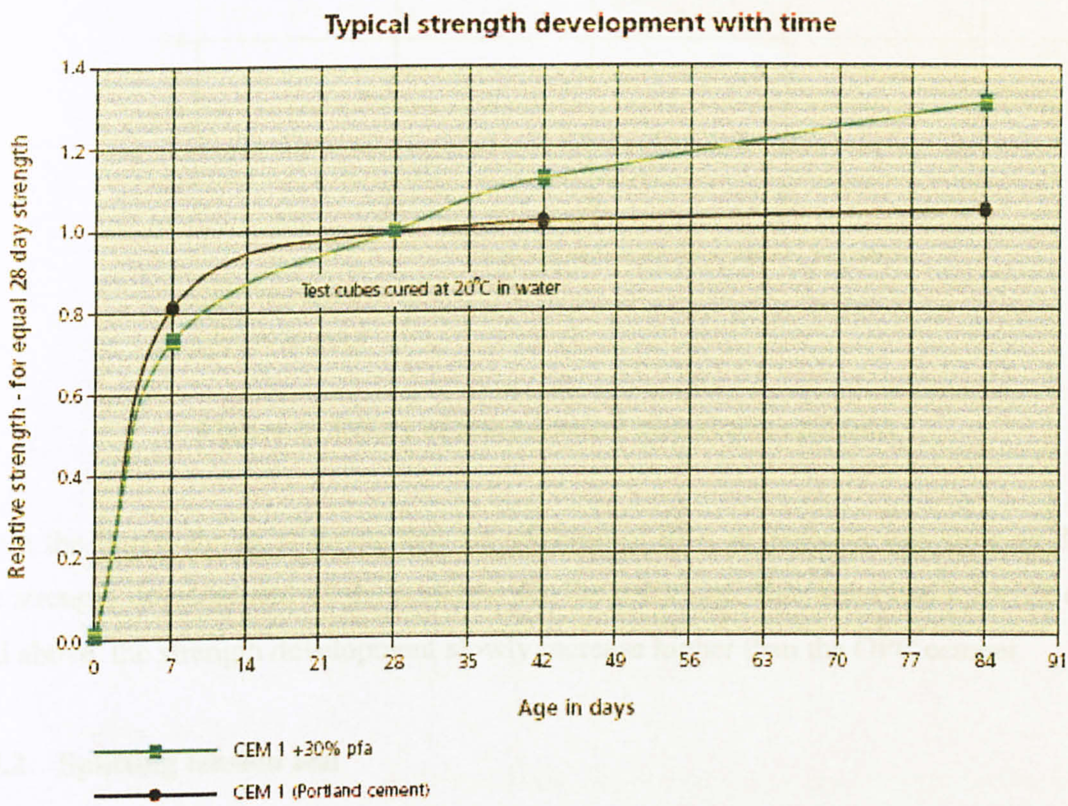

Figure 5: Typical strength development of concrete with time

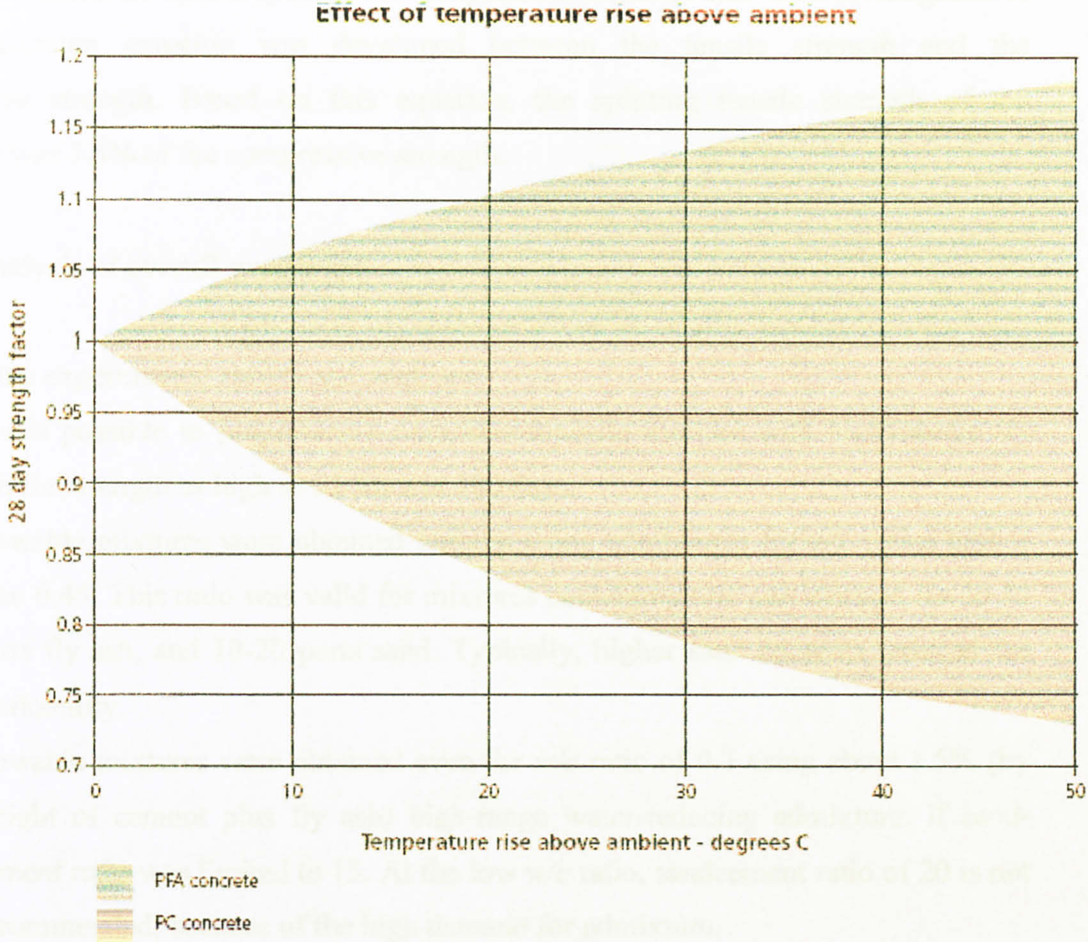

Figure 6: Effect of temperature rise above ambient

From the figure above, it shows that the addition of PFA in concrete was slowing down the strength development of the concrete for the early age. But when reach for 28 days and above, the strength development slowly increase higher than the OPC cement.

2.4.2 Splitting tension test

As mentioned earlier, splitting tensile strengths were obtained using 150 mm of diameter and 300m of height cylinders, loaded diagonally. These strength values indicated composite's ability to withstand tensile stresses that might occur due to shrinkage and minor ground movement in the case of curtain walls and backfills. Typical tensile strength results are presented in figure below. A careful review of the strength data indicated that variation of tensile strength behavior was similar to the variation of compression behavior with respect to the independent variables that were investigated. A linear regression equation was developed between the tensile strength and the compressive strength. Based on this equation, the splitting tensile strength of the composite was 7.5% of the compressive strength.

2.4.3 Analysis of overall properties

Based on the experimental results and analysis:

1. It was possible to proportion a cement-composite mixture with highvolume fly ash for strength as high as 21 MPa at 180 days.
2. Flowable mixtures were obtained without using admixtures for *w/c* ratios higher than 0.45. This ratio was valid for mixtures containing one part cement, six to 10 parts fly ash, and 10-20 parts sand. Typically, higher sand contents reduced the workability.
3. Flowable mixtures were obtained even for *w/c* ratio of 0.3 using about 1.5% (by weight of cement plus fly ash) high-range water-reducing admixture, if sand-cement ratio was limited to 15. At the low *w/c* ratio, sandcement ratio of 20 is not recommended, because of the high demand for admixture.
4. Strength gain rate was very low for the high-volume fly-ash cement composites. In most cases, the 180-day strength was more than 200% of the 28-day strength. The variation of strength gain with time indicated that the composite gained strength even after 180 days. Within the range tested (fly ash-cement ratios 6, 8, 10), higher fly-ash contents decreased the strengthgain rate.
5. As expected, lower *w/c* ratios and lower filler (fly ash and sand) contents provided higher strengths.
6. The amounts of fly ash and sand had a higher influence on strength at lower *w/c* ratios.
7. The stress-strain behavior of high-volume fly-ash cement composite was similar to normal low-strength concrete. The initial slope of the curve was, however,

lower than that of low-strength concrete. In general, the composite did absorb considerable energy before failure.

8. The splitting tensile strength was about *7.5%* of compressive strength.

2.5 TEST METHOD – STANDARD ASSOCIATED

2.5.1 ASTM C873 / C873M - 04e1 Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

This test method covers the determination of strength of cylindrical concrete specimens that have been molded in place using special molds attached to formwork. A concrete cylinder mold assembly consisting of a mold and a tubular support member is fastened within the concrete formwork prior to placement of the concrete. The elevation of the mold upper edge is adjusted to correspond to the plane of the finished slab surface. The mold support prevents direct contact of the slab concrete with the outside of the mold and permits its easy removal from the hardened concrete. Strength of cast-in-place cylinders may be used for various purposes, such as estimating the load-bearing capacity of slabs, determining the time of form and shore removal, and determining the effectiveness of curing and protection. Consolidation of concrete in the mold may be varied to simulate the conditions of placement. Internal vibration of concrete in the mold is prohibited except under special circumstances.

Significance and Use

Cast-in-place cylinder strength relates to the strength of concrete in the structure due to the similarity of curing conditions since the cylinder is cured within the slab. However, due to differences in moisture condition, degree of consolidation, specimen size, and length-diameter ratio, there is not a constant relationship between the strength of cast-in-place cylinders and cores. When cores can be drilled undamaged and tested in the same moisture condition as the cast-in-place cylinders, the strength of the cylinders can be expected to be on average 10 % higher than the cores at ages up to 91 days for specimens of the same size and length-diameter ratio.

Strength of cast-in-place cylinders may be used for various purposes, such as estimating the load-bearing capacity of slabs, determining the time of form and shore removal, and determining the effectiveness of curing and protection.

2.5.2 ASTM C496 / C496M - 04e1 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

Significance and Use

Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture).

Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

Scope

This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores. The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

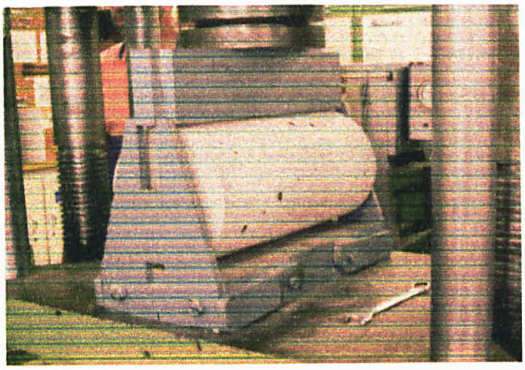

Figure7: Tensile test setup

2.5.3 ASTM C597 - Ultra Pulse Velocity through Concrete

Pulses of compression waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located a distance L from the transmitting transducer. The transit time T is measured electronically. The pulse velocity is calculated by dividing L by T.

This ASTM test method covers the determination of the pulse velocity of propagation of compression waves in concrete. The pulse velocity V is related to the physical properties of a solid by the equation:

$$V^2 = (K)\frac{E}{\rho}$$

Where:

K = a constant,

E = the modulus of elasticity, and

ρ = the mass density.

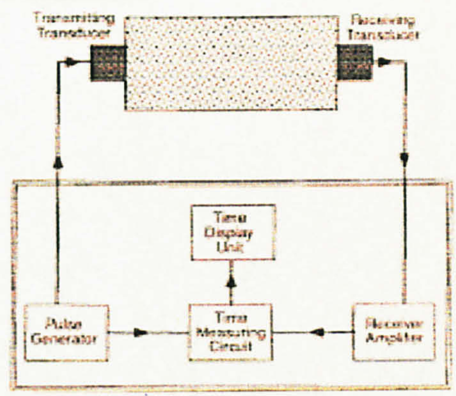

Figure 8: UPV procedure

This test method does not apply to the propagation of other vibrations within the concrete.

2.5.4 ASTM C805 – Rebound Hammer

This test method is use to assess the in-place uniformity of concrete, to delineate regions in a structure of poor quality or deteriorated concrete, and to estimate in-place strength development. It also can be used to determine the surface hardness of the samples. To use this method to estimate strength development, it requires establishment of a relationship between strength and rebound number for a given concrete mixture.

This method use a steel hammer impact, with a predetermined amount of energy, a steel plunger in contact with a surface of concrete, and the distance that the hammer rebounds is measured.

Figure 9: Rebound Hammer

Table 6: The specification of each test

TEST TYPE	STANDARD ASSOCIATED	EQUIPMENT	TESTING AGE - day(s)	SAMPLE SIZE	NO OF TEST	MEASUREMEN UNIT
Compression Test	**ASTM C873 / C873M - 04e1**	Compressive Strength Test Machine	3,7, 28, 56, 90	Cube sample (150mm X 150mm X 150mm)	3 samples of each day test.	N / mm2
Splitting Tension Test	**ASTM C496 / C496M - 04e1**	Compressive Strength Test Machine	28 and 90	Cylinder sample (150mm of height with 150mm of diameter)	3 samples of each day test.	N / mm2

CHAPTER 3
METHODOLOGY

The project has been started by preparing the materials to be use in the mix design concrete. One material that important to be prepared is Microwave Incinerated Rice Husk Ash (MIRHA). In order to get the MIRHA product, the rice husk is burned in the incinerator microwave oven of 500°C of temperature by 2 cycles burning method (Refer APPENDIX V). After that, the MIRHA is grinded by a grinding machine to get the extremely fine product of MIRHA. The grinding machine is to be set at 1200 rotation per minute (rpm). The total weight of MIRHA to be used in this design is estimated around 35 kg for overall mixes.

After preparation of MIRHA, the concrete is ready to be mixed. The desired strength of concrete to be mix is 70 N/mm2. The proportion of each material used is based on the high strength concrete design as stated in table 11.

3.1 CALCULATION FOR TESTING SAMPLE

There are several samples is prepared in order to be used in the testing of concrete later. Four tests is take place which is compressive strength test, rebound hammer test, Ultrasonic Pulse Velocity (UPV) test and splitting tension test. 2 major samples to be prepared to use in the testing that is cube samples and cylinder samples. The details below showed the respective sample and calculation of volume to be use in the mix.

Table 7: Test conducted and sample size

Sample	Test	Size
Cube	Compressive strength Rebound Hammer Ultrasonic Pulse Velocity	150mm x 150mm x 150mm
Cylinder	Splitting tension	150mm of diameter with 150mm of height

Sample	Dimension	Volume
Cube	150 mm X 150 mm X 150 mm	= 0.15 m X 0.15m X 0.15m X 9samples = 0.03 m^3
Cylinder	Diameter = 75 mm height = 150 mm	= Π X 0.075^2 X 0.15m X 2 = 0.005 m^3
Safety purpose (extra 5%)		= 0.03 m^3 + 0.005 m^3 = 0.035 m^3 X 1.05 = 0.037 m^3
Total		**= 0.037 m^3**

3.2 PREPARATION OF CONCRETE

For the first step, 4 samples is designed as a control concrete which 3 of them use the MIRHA as a cement replacement material (CRM) and 1 sample as a normal sample of concrete with Grade 70. The MIRHA value is varies as 0.0%, 5.0%, 7.5% and 10%. The ratio (percentage) of each material is shown in Table 10.

Then 4 testing samples will be prepared soon by replace the percentage of cement with both MIRHA and Pulverized fuel ash (PFA).The PFA percentage had been locked at 10% because the previous studies shown that optimum proportion of PFA to be use in concrete is 10%.

Table 9: The ratio for cement, MIRHA and PFA

Set	Cement (%)	MIRHA (%)	PFA (%)
1	100.0	0.0	0.0
2	95.0	5.0	0.0
3	92.5	7.5	0.0
4	90.0	10.0	0.0
5	90.0	0.0	10.0
6	85.0	5.0	10.0
7	82.5	7.5	10.0
8	80.0	10.0	10.0

3.3 CALCULATION OF CONCRETE PROPORTION

Cement (kg/m3)	Sand (kg/m3)	Aggregate (kg/m3)	Water (kg/m3)	Water / Cement ratio	Slump height (mm)
750	590	1000	225	0.3	50 - 100

This table is shown the normal concrete proportion for high strength concrete. The water/cement (w/c) ratio is set to be 0.3 and the slump height is in between 50 – 100mm. From this table, the weight of each material is calculated. The total volume for one set of mix is **0.037 m^3 (from Table 8)**.

The example of calculation of concrete proportion is attached in **APPENDIX I.**

Table 11 shows the overall proportion for every set of mix obtained.

Table 11: Overall mix proportion

Set	Type of concrete	OPC		MIRHA		PFA		sand	aggregate	water
		(%)	(kg)	(%)	(kg)	(%)	(kg)	(kg)	(kg)	(kg)
1	(Normal Concrete)	100.0	27.75	0.0	0	0.0	0	21.83	37.0	8.33
2	Ordinary Portland Cement	95.0	26.36	5.0	1.39	0.0	0	21.83	37.0	8.33
3	+	92.5	25.67	7.5	2.08	0.0	0	21.83	37.0	8.33
4	MIRHA	90.0	24.98	10.0	2.78	0.0	0	21.83	37.0	8.33
5	Ordinary Portland Cement	90.0	24.98	0.0	0	10.0	2.78	21.83	37.0	8.33
6	+	85.0	23.59	5.0	1.38	10.0	2.78	21.83	37.0	8.33
7	MIRHA	82.5	22.89	7.5	2.08	10.0	2.78	21.83	37.0	8.33
8	+	80.0	22.20	10.0	2.77	10.0	2.78	21.83	37.0	8.33
	PFA									

* All sets use the same contents of superplastisizer, maximum = 0.83 kg

Legend:

OPC - Ordinary Portland Cement

MIRHA - Micro Incinerated Rice Husk Ash

PFA - Pulverized fuel-ash

4.0 RESULT

4.1 Compression test

Table 12 shows the result obtains for the compression test.

Table 11: The result of compression strength in MPa

COMPRESSION TEST

Types		OPC		MIRHA		PFA		Strength (MPa)		
		%	kg	%	kg	%	kg	3	7	28
Normal concrete		100	31.5	0	0	0	0	33.10	50.64	69.51
OPC + MIRHA		95	29.93	5	1.58	0	0	37.30	56.71	77.19
		92.5	29.14	7.5	2.36	0	0	36.20	55.21	75.25
		90	28.35	10	3.15	0	0	34.20	53.70	73.20
OPC + MIRHA + PFA	**Set 1**	90	28.35	0	0	10	3.15	39.66	57.20	72.45
	Set 2	85	26.78	5	1.58	10	3.15	48.87	59.81	81.17
	Set 3	82.5	25.99	7.5	2.36	10	3.15	62.77	84.47	101.55
	Set 4	80	25.2	10	3.15	10	3.15	41.34	59.64	77.61

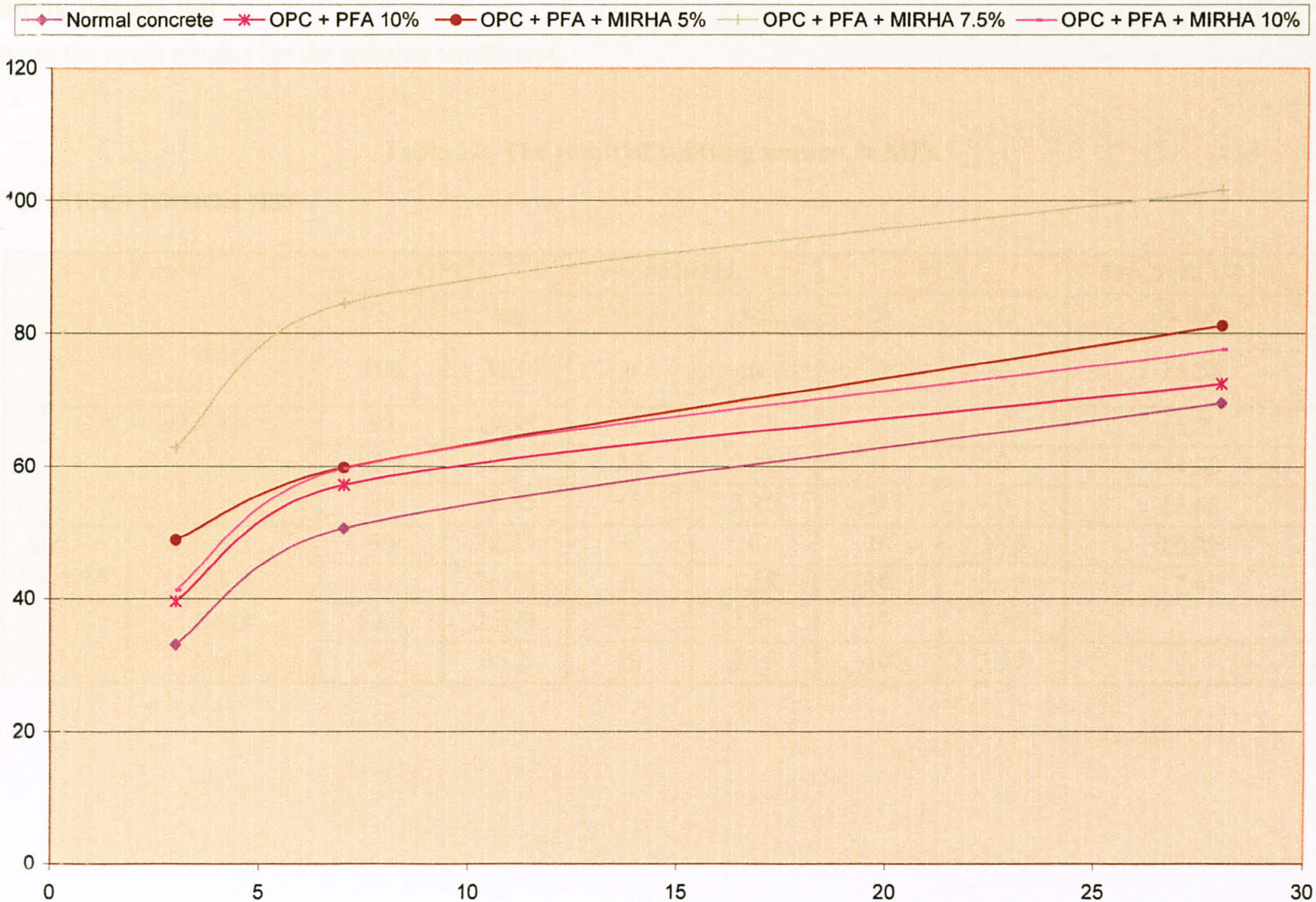

Figure 10: Strength development of the selected set

1.2 Splitting Tension test

Table 12 shows the result obtains for the splitting tensile test.

Table 12: The result of splitting tension in MPa

SPLITTING TENSION TEST

<table>
<tr><th colspan="2" rowspan="2">Types</th><th colspan="2">OPC</th><th colspan="2">MIRHA</th><th colspan="2">PFA</th><th>Strength (MPa)</th></tr>
<tr><th>%</th><th>kg</th><th>%</th><th>kg</th><th>%</th><th>kg</th><th>28 days</th></tr>
<tr><td colspan="2">Normal Concrete (Control)</td><td>100</td><td>31.5</td><td>0</td><td>0</td><td>0</td><td>0</td><td>15.58</td></tr>
<tr><td colspan="2" rowspan="3">OPC + MIRHA</td><td>95</td><td>29.93</td><td>5</td><td>1.58</td><td>0</td><td>0</td><td>15.73</td></tr>
<tr><td>92.5</td><td>29.14</td><td>7.5</td><td>2.36</td><td>0</td><td>0</td><td>14.23</td></tr>
<tr><td>90</td><td>28.35</td><td>10</td><td>3.15</td><td>0</td><td>0</td><td>13.65</td></tr>
<tr><td rowspan="4">OPC + MIRHA + PFA</td><td>Set 1</td><td>90</td><td>28.35</td><td>0</td><td>0</td><td>10</td><td>3.15</td><td>16.27</td></tr>
<tr><td>Set 2</td><td>85</td><td>26.78</td><td>5</td><td>1.58</td><td>10</td><td>3.15</td><td>17.42</td></tr>
<tr><td>Set 3</td><td>82.5</td><td>25.99</td><td>7.5</td><td>2.36</td><td>10</td><td>3.15</td><td></td></tr>
<tr><td>Set 4</td><td>80</td><td>25.2</td><td>10</td><td>3.15</td><td>10</td><td>3.15</td><td></td></tr>
</table>

5.0 DISCUSSION

From the result obtained, concrete containing MIRHA give higher strength as compared to the normal concrete. The highest strength was achieved by concrete containing 5% of MIRHA which increase until 14% from normal concrete. For the second highest strength is concrete containing 7.5 % of MIRHA which increase 8.25 % from normal concrete. For the third highest strength is concrete containing 10% of MIRHA which increase 5.3% from the normal concrete.

For the concrete containing MIRHA and PFA (locked to 10%), its also gives higher strength as compared to the normal concrete. The highest strength was achieved by concrete containing 7.5% of MIRHA and 10% of PFA which increase until 46% from the normal concrete. Second highest strength is concrete containing 5% of MIRHA and 10% of PFA which increase 16.7% from normal concrete. For the third and forth highest strength is concrete containing 10% of PFA followed by 10% of MIRHA and 10% PFA.

From the result obtained, we know that the admixtures such as MIRHA and PFA, both are pozzolanic material. A pozzolan is a material which, when combined with calcium hydroxide in the cement, exhibits cementitious properties or calcium silicate hydrate (C-S-H gel) produced. So it increases the strength of the concrete and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete.

From the result obtained, it also shows that the cement replacement materials works and also gives good characteristics to the concrete produced. Then, apart of cement that contributes to the air pollution due to carbon dioxide emission (from the manufacturing of cement) can be reduced by this project. Furthermore, the cost of cement is quite high in recent days, so it also help in reducing the cost of the concrete.

6.0 CONCLUSION

From this project, it was observed that an addition of MIRHA 7.5% and PFA 10 % gave the optimal mixtures to get an optimal strength of the concrete. The same proportion also gave the optimum result for the tensile strength of the concrete. The different was about 46 % stronger than the normal concrete.

The effect of MIRHA and PFA as a multiple binders on strength development of normal concrete has been determined from the compressive strength, tensile strength, surface hardness and integrity test. It can be said that MIRHA with additional of PFA can be applied to concrete in some amount as to maintain the strength to the concrete and at the same time, reduce the usage of OPC as to solve the problem that has been stated at the early phase of the project.

7.0 REFERENCES

1. SHRP-C/FR-91-103, 1991, '*High performance concretes, a state of the art report*. Strategic Highway Research Program, National Research Council, Washington DC.

2. R. D. Hooton, S. Mindess, J.-C. Roumain and A. J. Boyd, 2006, '*Materials Selection, Proportioning, Testing, and Standards for Concrete Durability*'. Concrete International

3. S. Mindess, 1994, '*Materials selection, proportioning and quality control*'.

4. K. Sakr, 2006,' *Effects of Silica Fume and Rice Husk Ash on the Properties of Heavy Weight Concrete*'.

5. Chao Lung Hwang and Satish Chandra, 1997, 'Waste Materials Used in Concrete Manufacturing, Chapter 4 : The use of rice husk ash in concrete,'.

6. O. Kayali, 2007, '*Fly ash light weight aggregate in high performance concrete*'.

7. "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens" *http://www.techstreet.com/cgi-bin/detail?product_id=5349*

8. "ASTM C873 / C873M - 04e1 Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds" *http://www.astm.org/Standards/C873.htm*

9. "ASTM C496 / C496M - 04e1 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens" *http://www.astm.org/Standards/C496.htm*

APPENDIX I

Take an example for set one,

Material	Weight (kg)
Cement	$= 0.037\ m^3 \times 750\ kg/m^3$ $= 27.75kg$
Sand	$= 0.037\ m^3 \times 590\ kg/m^3$ $= 21.83\ kg$
Aggregate	$= 0.037\ m^3 \times 1000\ kg/m^3$ $= 37.00\ kg$
Water	$= 0.037\ m^3 \times 225\ kg/m^3$ $= 8.33\ kg$
Superplastisizer	Maximum 3% from cement weight $= 0.03 \times 27.75\ kg$ $= 0.83\ kg$

So, this design has been used for the first mix.

Take an example for set no 2,

Material	Weight (kg)
Cement	95% from the normal concrete cement weight, = 0.95 X 27.75 kg = 26.36 kg
MIRHA	*5 % from the normal concrete cement weight, = 0.05 X 27.75 kg = 1.39 kg
Sand	= 0.037 m^3 X 590 kg/ m^3 = 21.83 kg
Aggregate	= 0.037 m^3 X 1000 kg/ m^3 = 37.00 kg
Water	= 0.037 m^3 X 225 kg/ m^3 = 8.33 kg
Superplastisizer	Maximum 3% from normal concrete cement weight, = 0.03 X 27.75 kg = 0.83 kg

* Since MIRHA is a cement replacement material, so the percentage of 5% MIRHA replace the proportion (weight) of cement from the normal concrete (previous).

This design has been used for second set.

APPENDIX II

UNIVERSITY TECHNOLOGY PETRONAS
CIVIL ENGINEERING PROGRAMME
BANDAR SERI ISKANDAR
31750 TRONOH
PERAK DARUL RIDZUAN

MIXING AND SAMPLING FRESH CONCRETE

1. OBJECTIVE

Mixing and sampling fresh concrete in the laboratory (as recommended by **BS 1881: Part 125:1986**)

2. APPARATUS

A non-porous timber or metal platform, a pair of shovels, a steel hand scoop, measuring cylinder and a small concrete mixer (if machine mix)

3. PROCEDURE

a. Weight the quantities of cement, sand and course aggregate to make 1:2:4 concrete mix at water ratio of 0.6

b. Hand Mixing

   i. Mix cement and sand first until uniform on the non-porous platform
   ii. Pour course aggregate and mix thoroughly until uniform
   iii. Form a hole in the middle and add water in the hole. Mix thoroughly for 3 minutes or until the mixture appears uniform in color.

c. Machine Mixing

   i. Wet the concrete mixer.
   ii. Pour aggregate and mix for 25 second.
   iii. Add half of water and mix for 1 minute and leave for 8 minutes.
   iv. Add cement and mix for 1 minute.
   v. Add remaining water available and mix for 1 minute.
   vi. Stop the machine and do hand mixing to ensure homogeneity.
   vii. Pour out the concrete onto the non porous surface.

4. **PRECAUTIONS**

a. The room temperature should be approximately 25-27 C

b. Make sure that fine and aggregate are dry. If they are wet find the content of the aggregates to determine the quantity of water required.

APPENDIX III

UNIVERSITI TEKNOLOGI PETRONAS	**UNIVERSITY TECHNOLOGY PETRONAS** **CIVIL ENGINEERING PROGRAMME** **BANDAR SERI ISKANDAR** **31750 TRONOH** **PERAK DARUL RIDZUAN**

COMPRESSIVE STRENGTH TEST CUBES – TEST FOR STRENGTH

1. OBJECTIVE

To determine the compressive strength (Crushing strength) of concrete according to **BS 1881: Part 116: 1983**

2. THEORY

One of the most important properties of concrete is its strength in compression. The strength in compression has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in compressive strength.

The compressive strength is taken as the maximum compressive load it can be carry per unit area. Compressive strength tests for concrete with maximum size of aggregate up to 40mm are usually conducted on 150mm cubes.

3. APPARATUS

Compression Testing Machine (it complies with the requirement of **BS 1610**)

4. PROCEDURE

a. Remove the specimen from curing tank and wipe surface water and grit off the specimen.
b. Weight each specimen to the nearest kg.
c. Clean the top and lower platens of the testing machine. Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.
d. Without shock, apply and increase the load continuously at a nominal rate within the range $0.2 N/mm^2 s$ to $0.4 N/mm^2$ until no greater load can be sustained. Record the maximum load applied to the cube.

e. Note the type of failure and appearance of cracks.

f. Calculate the compressive strength of each cube by dividing the maximum load by the cross sectional area. Express the results to the nearest 0.5 N/mm^2

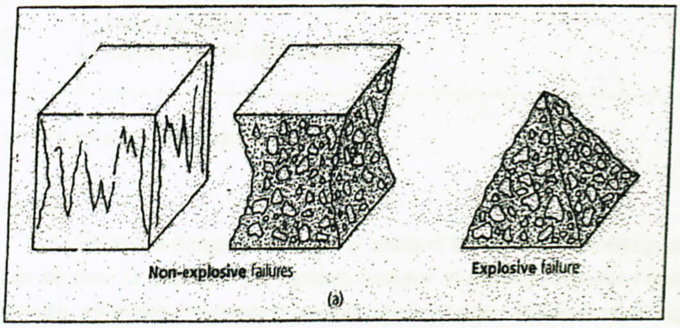

FIGURE 5: The outcome of cube test – normal case

APPENDIX IV

UNIVERSITI TEKNOLOGI PETRONAS	**UNIVERSITY TECHNOLOGY PETRONAS** **CIVIL ENGINEERING PROGRAMME** **BANDAR SERI ISKANDAR.** **31750 TRONOH** **PERAK DARUL RIDZUAN**

ULTRASONIC PULSE VELOCITY TEST (UPV)

1. OBJECTIVE

The UPV test is designed to study the quality of the concrete in existing structures. It also can be used to determine the dynamic modulus of elasticity, dynamic Poisson's ratio, homogeneity, estimated compression strength, depth of crack, thickness of damaged layers and density of concrete. Fire damaged structures can also be assessed using this non destructive testing technique. Test done using the UPV test technique conforms to **BS 1881: Part 201:1986** *"Non-Destructive"* methods of test for concrete measurement of the velocity of ultrasonic pulses in concrete.

2. APPARATUS

A pulse of longitudinal vibrations is generated by an electro-acoustical transducer (transmitter) and received by a similar receiver which is placed on the opposite side of the concrete member under test. The time taken (transmit time) for the pulse of vibration to travel between the transmitter and receiver when divided by the transmit time (t) gives the pulse velocity, V = L/t

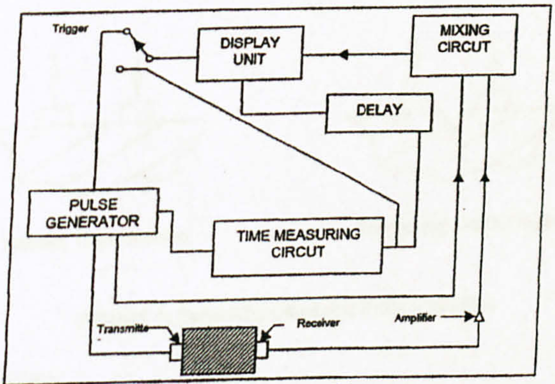

FIGURE 7: Schematic Diagram

3. PROCEDURE

a. Labeled the faces of the concrete cube with A, B, C, D, E and F
b. Make sure that A and B are place on the opposite faces.
c. The same rule applies to C,D ,E and F
d. Use of a coupling gel between the transducer and the concrete cubes or structures.
e. The transmitting and receiving transducers are placed on opposite surfaces of the concrete cube.
f. Push the transmitting and receiving transducers as strong as possible.
g. Take the lowest reading measured by UPV device

4. METHOD

The equipment (PUNDIT) used to determine the Ultrasonic Pulse Velocity in concrete consists of a transducer, receiver and the Main Control Unit. Different arrangements to determine ultrasonic pulse velocities are possible when testing concrete members for quality. Depth of cracks in test members can be determined by placing the transducers across the crack as shown in figure below.

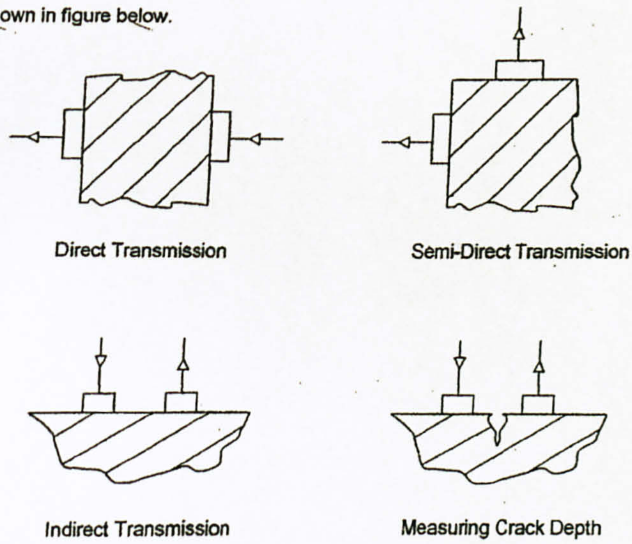

FIGURE 8: Determine Ultrasonic Pulse Velocities

APPENDIX V

PHASE	Temp	Duration	Remarks
PHASE 1	25°C – 150°C	1.5 hours	To remove the carbon and other volatile materials
Cooling	25°C		To ensure excess heat is not generated that can cause crystalline MIRHA for the next burning stage
PHASE II	25°C – 550°C	2.5 hours	To achieve amorphous silica content of MIRHA