SILICA FUME AND MICROWAVE INCINERATED RICE HUSK ASH (MIRHA) AS A MULTIPLE BINDER IN CONCRETE

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JANUARY 2009

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by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JANUARY 2009

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CERTIFICATION OF APPROVAL

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Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
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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.

AHMAD FARHAN BIN JOPRI

ACKNOWLEDGMENT

Alhamdulillah, most thankful to Allah Almighty who had gave me strength and good health to complete this Final Year Project.

Firstly, I would like to thank my family who has been my pillar of inspiration and strength.

My gratitude goes to Assoc Prof Ir Dr Muhd Fadhil Bin Nuruddin for proposing and supervising this project. Thank you for all the support, guidance and advices given to me in making this project a success. Believe it or not, this project makes me want to know more about scope of concrete technology in construction.

To Mr Halim, postgraduate student supervised under Dr Muhd Fadhil, thank you for helping me throughout two semesters to finish this research. He had given a very efficient work flow process for this research. He also had provided many materials including journal, sample of report and cover letter as a guidelines for me to perform this research.

To all lecturers and staffs from Civil Engineering Department of Universiti Teknologi PETRONAS, thank you for the support.

May Allah reward generously all those who have been there to love, guide, teach, motivate, support and inspire me during my hard time in

ABSTRACT

Concrete is a construction material composed of cement as well as other cementitious materials such as fly ash and slag cement, aggregate, sand, water, and chemical admixtures. The word concrete comes from the Latin word "concretus", which means "hardened" or "hard". Concrete can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continuously pushing the limits with the help of innovative chemical admixtures and supplementary cementitious materials

often incorporated in the concrete mix to reduce cement contents, improve workability, increase strength and enhance durability. There are many types of admixtures being used in concrete. Strict air-pollution controls and regulations have produced an abundance of industrial byproducts that can be used as admixtures such as silica fume and rice husk ash. The use of such byproducts in concrete construction not only enhances the properties of concrete, but it also reduces cost, keep environment clean, and can avoid the byproducts form being land-filled. Furthermore, admixtures can replace a portion of the cement content and it will greatly reduce the cost especially for mass amount of concrete.

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CHAPTER 1

1.0 INTRODUCTION

1.1 BACKGROUND

Concrete is a main material in building construction. Almost all houses, high rise buildings and shops in Malaysia uses concretes as it had many advantages such as excellent resistance to water, strong, durable, cheap, fire resistance and its structural elements can be formed into many sizes and types. Concrete is a construction material composed of cement as well as other cementitious materials such as fly ash and slag cement, aggregate, sand, water, and chemical admixtures.

The word concrete comes from the Latin word "concretus", which means "hardened" or "hard". Concrete can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continuously pushing the limits with the help of innovative chemical admixtures and supplementary cementitious materials. Supplementary cementitious materials are often incorporated in the concrete mix to reduce cement contents, improve workability, increase strength and enhance durability. There are many types of admixtures being used in concrete. Strict air-pollution controls and regulations have produced an abundance of industrial byproducts that can be used as admixtures such as silica fume and rice husk ash. The use of such byproducts in concrete construction not only enhances the properties of concrete, but it also reduces cost, keep environment clean, and can avoid the byproducts form being land-filled. Furthermore, admixtures can replace a portion of the cement content and it will greatly reduce the cost especially for mass amount of concrete.

This project will involve two additives in concrete which is Silica Fume and Microwave Incinerated Rice Husk Ash (MIRHA). These two materials will act as a multiple binder in concrete and to improve the properties of concrete.

1.2 PROBLEM STATEMENT

Since long time ago, normal concrete has been used as the material for construction either in bridges, buildings dams and other structures. The main problem faced by construction industries while using the normal concrete is the limited strength of the concrete. The maximum strength of the concrete cannot sustain the design load of the structure. Nowadays, mineral admixtures have been introduced broadly all over the world as a new approach in enhancing the properties of normal concrete. However, when adding minerals admixtures into the concrete, the optimum amount of admixtures must be achieved in order to obtain the expected strength of the concrete. It is because the high amount of admixtures will not necessarily result in high strength of concrete.

Another problem that the construction industries have to overcome when using the OPC is the increase of carbon dioxide (CO_2) in air. The largest emissions from cement (actually clinker) manufacture is CO_2, amounting to nearly 1 metric ton of gas per metric ton of clinker. About one-half of which is derived from the calcinations of calcium carbonate raw materials, and the rest, from the combustion of fuels.

In current market, there are no combined set multiple binders which can be utilized in the construction industry. In the existing practices, the amount of these mineral admixtures had to be calculated before being added into the concrete. This project is design to find the optimum mix proportion for the multiple binders namely Microwaved Incinerated Rice Husk Ash (MIRHA), Silica Fume and OPC.

1.3 OBJECTIVE

1. To identify optimum proportion for binders and cement containing MIRHA and Silica Fume.
2. To determine the effect of Silica Fume and MIRHA as binders to the concrete's properties.

1.4 SCOPE OF STUDY

The scope of study conducted during this project includes the analysis of mechanical properties for every mixes. The analysis will be based on some tests conducted such as Compressive Strength Test, Porosity Test, Surface Hardness Test and Splitting Tension Test. For Compressive Strength Test, the data will be collected at 3, 7 and 28 days of age of the concrete with 3 samples per test. For Porosity, Dry Density, UPV and Water Absorption Test, the 28-day samples from each mix are tested with one sample per test. The sample consists of cube (150 mm x 150 mm x 150 mm) and cylinder (150 mm x 150 mm).

There are 3 sets of concrete with different compositions. The first set comprises of OPC, sand aggregate and water. The second set has the same composition as the first set with addition of MIRHA and the third set have the same composition as the first set with addition of MIRHA and Silica Fume.

The final analysis will be done by comparing all the data to get the optimal mix proportion as to fulfil the objectives of this study. Besides, the effect of MIRHA and Silica Fume on strength development will be observed by using the result of Compressive Strength.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 CONCRETE IN PRACTICE

Concrete is widely used in domestic, commercial, recreational, rural and educational construction. Communities around the world rely on concrete as a safe, strong, and simple building material. It is used in all types of construction, from domestic work to multi-storey office blocks and shopping complexes. Concrete is a composite material that composed of cement, water, sand and aggregate. Concrete is a well known structural component with typical compressive strength of approximately 1450 N/mm^2 to 5800 N/mm^2 [3]. Concrete are often mixed in improvised containers to have optimum mixing. There are three types of concrete which is Heavy weight Concrete, normal weight concrete and light weight concrete.

2.2 POZZOLANIC AND HYDRAULIC REACTION

Mineral admixtures can be divided into two categories based on their type of reaction, which is hydraulic or pozzolanic. Hydraulic materials react directly with water to form cementitious compounds, while pozzolanic materials chemically react with calcium hydroxide (CH), a soluble reaction product, in the presence of moisture to form compounds possessing cementing properties [5].

The word "pozzolan" was actually derived from a large deposit of Mt. Vesuvius volcanic ash located near the town of Pozzuoli, Italy. Pozzolanic can be used either as an addition to the cement or as a replacement for a portion of the cement. Most often, supplementary cementitious materials will be used to replace a portion of the cement content for economical or property-enhancement reasons.

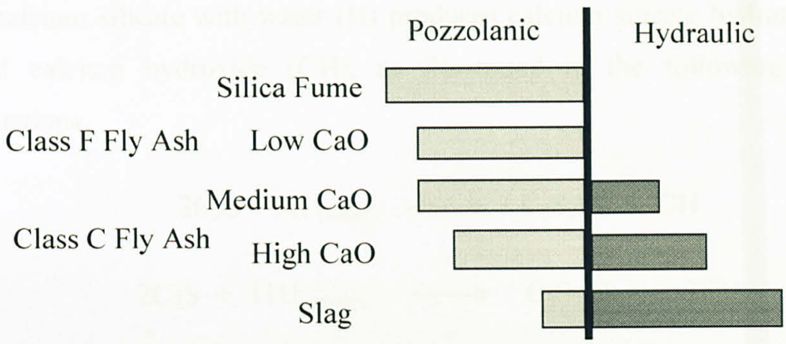

Figure 2.0: The Differences of Pozzolanic and Hydraulic Respond [5]

Figure 2.0 shows the differences between pozzolanic and hydraulic respond in supplementary materials. There are five materials which is Silica Fume, Low Calcium oxide (CaO), Medium CaO, High CaO and Slag. Silica Fume and Low CaO has pozzolanic reaction while Medium CaO, High CaO and Slag has both pozzolanic and hydraulic reactions. This shows that Silica Fume and Low CaO has high content of pozzolans and suitable to use as supplementary materials.

There are inorganic materials that also have pozzolanic or latent hydraulic properties. Pozzolans, such as fly ash and silica fume, are the most commonly used mineral admixtures in high-strength concrete. These materials can give additional strength to the concrete by reacting with Portland cement hydration products to create additional C-S-H gel, the part of the paste responsible for concrete strength. Without using chemical admixtures, it would be difficult to produce high-strength concrete mixture.

Hydration is the result of a chemical reaction that occurs between water and chemical compounds present in Portland cement. Portland cement is predominately composed of two calcium silicates which account for 70 percent to 80 percent of the cement. The two calcium silicates are dicalcium silicate (C_2S) and tricalcium silicate (C_3S)[5]. The other compounds present in Portland cement are tricalcium aluminate (C_3A), tetracalcium aluminoferrite (C_4AF) and gypsum. The reaction of dicicalcium silicate and tricalcium silicate with water (H) produces calcium silicate hydrate (C-S-H) and calcium hydroxide (CH), as illustrated in the following chemical equations.

$$2C_2S + 9H_{\text{(water)}} \longrightarrow C_3S_2H_8 + CH$$

$$2C_3S + 11H_{\text{(water)}} \longrightarrow C_3S_2H_8 + 3CH$$

C-S-H accounts for more than half the volume of the hydrated cement paste while CH accounts for about 25% of the paste volume. The remainder of hydrated Portland cement is predominantly composed of Calcium Sulfoaluminates (ettringite) and capillary pores.

C-S-H is a poorly crystalline material with a variable composition that forms extremely small particles less then 1.0υm in size. C-S-H is the mains cementitious compound, or glue that gives concrete its inherent strength. The structure of C-S-H becomes much more stable and resistant to subsequent environmental changes upon prolonged moist curing or curing at elevated temperatures, Calcium hydroxide on the other hand, is a well-crystallized material with a fixed composition, CH contributes somewhat to concrete's inherent strength because it will form large crystals inside voids, thereby reducing the porosity. However, CH is a soluble compound, meaning it will move throughout the pore system in the presence of water, making it extremely vulnerable to chemical attack.

C-S-H is also a superior reaction product, because it creates a denser microstructure that increases strength, reduces the permeability of the concrete and improves its resistance to chemical attack. The formation of CH, on the other hand, increases the concrete's porosity and is susceptible to sulphate attack. The pozzolanic reaction converts the soluble CH to C-S-H, increasing the overall strength and durability of the concrete.

2.3 CEMENT REPLACEMENT MATERIALS (CRM)

2.3.1 Microwave Incinerated Rice Husk Ash (MIRHA)

Rice husk as a by-product of paddy, tobacco waste from the cigarette factory, sugar cane in sugar industries, and groundnut shell are some examples of by products that are produced largely from agricultural sector.

Agriculture wastes are being produced in the whole world every year. The problem occurs when it comes to dispose these wastes. It become more challenging as the wastes possesses rough and abrasive surfaces that are highly resistant to natural degradation. These problems lead the researchers to find the proper methods in utilizing this waste. Biotechnology, cement and energy generation industries are recognized as the large sectors that are able to consume such huge quantities of these wastes. With the biotechnology, some agriculture wastes like wheat straw can be converted into nutrient rich bio-fertilizer (vermicompost) for sustainable land restoration practices. De-oiled soya can be used as the potential adsorbents for the removal of hazardous part from wastewater, coconut coir and durian peels as the desiccant for air conditioning system, and also selected herbaceous crops residue including *Brassica carinatai* are currently under study as the potential energy resources [10].

Meanwhile, wastes such as rice husk, sugar cane waste, tobacco waste, and groundnut shell can contribute to cement industries to become cement replacement material (CRM). It gives opportunity to the construction industries to reduce their cost while also preserving the environmental quality. The use of cement in concrete can be partially replaced by this pozzolanic material that is obtained from the combustion of agriculture waste.

There are 75 countries in the world that cultivated rice as a major agriculture food crop. About 400 million tons of paddy rice are produced annually in these countries. The survey done by a group of environmentalist shows that 1 ton of rice husk is generated from every 5 tons of paddy; thus, there should be about 80 million tons of rice husk available annually worldwide of which 64 million tons are produced in the Far East countries.

The increasing demand for rice by the growing populations in the rice-eating regions of the world creates an upward trend in the annual production of paddy rice. Due to the improvement in the milling process, there is also an expected increase in the amount of rice husk to be generated. The disposal of this low value by-product-rice husk-will continue to pose as a problem to the 75 countries where rice is grown. Apart from the construction potentials of rice husk its conversion into ash cement is, therefore, a better alternative to the present-day dumping and burning methods of disposing it.

Apart from its potential use as low grade fuel, insulation material and filler, rice husks can be used (after having incinerated to produce reactive ash) as a pozzolana to replace, partially, cement and also to be used in block-making.

In view of its abundant availability, many research institutions have undertaken considerable research over the last two decades, and the results and findings have been well documented. Table 2.0 gives typical example of results of the average compressive strengths of mortar cubes made of Portland rice-husk ash cements.

Rice-husk ash not only for block-making, a recent research work has proved that rice-husk ash can be used in manufacturing sodium silicate (waterglass) solution. Waterglass can be used as water proofing agent if applied, as paint to the external walls, foundation plinths, etc. It has also been used in the manufacture of adobe blocks to increase the durability of walls [10]

The different between rice-husk ash and Microwave Incinerated Rice Husk Ash (MIRHA) is MIRHA is burnt in the Modern incinerator to avoid environmental problem caused by open burning. 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.

Microwaves are part of the electromagnetic spectrum and are located between 300 MHz and 300 GHz. Microwave heating is defined as the heating of a substance by electromagnetic energy operating in that frequency range. There is a fundamental difference in the nature of microwave heating when compared to conventional methods of heating material. Conventional heating relies on one or more of the heat transfer mechanisms of convection, conduction, or radiation to transfer thermal energy into the material. In all three cases, the energy is deposited at the surface of the material and the resulting temperature gradient established in the material causes the transfer of heat into the core of the object. Thus, the temperature gradient is always into the material with the highest temperatures being at the surface [3].

In microwave heating, the microwave energy not only interacts with the surface material but also penetrates the surface and interacts with the core of the material as well. Energy is transferred from the electromagnetic field into thermal energy throughout the entire volume of the material that is penetrated by the radiation. Microwave heating does not rely on conduction from the surface to bring heat into the core region. Since the heating rate is not limited by conduction through the surface layer, the material can be heated quicker. Another important aspect of microwave heating is that it results in a temperature gradient in the reverse direction compared to conventional heating. That is to say, the highest temperature occurs at the centre of the object and heat is conducted to the outer layer of the material [3].

Figure 2.1 : Rice Husk before burnt

Figure 2.2 : Rice Husk after burnt become MIRHA

Burning temperature, time and environment, have different effects to the MIRHA produced. The quality depends on the method of ash incineration and degree of grinding. Burning with higher temperature will increase the SiO_2 content. But it is no suggested to burn rice husk above $800^{\circ}C$ longer than one hour, because it tends to cause a sintering effect (coalescing of fine particles) and is indicated by a dramatic reduction in the specific surface [3]. Table 2.1 shows the chemical composition of RHA under different burning temperature.

		Temperature (°C)				
		<300	400	600	700	1000
Element (%)	Si	81.90	80.43	81.25	86.71	92.73
	K	9.58	11.86	11.80	7.56	2.57
	Ca	4.08	3.19	2.75	2.62	1.97
	Na	0.96	0.92	1.33	1.21	0.91
	Mg	1.25	1.20	0.88	0.57	0.66
	S	1.81	1.32	1.30	1.34	0.16
	Ti	0.00	0.00	0.00	0.00	0.45
	Fe	0.43	1.81	0.68	0.00	0.68
Oxide (%)	SiO_2	88.01	88.05	88.67	92.15	95.48
	MgO	1.17	1.13	0.84	0.51	0.59
	SO_3	1.12	0.83	0.81	0.79	0.09
	CaO	2.56	2.02	1.73	1.60	1.16
	K_2O	5.26	6.48	6.41	3.94	1.28
	Na_2O	0.79	0.76	1.09	0.99	0.73
	Fe_2O_3	0.29	0.74	0.46	0.00	0.43

Table 2.0: Chemical Composition of RHA Under Different Burning

Temperatures

The table above clearly indicates that if the temperature is increased above 300°C, the chemical element is decreasing.

Combustion environment also give effects on the quality of rice-husk ash. It should be noted that a change in the rate of oxidation from moderately oxidizing conditions (CO_2 environment) to highly oxidizing conditions (oxygen environment) is responsible for the steep drop in the micro porosity and surface area [10]. The effect of the combination of various conditions to RHA is shown in Table 2.2.

Burning Temperature (° C)	Hold Time	Environment	Properties of ash	
			Crystalline	Surface Area (m^2/g)
500-600	1 min	Moderately oxidizing	Non crystalline	122
	30 min			97
	2 hours			76
700-800	15 min – 1 hr	Moderately oxidizing	Non crystalline	100
	> 1 hour	Highly oxidizing	Partially crystalline	6-10
> 800	> 1 hour	Highly oxidizing	Crystalline	< 5

Table 2.1: Effect of Burning Conditions on the crystal Structure and Surface Area of Rice Husk Ash

If the burning time is to longer, cellular form and coalescence of fine pores will collapse. It will subsequently cause a reduction in surface area. When burning at high temperature with longer time, a crystalline structure is formed with a sharp reduction in surface area. This lowers the pozzolanic activity. Figure 2.3 indicates the ideal time/temperature path to obtain optimum quality rice husk ash with a microporous and cellular structure which is highly reactive [12].

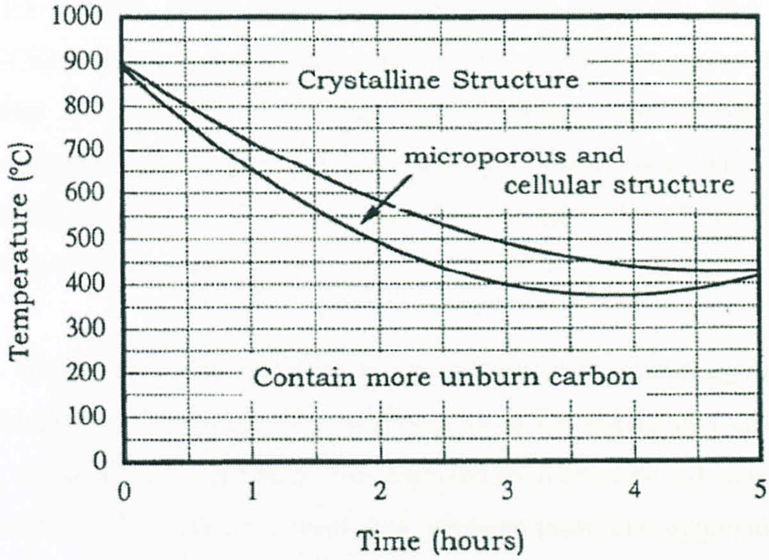

Figure 2.3: The Optimum Incineration Condition Curve for obtaining Reactive Cellular RHA

Silica oxide content obtained from open burning method will be lower than those obtained from controlled burning (muffle furnace). Properties of different RHA sample that is obtained in this previous research is shown in Table 2.3

Burning Method	Colour	LOI (%)	SiO_2 Total (%)
Annular Oven (Open Burning)	Light Grey	10.8	81.95
Brick Oven (Open Burning)	Light Grey	12.1	85
Pit Burning (Open Burning)	Grey	15.3	82
Muffle Furnace (Controlled Burning)	Dull White	0.84	88.50
Rice Factory (Uncontrolled Burning)	Black	20.5	76.7

Table 2.2: Properties of RHA under Different Burning Procedure

2.2.2 Silica Fume

Silica fume is an industrial byproduct of high-purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or ferrosilicon alloys. Silica is removed from exhaust gases as it cools and condenses into ultrafine droplets of silica glass. Silica fume has a high content of amorphous silicon dioxide (92 percent to 94 percent SiO_2). Silica fume can be used as an addition to cement, but it is usually used as a 5 percent to 10 percent replacement by mass for cement. Silica fume is typically more expensive than cement and is considered a property-enhancing material. Silica fume improves the strength and durability of concrete by creating denser cement matrix when compared to conventional concrete. Research has found that when silica fumes is used at a 15 percent replacement level, there are roughly 2 million silica fume particles for each grain of cement present.

Silica fume also modifies the paste structure around aggregares and other embedded items. This critical region is known as the interfacial transition zone (ITZ) and in conventional concrete is characterized by a massive calcium hydroxide layer laden with voids, creating a weak link between paste and aggregates. Due to their small size, silica fumes particles pack around the aggregate more efficiently, reducing porosity, modifying the paste structure and preventing bleeding. Many researchers believe this mechanism gives silica fume concrete its increased strength gain when compared to conventional concrete

Silica fume is a pozzolan and will consume roughly 50 percent of the calcium hydroxide present within the first 28 days when used at a 10 percent replacement level under normal curing conditions. The pozzolanic reaction is extremely sensitive to temperature and will be greatly accelerated by steam curing and other accelerated curing methods making it possible to achieve much higher early strengths. Due to its extremely small size and high surface area (20,000 m^2/kg), silica fume minimizes bleeding, which may lead to plastic shrinkage cracking. Most curing should begin as soon as possible to prevent this from curing.
As previously mention, silica fume is a property-enhancing material and can be used to meet durability requirements in project specifications. Silica fume also can be used to increase the compressive strength of lightweight concrete as well as conventional concrete.


Figure 2.4: Various types of silica fume

The addition of admixtures to cement has been found to enhance cement properties:

- The addition of speeds up setting time, although the water requirement is greater than for OPC.
- Improved compressive strength due to its higher percentage of silica.
- Admixtures has improved resistance to acid attack compared to OPC, though to be due to the silica present in the admixtures which combines with the calcium hydroxide and reduces the amount susceptible to acid attack
- More recent studies have shown admixtures have uses in the manufacture of concrete for the marine environment. Replacing 10% Portland cement with admixtures can improve resistance to chloride penetration
- Several studies have combined silica fume and MIRHA in various proportions. In general, concrete made with Portland cement containing both MIRHA and silica fume has a higher compressive strength that concrete made with Portland cement containing either MIRHA or silica fume in their own.
- Additives materials can improve compressive and tensile strength of the concrete.
- Several studies had proved that flexural strength had increase, when suitable proportion of mineral admixtures is added into the concrete

2.4 EFFECT OF CRM TO THE TEST

2.4.1 Compression Test

By definition, the compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (Usually cylindrical) is shortened as well as spread laterally. A Stress–strain curve is plotted by the instrument and would look similar to the figure 2.4:

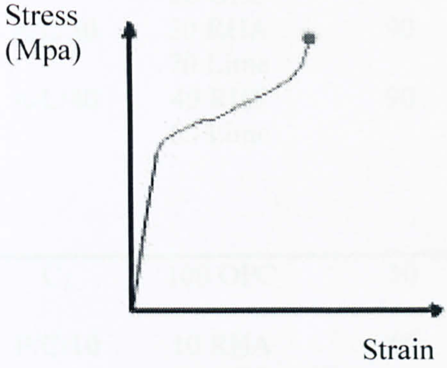

Figure 2.5: Engineering Stress-Strain curve for a typical speciment

Figure 2.5 shows the relations of stress and strain when the specimen is tested. The compressive strength of the material would correspond to the stress at the red point shown on the curve. Even in a compression test, there is a linear region where the material follows Hooke's Law. Hence for this region $\sigma = E\varepsilon$ where this time E refers to the Young's Modulus for compression.

This linear region terminates at what is known as the yield point. Above this point the material behaves plastically and will not return to its original length once the load is removed.

Sample No.	Composition of the cementitious material (percentage)	Number of specimens tested	Age (days)	Compressive strength	Remarks
C_1	100 OPC	30	7	12.4	Control samples 100 per cent OPC
P/C/10	10 RHA 90 OPC	60	7	14.3	115.3 per cent of controlled samples strength
P/C/20	20 RHA 80 OPC	60	7	12.9	104.0 per cent of controlled samples strength
P/C/30	30 RHA 70 OPC	60	7	11.7	94.0 per cent of controlled sample strength
P/C/40	40 RHA 60 OPC	60	7	10.5	84.7 per cent of controlled strength
P/C/50	50 RHA 50 OPC	60	7	10.2	82.3 per cent of controlled strength
A/L/30	30 RHA 70 Lime	90	7	8.2	Samples were at 50°C for 4 days
A/L/40	40 RHS 60 Lime	90	7	10.2	Strength for such accelerated curing is equivalent to the strength of 28 days normal curing
C_1	100 OPC	30	28	17.85	Control samples 100 per cent OPC
P/C/10	10 RHA 90 OPC	60	28	19.41	108.7 per cent of controlled samples strength
P/C/20	20 RHA 80 OPC	60	28	16.88	94.6 per cent controlled samples strength
P/C/30	30 RHA 70 OPC	60	28	15.33	81.1 per cent of controlled samples strength
P/C/40	40 RHA 60 OPC	60	28	14.29	80.1 per cent of controlled samples strength
P/C/50	50 RHA 50 OPC	60	28	12.24	68.6 per cent of controlled samples strength

Table 2.3 : Average compressive strength of the RHA/OPC mortar cubes [4]

Table 2.4 shows that when 10% of MIRHA replaced OPC, the compressive strength had increase and when 20% of MIRHA is replaced, the compressive strength suddenly dropped to 12.9 Mpa. The same situation occurs when the amount of MIRHA is increased until 50%. The same thing occurs for 28days concrete. The author had concluded that the best amount of MIRHA in the concrete is 10% of MIRHA with 90% of cement [4]

2.4.2 Splitting Tension Test

Splitting Tension Test is conducted to obtain the tensile strength of the concrete. The results of splitting tensile strength are shown in Table 2.5 and Figure 2.5. 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.

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

Table 2.4 : Average compressive strength of the RHA/OPC mortar cubes [13]

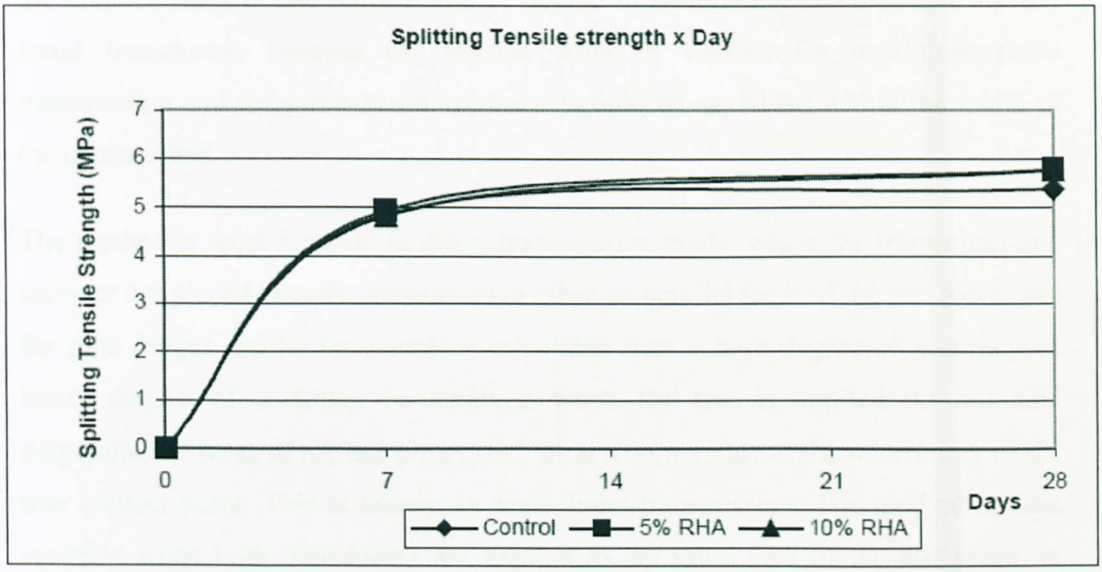

Figure 2.6 : Average compressive strength of the RHA/OPC mortar cubes [13]

The induced tensile stress state causes the specimen to fail by splitting. The maximum value of the tensile stress, computed at failure from the theory of elasticity, is the splitting tensile strength, f_{st}, ordinarily assumed in the standards to be a material property.

The main advantage of the splitting test is that the compressive loads are required. A cylindrical specimen of concrete is compressed along two diametrically opposed generators so that a nearly uniform tensile stress is induced in the loading plane. To prevent local failure in compression at the loading generators, two thin strips are placed between the loading platens and the specimen. It can be used to distribute the load.

2.4.3 Ultrasonic Pulse Velocity (UPV) Test

The ultrasonic pulse velocity (UPV) of a material can be determined by placing a pulse transmitter on one face of a sample of the material, and a receiver on the opposite face. A timing device measures the transit time of the ultrasonic pulse through the material. If the path length is known, then the UPV can be calculated from the path length divided by the transit time.

The accuracy of the method will depend on the geometry of the test, and the width of the contact faces of the transducers. A degree of uncertainty is introduced by flat faced transducers because the precise point of contact for maximum pulse transmission and reception is not known - it could be anywhere within the width of the contact face.

The method is most accurate in direct transmission mode, where the transmitter and receiver are placed directly opposite each other on parallel faces of the test piece, and the path length can be measured or calculated with a high degree of accuracy. A lesser degree of accuracy is achieved when the test is applied on mutually perpendicular faces of the test piece, such as at a corner, due to the uncertainty of the true contact point. This is known as semi-direct transmission. The method is least accurate when both transducers are applied to the same face of the test piece, or indirect transmission. Also, the inaccuracy will be proportionally greater for shorter transmission path than for longer ones.

CHAPTER 3

3.0 METHODOLOGY

3.1 PREPARATION OF ADDITIVES MATERIALS

During this project, two mineral admixtures are being used, which is silica fume and MIRHA. To prepare MIRHA, first, rice husk is burn in the incinerator oven with the temperature of 500C. After the rice husk had been burn, then it will left for cooling and after that, will be burn again for the second time (2 cycles burning) with a same temperature. After obtained the rice husk ash, it will then be grind in a grinder with 1200 rpm and then can be used in the concrete mixture.

The result for each properties of different mixture will then be compared to prove the hypothesis of the project. Throughout this project, the expected amount of rice husk ash needed is about 78 kg. The silica fume didn't need any preparation as it is already in the lab, ready to use.

3.2 PREPARATION OF CONCRETE

Several samples of concrete will be produced based on the test that had been determined. The size of each samples are shown in table 3.0.

Concrete	Size (mm)
Cube	150 x 150
Cylinder	150 x 150

Table 3.0 : The size of the concrete samples

The first sample is the plain concrete, which will act as a control item. The grade of the concrete would be 70. The plain concretes are made with the combination of cement, sand, aggregate and water. There are 9 plain concrete will be made and to be test at the age of 3 days, 9 days and 28 days.

Second set of samples, comprises of OPC and MIRHA. The amount of MIRHA are varies at 0%, 5%, 7.5% and also 10%. The portions of the mixture are shown in table 3.0.

Third set of the concrete samples will have the combination of OPC, MIRHA and Silica Fume. The amount of Silica Fume had been locked to 8% since the previous research had been proved that it will react actively at that point. A sample of concrete that combine an OPC and Silica Fume (without MIRHA) also will be made to compare it with other samples. The portions of the mixture are shown in table 3.0.

Cement (%)	SF (%)	MIRHA (%)
92	8	0
87	8	5
84.5	8	7.5
82	8	10

Table 3.1: The Portions of concrete

3.3 LABORATORY TEST

Compression Test

The compression test will be conducted on cube concrete on the 3rd days, 7th days, and 28th days. The purpose of compression test is to determine the behaviour of materials under crushing loads. The test is done by compressing the specimen and the deformation of it will be determined at various samples and the result will be recorded.

Compressive properties describe the behaviour of a material when it is subjected to a compressive load. Loading is at a relatively low and uniform rate. Compressive strength and modulus are the two most common values produced. The specimen is placed between compressive plates parallel to the surface. The specimen is then compressed at a uniform rate. The maximum load is recorded along with stress-strain data.

Figure 3.0: Compression testing machine

Splitting Tension Test

The other test that will be run is splitting tension test by using the cylinder concrete and also will be test after 28 days and 90 days. Each age of days will use 3 samples. The splitting tensile test is used to measure the tensile strength of concrete. A cylindrical specimen of concrete is compressed along two diametrically opposed generators so that a nearly uniform tensile stress is induced in the loading plane. To prevent local failure in compression at the loading generators, two thin strips are placed between the loading platens and the specimen. It can be used to distribute the load.

The induced tensile stress state causes the specimen to fail by splitting. The maximum value of the tensile stress, computed at failure from the theory of elasticity, is the splitting tensile strength, f_{st}, ordinarily assumed in the standards to be a material property.

Ultrasonic Pulse Velocity (UPV)

The velocity of an ultrasonic pulse through a material is a function of the elastic modulus and density of the material. The pulse velocity can therefore be used to assess the quality and uniformity of the material. The ultrasonic pulse velocity (UPV) of a material can be determined by placing a pulse transmitter on one face of a sample of the material, and a receiver on the opposite face. A timing device measures the transit time of the ultrasonic pulse through the material. If the path length is known, then the UPV can be calculated from the path length divided by the transit time.

Figure 3.1: Ultrasonic Pulse Velocity Test

3.4 STANDARD TEST METHOD

3.4.1 Standard Test Method for Compression Test

This test method covers the determination of strength of cylindrical concrete specimens that have been molded and cured in place using special molds attached to formwork for slabs. 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. A strength correction factor is required if the length-diameter ratio is less than 1.75.

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.

3.4.2 Standard Test Method for Splitting Tension Test

This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens. This method consists of applying a diametric compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength.

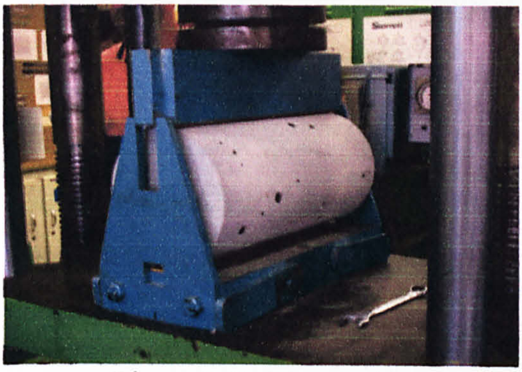

Figure 3.2 : Tensile test setup

Figure 3.3:Specimen after test

The induced tensile stress state causes the specimen to fail by splitting. The maximum value of the tensile stress, computed at failure from the theory of elasticity, is the splitting tensile strength, f_{st}, ordinarily assumed in the standards to be a material property.

3.4.3 Standard Test Method for Rebound Hammer Test

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 3.4: Rebound hammer

Figure 3.5: surface hardness testing

3.4.4 Standard Test Method for Slump Test

Slump Test is an in situ test or a laboratory test used to determine and measure how hard and consistent a given sample of concrete is before curing. The goal of the Concrete Slump Test is to measure the consistency of concrete. Many factors are taken into account when satisfying requirements of concrete strength, and to make sure that a consistent mixture of cement is being used during the process of construction. The test also further determines the "workability" of concrete, which provides a scale on how easy, is it to handle, compact, and cure concrete.

Before starting the test be sure to start the test within 5 min after obtaining the final portion of the composite sample. When performing the test, first dampen the slump cone and place it on a flat, moist, nonabsorbent, rigid surface. The concrete then fill into the cone in three layers, each approximately one third of the volume of the cone from the composite sample obtained and while standing on the two foot pieces of the cone. In placing each scoopful of concrete, rotate the scoop around the top edge of the cone as the concrete slides from it to ensure even distribution of concrete within the mold. Tamp each layer with 25 strokes by the rod (using the rounded end), and uniformly distribute the strokes over the entire cross section of each layer. Tamp the bottom layer throughout its depth and also tamp the second layer and the top layer each throughout its depth so that the strokes just penetrate into the underlying layer. Remove excess concrete from the opening of the slump cone by using tamping rod in a rolling motion until flat. Slowly and carefully remove the cone by lifting it vertically (5 seconds +/- 2 seconds), making sure that the concrete sample does not move. Wait for the concrete mixture as it slowly slumps. After the concrete stabilizes, measure the slump-height by turning the slump cone upside down next to the sample, placing the tamping rod on the slump cone and measuring the distance from the rod to the original displaced center.

Figure 3.6: Slump test cone

Figure 3.7: Concrete tamping

3.4.5 Standard Test Method for Ultra Velocity Test (UPV) Test

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.

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

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

The results for Compression Test, Splitting Tension Test, Rebound Hammer Test and UPV Test are as follows:

Types		OPC		MIRHA		SF		Strength (Mpa)			Stress (Mpa)		
		%	kg	%	kg	%		3 days	7 days	28 days	3 days	7 days	28 days
Normal Concrete (Control)		100	31.5	0	0	0	0	33.1	50.64	69.51	50.32	56.71	52.83
OPC + MIRHA		95	29.93	5	1.58	0	0	37.3	56.71	77.19	37.16	50.63	77.18
		92.5	29.14	7.5	2.36	0	0	36.2	55.21	75.25	36.52	48.26	76.52
		90	28.35	10	3.15	0	0	34.2	53.7	73.2	35.23	47.24	70.03
OPC+ MIRHA +SF	Set 1	92	28.98	0	0	8	0	58.24	63.02		58.47	63.16	
	Set 2	87	27.41	5	1.58	8	0	56.31	60.00		56.35	60.02	
	Set 3	84.5	26.62	7.5	2.36	8	0	54.36	59.10		54.56	58.82	
	Set 4	82	25.83	10	3.15	8	0	49.78	56.58		46.9	57.63	

Table 4.0 : Results of Compression Test

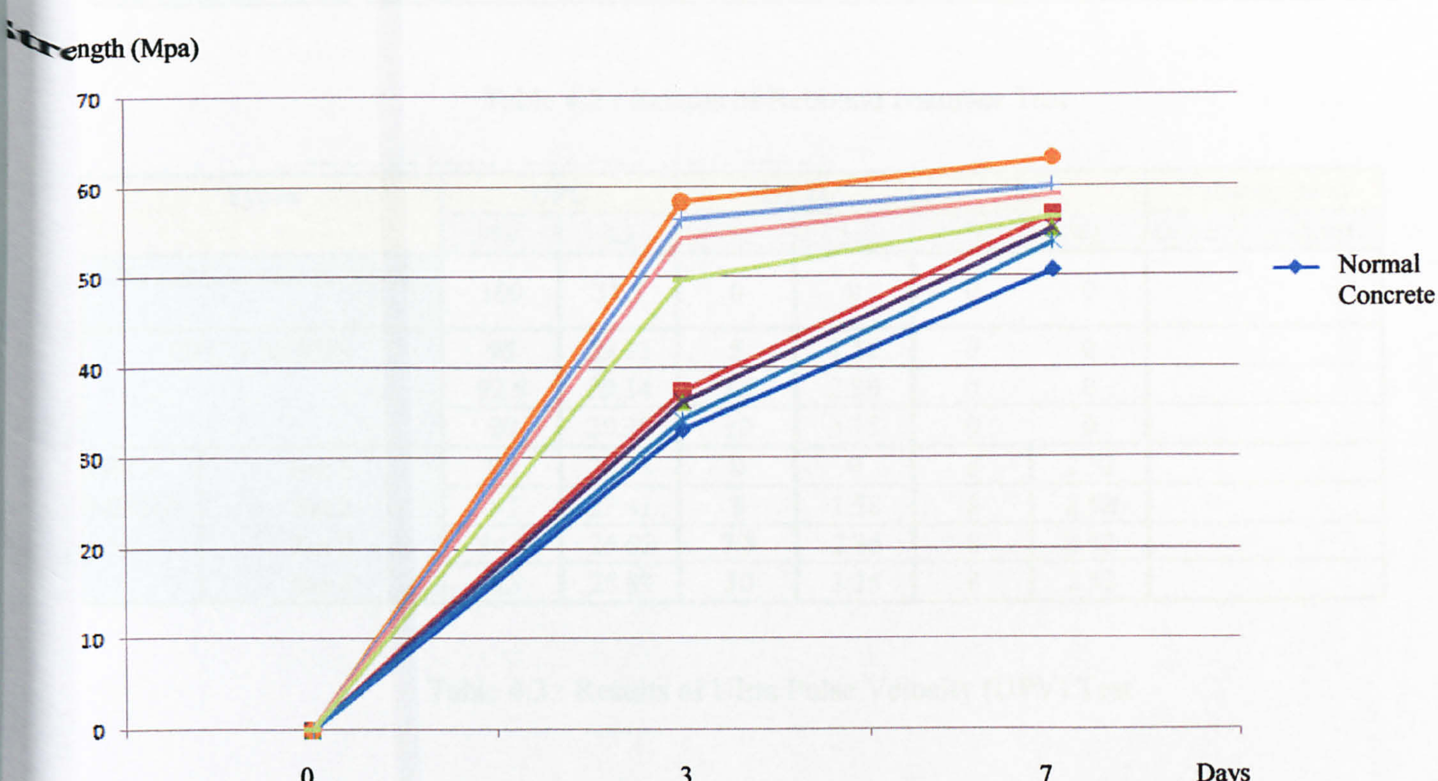

Figure 4.0 : Graphs of different samples of concrete

CHAPTER 4

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

The results for Compression Test, Splitting Tension Test, Rebound Hammer Test and UPV Test are as follows:

Types		OPC		MIRHA		SF		Strength (Mpa)			Stress (Mpa)		
		%	kg	%	kg	%		3 days	7 days	28 days	3 days	7 days	28 days
Normal Concrete (Control)		100	31.5	0	0	0	0	33.1	50.64	69.51	50.32	56.71	52.83
OPC + MIRHA		95	29.93	5	1.58	0	0	37.3	56.71	77.19	37.16	50.63	77.18
		92.5	29.14	7.5	2.36	0	0	36.2	55.21	75.25	36.52	48.26	76.52
		90	28.35	10	3.15	0	0	34.2	53.7	73.2	35.23	47.24	70.03
OPC + MIRHA + SF	Set 1	92	28.98	0	0	8	0	58.24	63.02		58.47	63.16	
	Set 2	87	27.41	5	1.58	8	0	56.31	60.00		56.35	60.02	
	Set 3	84.5	26.62	7.5	2.36	8	0	54.36	59.10		54.56	58.82	
	Set 4	82	25.83	10	3.15	8	0	49.78	56.58		46.9	57.63	

Table 4.0 : Results of Compression Test

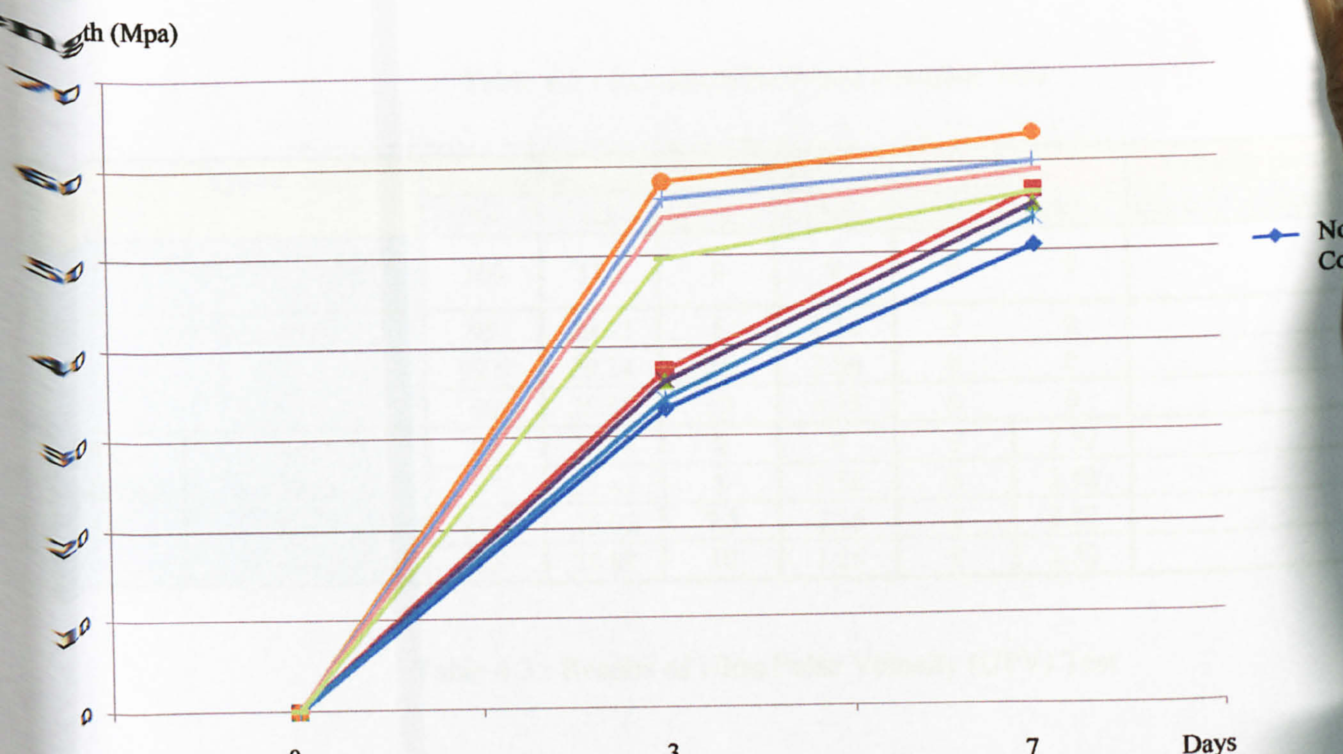

Figure 4.0 : Graphs of different samples of concrete

4.0 RESULTS AND DISCUSSIONS

4.1 RESULTS

The results for Compression Test, Splitting Tension Test, Rebound Hammer Test and UPV Test are as follows:

Types		OPC		MIRHA		SF		Strength (Mpa)			Stress (Mpa)		
		%	kg	%	kg	%		3 days	7 days	28 days	3 days	7 days	28 days
Normal Concrete (Control)		100	31.5	0	0	0	0	33.1	50.64	69.51	50.32	56.71	52.83
OPC + MIRHA		95	29.93	5	1.58	0	0	37.3	56.71	77.19	37.16	50.63	77.18
		92.5	29.14	7.5	2.36	0	0	36.2	55.21	75.25	36.52	48.26	76.52
		90	28.35	10	3.15	0	0	34.2	53.7	73.2	35.23	47.24	70.03
OPC+ MIRHA +SF	Set 1	92	28.98	0	0	8	0	58.24	63.02		58.47	63.16	
	Set 2	87	27.41	5	1.58	8	0	56.31	60.00		56.35	60.02	
	Set 3	84.5	26.62	7.5	2.36	8	0	54.36	59.10		54.56	58.82	
	Set 4	82	25.83	10	3.15	8	0	49.78	56.58		46.9	57.63	

Table 4.0 : Results of Compression Test

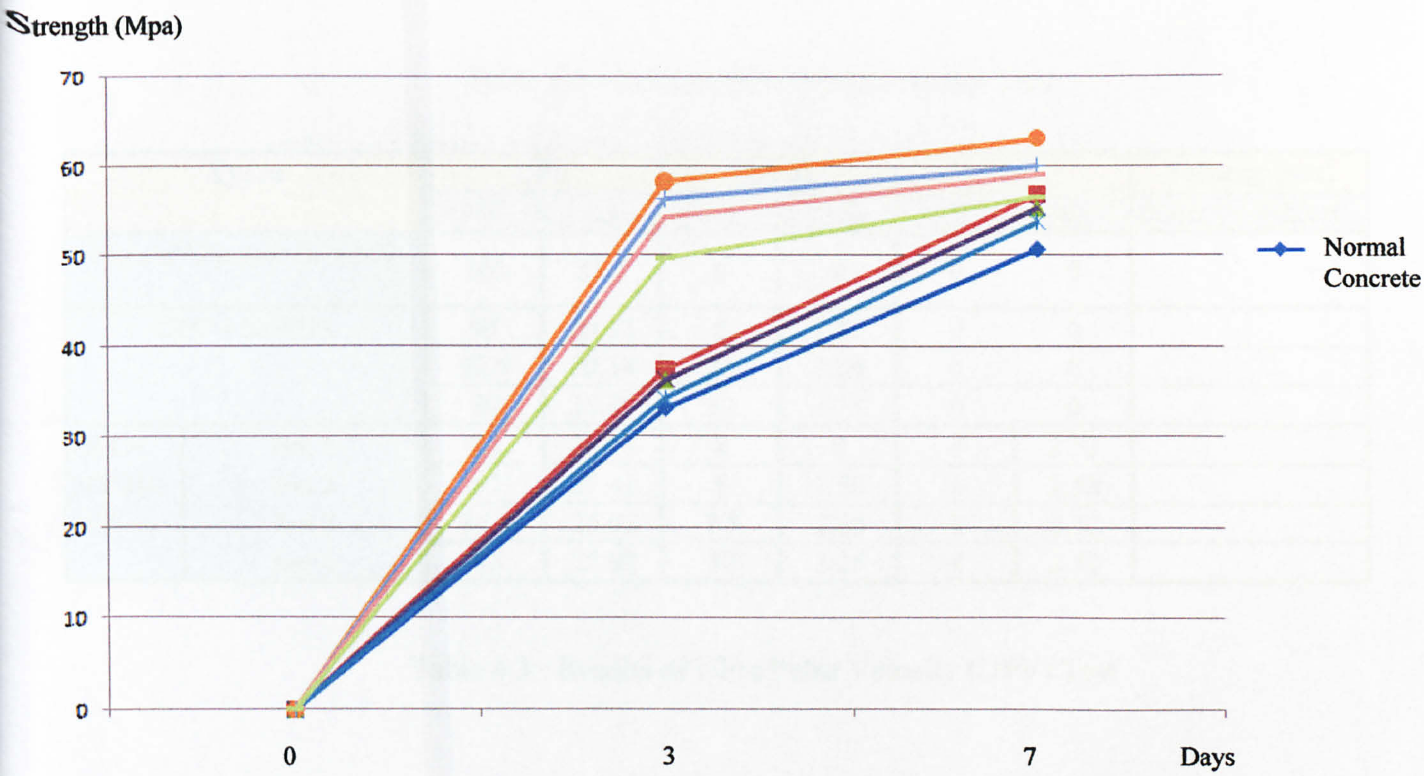

Figure 4.0 : Graphs of different samples of concrete

Types		OPC		MIRHA		SF		Strength (Mpa)
		%	kg	%	kg	%	kg	28 days
Normal Concrete (Control)		100	31.5	0	0	0	0	19.5
OPC + MIRHA		95	29.93	5	1.58	0	0	22.9
		92.5	29.14	7.5	2.36	0	0	23.4
		90	28.35	10	3.15	0	0	24.1
OPC+ MIRHA +SF	Set 1	92	28.98	0	0	8	2.52	
	Set 2	87	27.41	5	1.58	8	2.52	
	Set 3	84.5	26.62	7.5	2.36	8	2.52	
	Set 4	82	25.83	10	3.15	8	2.52	

Table 4.1 : Results of Splitting Tension Test

Types		OPC		MIRHA		SF		Velocity (m/s)	
		%	kg	%	kg	%	kg	Direct	Indirect
Normal Concrete (Control)		100	31.5	0	0	0	0		
OPC + MIRHA		95	29.93	5	1.58	0	0		
		92.5	29.14	7.5	2.36	0	0		
		90	28.35	10	3.15	0	0		
OPC+ MIRHA +SF	Set 1	92	28.98	0	0	8	2.52		
	Set 2	87	27.41	5	1.58	8	2.52		
	Set 3	84.5	26.62	7.5	2.36	8	2.52		
	Set 4	82	25.83	10	3.15	8	2.52		

Table 4.2 : Results of Rebound Hammer Test

Types		OPC		MIRHA		SF		Velocity (m/s)	
		%	kg	%	kg	%	kg	Direct	Indirect
Normal Concrete (Control)		100	31.5	0	0	0	0		
OPC + MIRHA		95	29.93	5	1.58	0	0		
		92.5	29.14	7.5	2.36	0	0		
		90	28.35	10	3.15	0	0		
OPC+ MIRHA +SF	Set 1	92	28.98	0	0	8	2.52		
	Set 2	87	27.41	5	1.58	8	2.52		
	Set 3	84.5	26.62	7.5	2.36	8	2.52		
	Set 4	82	25.83	10	3.15	8	2.52		

Table 4.3 : Results of Ultra Pulse Velocity (UPV) Test

4.2 DISCUSSIONS

From the results of Compression Test, we can see that the strength of the concrete with MIRHA has a higher strength at the age of 28 days. There was also a different existed in the strength development of the concrete when additional mixtures of Silica Fume were added. The concrete with Silica Fume had a higher strength at the age of 28 days. So, it was proved that additional of mixtures had taken an effect on the concrete strength. It was because the pozzolanic reaction occurs between pozzolan materials; MIRHA and Silica Fume, with the Calcium hydroxide to produce a stronger C-S-H gel bonding. The optimum reaction as we can see from the table was when 5 % of MIRHA were added. Maybe at the excess amount of MIRHA; 7.5 % and 10 %, were added, it had made the reaction become slower and made the strength development increase at slow rate. From the table also we can observe that the concrete that had a mixtures of MIRHA 5 % that added with Silica Fume had the highest strength at the age of 28 days. So we can say this was the optimum admixture that can be used to have a stronger concrete. The different of this mixtures concrete with the normal concrete was about 10 %. The strength development of the concrete at also clearly shown in the graph (figure 4.0).

Base on Table 4.1, the result for tensile strength was shown. It observed that from the table, at age 28 days, the concrete that added with MIRHA had a higher tensile strength compared to the normal concrete. The tensile strength optimum when 5 % of MIRHA were added. The tensile strength becomes stronger when additional admixtures of Silica Fume were added and the optimum value again when it contains 5 % of MIRHA.

The surface hardness of the concrete also different according the admixtures that added to the concrete. From Table 4.2, it observed that concrete that added with MIRHA and Silica Fume can add strength to the concrete. It can be compared with the normal concrete. Same as the integrity of the concrete where the mixture in the concrete become well distributed since addition of MIRHA and Silica Fume strengthen the C-S-H gel bonding.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The conclusion of this project, it was observed that an addition of MIRHA 5 % and Silica Fume 8 % 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 effect of MIRHA and Silica Fume 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 Silica Fume 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.

5.2 Recommendation

As for recommendation, this set of multiple binders should be introduced to the industries to solve the problems stated above and at the same time to produce cost effective structural concrete.

Besides that, a set of proportion of different admixtures can also be made to obtain on which admixtures can be used in the concrete mixtures to increase the strength and at the same time decrease the usage of Ordinary Portland Cement.

TEST TYPE	STANDARD ASSOCIATED	EQUIPMENT	TESTING AGE - day(s)	SAMPLE SIZE	NO OF TEST	MEASUREMENT UNIT
Compression Test	**ASTM C873 / C873M - 04e1**	Compressive Strength Test Machine	3,7, 28	Cube sample (150mm X 150mm X 150mm)	3 samples of each day test.	N / mm2
Splitting Tension Test	**ASTM C496 / C496M - 04e1**		28	Cylinder sample (150mm of height with 150mm of diameter)	3 samples of each day test.	mm-kg
Surface Hardness Test		Rebound Hammer	28	Cube sample (150mm X 150mm X 150mm)	3 samples of each day test	N / mm2
Ultra Pulse Velocity		UPV Device	28	Cube sample (150mm X 150mm X 150mm)	3 samples of each day test	m/s

Table 5.0 : Experimental Detail

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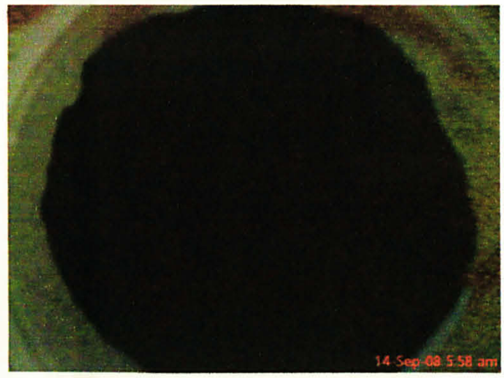
APPENDICES

Appendix A: Materials used for the project

Cement



MIRHA

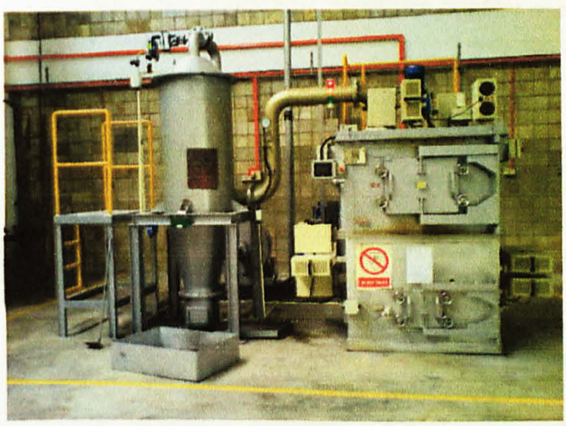
Sand

Water with super plasticizer

Appendix B: Equipment used in the project

Concrete Mixer

Compression Testing Machine



Microwave Incinerator

Grinding Machine

Vacuum Tank (Porosity Apparatus)

Appendix C: Lab manual for mixing and sampling concrete

UNIVERSITI TEKNOLOGI PETRONAS	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 D: Lab manual for compressive strength test

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 $0.2 N/mm^2s$ 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

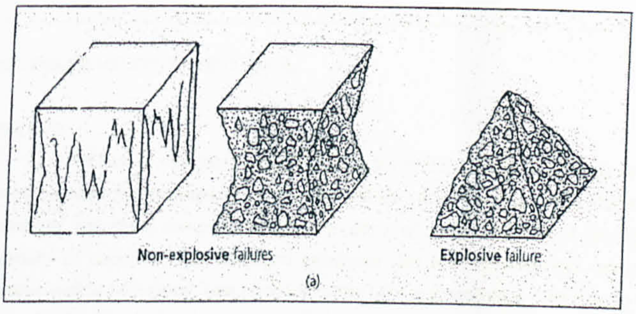


FIGURE 5: The outcome of cube test – normal case

Appendix E: Lab manual for Ultrasonic Pulse Velocity (UPV) Test

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

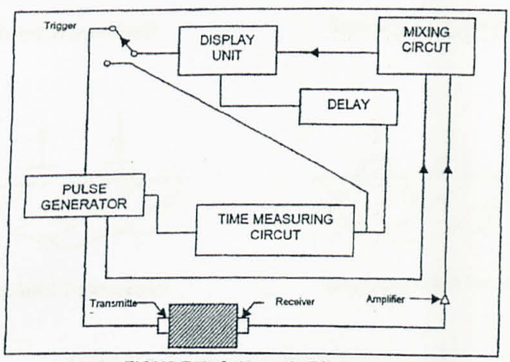


FIGURE 7: Schematic Diagram

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.

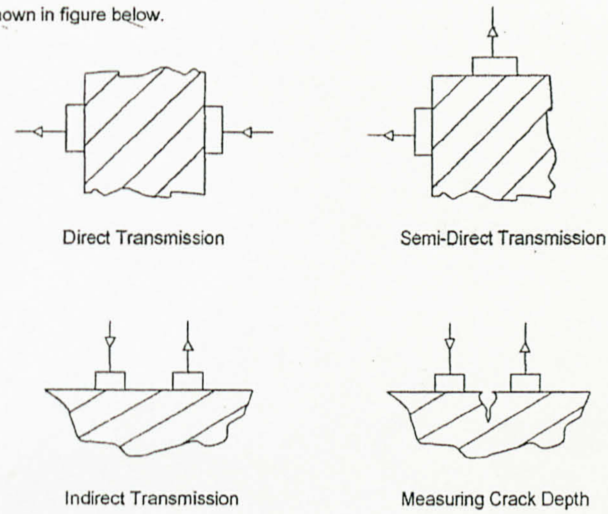


FIGURE 8: Determine Ultrasonic Pulse Velocities