The effect of Microwave Incinerated Rice Husk Ash on foamed mortar

by

Nor Azian binti Abusman

Supervisor: Associate Professor Ir Dr Hj Muhd Fadhil Nuruddin

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

JULY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

The effect of Microwave Incinerated Rice Husk Ash on foamed mortar

by

Nor Azian binti Abusman

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(Associate Professor Ir Dr Hj Muhd Fadhil Nuruddin)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

July 2008

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.

NOR AZIAN BINTI ABUSMAN

The effect of Microwave Incinerated Rice Husk Ash on foamed mortar

ABSTRACT

Concrete is one of the most widely used construction materials in the world such as for building project or bridge construction. However, the production of portland cement, an essential constituent of concrete, leads to the release of significant amount of CO_2, a greenhouse gas. In recent trends, the enhancements of the properties of concrete are made by incorporating huge amount of wastes particularly the solid wastes such as rice husk as partial cement replacement material. This phenomenon has turned wastes to value. The main objectives of this research are to determine the optimum of MIRHA content in foamed concrete mix proportion and to establish the effect of MIRHA on the properties of foamed concrete. The scope of study comprises test and analysis conducted on MIRHA as cement replacement material in concrete, strength and density of foamed mortar. In this study, mix proportion parameters of foamed concrete are analyzed by using the Taguchi's experiment design methodology for optimal design. For that purpose, mixtures are designed in a L16 orthogonal array with five factors, namely, MIRHA content; Water to cementitious materials ratio (W/C); sand to cementitious materials ratio (s/c); Superplasticizer content (SP); Foam agent content (FC). The mixtures are extensively tested, both in fresh and hardened states and to meet all of the practical and technical requirements of foamed concrete. The experimental results are analyzed by using the Taguchi experimental design methodology. The best possible levels for mix proportions are determined for maximization of ultrasonic pulse velocity (UPV), compressive strength and splitting tensile strength. It is hoped that this research will help the construction industry in Malaysia to be more successful.

ACKNOWLEDGEMENT

Compiling and coming out with a final report such as this and making sure its information are accurate is an enormous task. I would like to express my sincerest appreciation to everyone who was involved throughout the entire process of this Final Year Project. I would like to single out a few individuals for special recognition; AP.Ir Dr Hj Muhd Fadhil Nuruddin my respected supervisor, for his guidance and willingness to share ideas. His suggestions, support, boundless patience, and at times, his sympathetic ear have made this research work a success. Ridho Bayuaji my tutor for coordinating the work. His cooperation and readiness to try new things is highly appreciated. To the entire technician in Civil Engineering and Mechanical Engineering Department, thank you for assisting me in completing my project. Last but not least, my friends Mariadas Brian and Robeyatul Adawiyah who have helped me in many ways while doing the concrete mixing and laboratory work. . Without the cooperation of all of them, I would have faced difficulty through out the course. Together we started, together we end it. Thank you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is one of the most widely used construction materials in the world. However, the production of Portland cement, an essential constituent of concrete, leads to the release of significant amount of CO_2 [1], a greenhouse gas. One ton of Portland cement clinker production creates one ton of CO_2 and other greenhouse gases (GHGs) [2]. Environmental issues will play a leading role in the sustainable development of the cement and concrete industry in this century. In the other hand, recent trends in enhancements the properties of concrete are made by incorporating huge amount of wastes particularly the solid such as rice husk as partial cement replacement material, which turned wastes to value.

Since the earthquake, forces that influence civil engineering structures and buildings are proportional to their mass, reducing the mass of the structure or building is of utmost importance to ensure its resistance against earthquake disaster. Lightweight structural design can also help reduce the overall construction costs. One way to reduce the mass or dead weight of a structure is to use lightweight concrete in the construction.

As an inexpensive sorption material the cellular concrete was chosen. This type of concrete has been developed as a result of looking for weight reduction of concrete products. The very effective way of the concrete weight reduction lies in an introduction of stable voids within the hardened cement paste. During the manufacturing process bubbles of gas liberate and constitute numerous small cells within the concrete product. Therefore, names: aerated concrete, gas concrete and foamed concrete are used. ''Strictly speaking, the term 'concrete' is inappropriate because no coarse aggregate is present''

Foamed concrete is lightweight material as having air content more 25% that distinguishes it from normal concrete material. Besides, foamed concrete is lightweight material and have the other overcoming, there are its flow ability, self-compacting and self-leveling nature. Many researchers explored foamed concrete that reduce density of concrete. Foamed concrete is reported as the most economical and controllable pore-forming process as there are no chemical reactions involved.

MIRHA is a by product of paddy that can be obtained with the combustion process of rice husk. The high content of amorphous silica and very large surface area make RHA become a highly reactive pozzolanic material that can be used to improve the strength and durability of concrete. Generally, reactivity of pozzolanic material can be achieved by increasing the fineness degree of the material [6]. However, Mehta has argued that grinding of MIRHA to a high degree of fineness should be avoided, since it derives its pozzolanic activity mainly from the internal surface area of the particles. At a certain stage of grinding the MIRHA, the porous structure of the particle will collapse, thereby reducing the surface area of the MIRHA.

1.2 PROBLEM STATEMENT

The significant method to increase strength of foamed concrete was to use autoclaved method in the curing regime. The autoclaved method is mostly employed in the construction industry on precast elements and is quite expensive. For OPC itself usually the concrete is heavier than MIRHA with foamed concrete. So that, the budget can reduces by MIRHA as replacement material. In cost of view, MIRHA is cheaper than OPC since it is by product of paddy.

This research is focused on the effect MIRHA with the material composition that is highly reactive so it can be used as cement replacement material, and also the optimum replacement percentage of MIRHA that is required to improve the quality of foamed concrete with simply curing in foamed concrete.

1.3 OBJECTIVES

Upon completing the project, a few objectives need to be achieved. The objectives of study are as follows:

1. To determine the optimum percentage of MIRHA in a mix proportion of foamed concrete
2. To establish the effect of MIRHA on the properties of foamed concrete.

1.4 SCOPE OF STUDY

The scope of study comprises research conducted on percentage in design of MIRHA as cement replacement material in concrete with density 1400 to 1800 kg/m^3. Second is, testing of MIRHA concrete strength at age 3,7 and 28 days and density using ASTM C 330, for structural application standard

Compressive strength test are conducted on MIRHA concrete samples of size 50x50x50 mm. The ages of tests are 3, 7 and 28 days. In the study, investigation is carried out using MIRHA as a cement replacement material at of 0%, 5%, 10% and 15% with concrete density of 1400 to 1800 kg/m^3. For split test, MIRHA concrete sample sizes are 200 x diameter 100mm. The age of test is 28 days.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2 LITERATURE REVIEW

2.1 Introduction

Foamed concrete is generally defined as a lightweight material consisting of portland cement, cement-silica, cement–pozzolan, lime pozzolan or lime-silica plates, or pastes containing blends of these ingredients and having a homogeneous void or cell structure attained with foaming agents. The density of lightweight concrete is 1750 kg/m^3. Air contents from 30-80 percent are not uncommon. When comparing foam concrete with other materials, one must keep in mind that:

1. It is ecologically clean, breathes, uninflammable.
2. easy to produce in steady-state conditions as well as on a construction site
3. is produced from components available in any region
4. its prime cost is low

2.2 Foamed Concrete

2.2.1 Definition of foamed concrete

Foam concrete is a type of porous concrete. According to its features and uses it is similar to aerated concrete. The synonyms are:

1. aerated concrete
2. lightweight concrete
3. porous concrete

Foam concrete is created by uniform distribution of air bubbles throughout the mass of concrete. Foam concrete is produced by mechanical mixing of foam prepared in advance with concrete mixture, and not with the help of chemical reactions. Foam is prepared in special device foam generator and after that mixing in special mixer. (For example machine Fomm-Prof consist from special mixer and foam generator mounting together).

Fomm-Prof machines could produce foam concrete with different densities from 200kg/cub.m. to 1600kg/cub.m.

Density 300-500 kg/m3 (19-38 lbs/ft3) Made with Cement & Foam Only

Foam concrete with this densities is used in roof and floor as insulation against heat and sound and is applied on rigid floors (i.e. in itself it is not a structural material). It is used interspaces filling between brickwork leaves in underground walls, insulation in hollow blocks and any other filling situation where high insulating properties are required.

Density 600-900 kg/m3 (38-56 lbs/ft3) Made with Sand, Cement & Foam

Used for the manufacture of precast blocks and panels for curtain and partition walls, slabs for false ceilings, thermal insulation and soundproofing screeds in multi-level residential and commercial buildings. Foam concrete of this density range is also ideal for bulk fill application.

Density 1000-1200 kg/m3 (56-75 lbs/ft3) Made with Sand, Cement & Foam

This material is used in concrete blocks and panels for outer leaves of buildings, architectural ornamentation as well as partition walls, concrete slabs for roofing and floor screeds.

Density 1200-1600 kg/m3 (75-100 lbs/ft3) made with Sand, Cement & Foam

This material is used in precast panels of any dimension for commercial and industrial use, garden ornaments and other uses where structural concrete of light weight is an advantage. Table 2.1 shows the main features and characteristics of foamed concrete.

Table 2.1: Main features and characteristics of foamed concrete:

Type of foam concrete	Sort of foam concrete according to average density	Non-autoclave foam concrete	
		28 day compressive strength MPa**	Thermal Conductivity W/mk
Heat-insulated	D400	1	0.1
	D500	1.4	0.12
Constructional-heat-insulated	D600	3.5	0.14
	D700	5	0.18
	D800	7	0.21
	D1000	10	0.24
Constructional	D1100	14	0.34
	D1200	17	0.38

** The effects of foamed concrete density, cement type and content, water/cement ratio, foam type and curing regime will influence the compressive strength.

The importance of the foam within any foamed material cannot be over emphasized and is of particular importance when producing foamed materials for structural uses and mass void in fills. It is therefore important to understand the two main types of foam that are used in the production of foamed concretes.

Wet Foam

Wet foam is produced by spraying a solution of foaming agent (usually synthetic) and water over a fine mesh. This action causes a drop in pressure across the mesh allowing air to be sucked from atmosphere to equal the pressure. This equalization of pressure causes the solution to expand into what can best be described as foam similar in appearance to bubble structure and although relatively stable it is not recommended for the production of low density (bellow 1100 kg/m^3) foamed materials. It is also not suitable for pumping long distances or pouring to any great depth.

Dry Foam

Dry foam is produced by forcing a similar solution of foaming agent and water through a series of high density restriction whilst at the same time forcing compressed air in to a mixing chamber. The action of forcing this pressurized air into the solution expands the solution into thick, tight foam, similar in appearance to shaving foam. The bubble size is typically less than 1 mm in diameter and of an even size. This type of foam is extremely stable and these stable properties are passed onto foamed materials when the foam is blended with the base materials.

As detailed previously this stability is particularly important when the ratio of foam to base materials is greater than 50:50. When the foam becomes the dominant partner within the mix it has to retain its stability to avoid collapse during, pumping, curing, pouring, etc. Foamed concrete produced using dry foam can be pumped further, poured deeper and exhibits better flow characteristics than a like for like mix produced with a wet foam system.

2.2.2 Advantages of foamed concrete

1. Reliability - Foam concrete is an almost ageless and everlasting material not subject to the impact of time. It does not decompose and is as durable as rock. High compression resistance allows using produce with lower volumetric weight while construction, which increases the temperature lag of a wall.
2. Warmth - Due to high temperature lag, buildings constructed from foam concrete are able to accumulate heat, which allows minimizing heating expenses by 20-30%.
3. Microclimate - Foam concrete prevents loss of heat in winter, is humidity proof, and allows avoiding very high temperatures in summer and controlling air humidity in a room by absorbing and output of moisture, thus helping create a favorable microclimate (Microclimate in a wooden house).

4. Quickness of Mounting - Small density, and, therefore, lightness of foam concrete, large sizes of blocks compared with bricks, allow increasing the speed of lying by several times. Foam concrete is easy to process and trim to cut channels and holes for electrical wiring, sockets, and pipes. The simplicity of lying is reached through high exactness of linear dimensions; the tolerance is +/- 1 mm.
5. Accosting Insulation - Foam concrete has a relatively high property of acoustical absorption. In buildings constructed of porous concrete the acting requirements for acoustic insulation are met.
6. Ecological compatibility - During maintenance, foam concrete does not produce toxic substances and in its ecological compatibility is second only to wood. Compare: the coefficient of ecological compatibility of porous concrete is 2; of wood 1; of brick 10; of keramzite blocks 20.
7. Appearance - Due to high workability, it is possible to produce various shapes of corners, arches, pyramids, which will attach beauty and architectural expressiveness to your house.
8. Economy - High geometrical exactness of dimensions of concrete produce allows lying blocks on glue, to avoid frost bridges in a wall and to make inner and outer plaster thinner. Foam concrete weighs from 10% to 87% less than standard heavy concrete. Sufficient reduction of weight leads to sufficient economy on basements.
9. Fire Safety - Foam concrete produce protect from fire spread and correspond to the first degree of refractoriness, which is proved by tests.

Thus, it is can be used in fire-proof constructions. Under the impact of intensive heat, like blow lamp, on the surface of foam concrete, it does not split or blow, as it happens with heavy concrete. AS a result, armature is longer protected from heating. Tests show that foam concrete 150 mm wide can protect from fire for 4 hours. During tests carried out in Australia, an outer side of a foam concrete panel 150 mm wide was exposed to temperatures up to 1200^0C.

10. Transportation - Favorable combination of weight, volume and packaging makes all building constructions convenient for transportation and allow to use motor or railway transport.
11. Range of uses - Thermal and acoustic insulation of roofs, floors, warming of pipes, production of collapsible blocks and panels of partitions in buildings, as well as floors and basements foam concrete of higher density.

2.2.3 Disadvantages of foamed concrete

When proposing to utilize foamed concrete it is important to consider all design criteria particularly in the following areas

1. Compressive and Flexural strength will degrade typically as a function of density
2. Retention values of attachment fixtures – again this is a function mainly of density. Particular attention needs to be given to those areas where continuous impact may occur – door jambs etc
3. Unless purpose designed equipment is used mixing may be a problem as the foam tends to float at the surface of the mix and thus its effectiveness is diminished. Issue readily addressed be injecting foam into rather than on to mix in the case of an open mixer, or in the case where foam is introduced into a flowing product line it is not a problem.

2.3 Mix Design

When designing a foamed concrete mix, two variables, namely the cement content and the foam content should established and there fore two equations have to be solved. To make up one cubic meter of foamed concrete the sum of the material weights should be equal to the required casting density and the sum of the volume of all the constituent materials should be one cubic meter (or 100 liter), the two equations can be written as follows:

$$\rho m = x + x(\frac{w}{c}) + x(\frac{a}{c}) + x(\frac{s}{c}) + x(\frac{a}{c})(\frac{w}{a}) + x(\frac{s}{c})(\frac{w}{s}) + RD_f.V_f(1) \qquad (1)$$

$$1000 = \frac{x}{RD_c} + x(\frac{w}{c}) + \frac{x(\frac{a}{c})}{RD_a} + \frac{x(\frac{s}{c})}{RD_s} + x(\frac{a}{c})(\frac{w}{a}) + x(\frac{s}{c})(\frac{w}{s}) + .V_f(2) \qquad (2)$$

Where:

rm = target casting density (kg/m3)

X = cement content (kg/m3)

w/c= water/cement ratio

a/c = ash/cement ratio

s/c = sand/cement ratio

w/a= water/ash ratio

w/s= water/sand ratio

Vf = volume of foam (l)

RDf = relative density of foam

RDc = relative density of cement

RDa = relative density of ash

RDs = relative density of sand

2.3.1 Material Properties

As in normal concretes the greater the air content the weaker the material, so with foamed concrete densities ranging from 400 kg/m3 to 1600 kg/m3 it is not surprising that the lower densities produce the lower strengths. Table 2.2 shows the typical properties of conventional foamed concrete.

Table 2.2: Typical Properties of conventional foamed Concrete

Dry Density (kg/m3)	Compressive Strength (N/mm2)	Thermal Conductivity W/mk	Modulus Elasticity kN/mm2	Drying Shrinkages %
400	0.5-1.0	0.1	0.8-1.0	0.3-0.35
600	1.0-1.5	0.11	1.0-1.5	0.22-0.25
800	1.5-2.0	0.17-0.23	2.0-2.5	0.20-0.22
1000	2.5-3.0	0.23-0.3	2.5-3.0	0.18-0.15
1200	4.5-5.5	0.38-0.4	3.5-4.0	0.11-0.09
1400	6.0-8.0	0.5-0.55	5.0-6.0	0.09-0.07
1600	7.5-10.0	0.62-0.66	10.0-12.0	0.07-0.06

2.3.2 Engineering Properties

a. Density 800-2080 kg/m^3
b. The Modulus of elasticity of cellular concrete is generally between 1.7 and 3.5 GPa
c. Cellular concrete exhibits high shrinkage, ranging from 700×10^{-6} for cellular concrete with an oven-dry density of 1600 kg/m^3 to 3000×10^{-6} when the oven-dry density is 400 kg/m^3
d. The moisture movement is also high.
e. The usual range of the coefficient of permeability is 10^{-6} to 10^{-10} m/s .

2.4 Cement Replacement Material

After aluminium and steel, Portland cement is the most energy-intensive product and efforts are being made to find cement replacement material. The use of MIRHA offers one such possibility.

2.4.1 Microstructure Incinerated Rice Husk Ash

Due to growing environmental concerns and the need to conserve energy and resources, efforts have been made to burn the rice husk at a controlled temperature and atmosphere, and to utilize the ash so produced as a supplementary cementing material Microwave Incinerated Rice Husk Ash, being available as a waste product, is very cheap in comparison to cement. It is expected that if replacement of a certain portion of cement with indigenously produced MIRHA does not adversely change the strength and durability of concrete, it would be cost effective.

Microstructure Incinerated Rice Husk Ash (MIRHA) as a by product of rice paddy milling industries is resulted from about 20% of a dried rice paddy. It has a large dry volume due to its low bulk density (90 – 150 kg/m^3) [1]. Current world rice production which already exceeds 600 million tons per year [2] truly gives a problem to the disposal of its husk.

The chemical composition of rice husk is similar to that of many common organic fibers and contains:

- Cellulose ($C_5H_{10}O_5$), a polymer of glucose, bonded with B-1.4
- Lignin ($C_7H_{10}O_3$), a polymer of phenol
- Hemi cellulose, a polymer of xylose bonded with B-1.4 whose Composition is like xylem ($C_5H_8O_4$)
- SiO_2, the primary component of ash.

The holocellulose (cellulose combined with hemi cellulose) content in rice husk is about 54%, but the composition of ash and lignin differ slightly depending on the species [1, 3].

In the samples super plasticizer was used to have slightly higher strengths and more workability. Strength properties of concrete produced by using MIRHA as a supplementary cementing material have been compared with their plain concrete counterpart.

The main use of rice husk is as fuel in the rice paddy milling process [4]. The use of this fuel generates a huge volume of ash and in certain country; this ash is dumped into water stream which later causes pollution and contamination of springs [4]. It inspires many researchers in the world to find a proper solution for this problem. High silica content with the micro porous structure inside Microstructure Incinerated Rice Husk Ash (MIRHA) leads to the utilization of MIRHA as Cement Replacement Material.

2.4.2 Microstructure Incinerated Rice Husk Ash as Cement replacement Material

For developing countries where rice production is abundant, the use of Microstructure Incinerated Rice Husk Ash (MIRHA) to partially substitute for cement is attractive because of its high reactivity [1]. Current researches have shown that partial replacement of OPC with MIRHA will improve the concrete performance, either its strength or durability [4, 5]. Since the pozzolanic reactivity of MIRHA is influenced by the presence of high silica content and large internal surface area, the burning process should be controlled to remove the cellulose and lignin portion while preserving the original cellular structure of rice husk [5]. The silica also should be held in a non crystalline state and in highly micro porous structure [6, 1].

2.4.3 The Quality of MIRHA

The quality of MIRHA 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 structure [1]. Burning temperature, time, and environment, each of this condition has different effect to the MIRHA produced. Table

2.3 below is showing the chemical composition of MIRHA under different burning temperature.

Table 2.3 Chemical Composition of RHA (Taiwan) under Different Burning Temperatures, Hwang and Wu [3]

		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 2.3 shows that burning the RHA with higher temperature will increase the SiO_2 content. But it is not suggested to burn rice husk above 800°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 [1].

Combustion environment also plays an important role. 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) was responsible for the steep drop in the micro porosity and surface area [1]. The effect of the combination of these three conditions to MIRHA is shown in Table 2.4.

Table 2.4. Effect of Burning Conditions on the Crystal Structure and Surface Area of Rice Husk Ash. Adapted from Ankra [7]

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

Longer burning time will cause collapse of the cellular form and also coalescence of the fine pores [3], which consequently causes a reduction in surface area [3]. At higher temperatures with longer burning times, a crystalline structure is formed with a sharp reduction in surface area. This lowers the pozzolanic activity. Figure 2.1 indicates the ideal time/temperature path to obtain optimum quality rice husk ash with a microporous and cellular structure which is highly reactive [1].

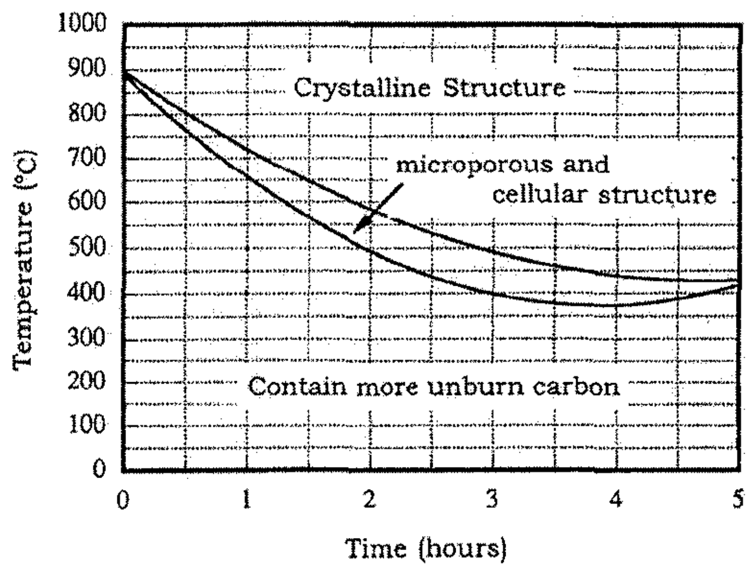


Fig 2.1 The Optimum Incineration Condition Curve for obtaining Reactive Cellular RHA. Adapted from Hwang and Chandra [8].

2.4.4 Influence on Concrete

Hydration Mechanism

Performance of concrete with MIRHA can be predicted by studying the hydration mechanism of its paste. The hydration process of cement with water produces interior heat that if the temperature is too high, may develops crack in the cement paste [3]. Figure 2.2 revealed that addition of MIRHA into the concrete could give lower heat evolution even they are in the same curve shape for both concrete with or without MIRHA. The water to cement ratio combined with the amount of MIRHA added result in various heat evolutions. The curve also shows the delaying period between first peak and second peak.

At higher MIRHA content, K^+ and SiO react with Ca^{2+} to lower both the first and second peaks. Higher water to cement ratio may also lower the heat of hydration due to the diluting effect of water. At the second stage of hydration (dormant period), the concentration of Ca^{2+} decreases, thereby increasing the saturation time of ion and thus delaying the second peak [1].

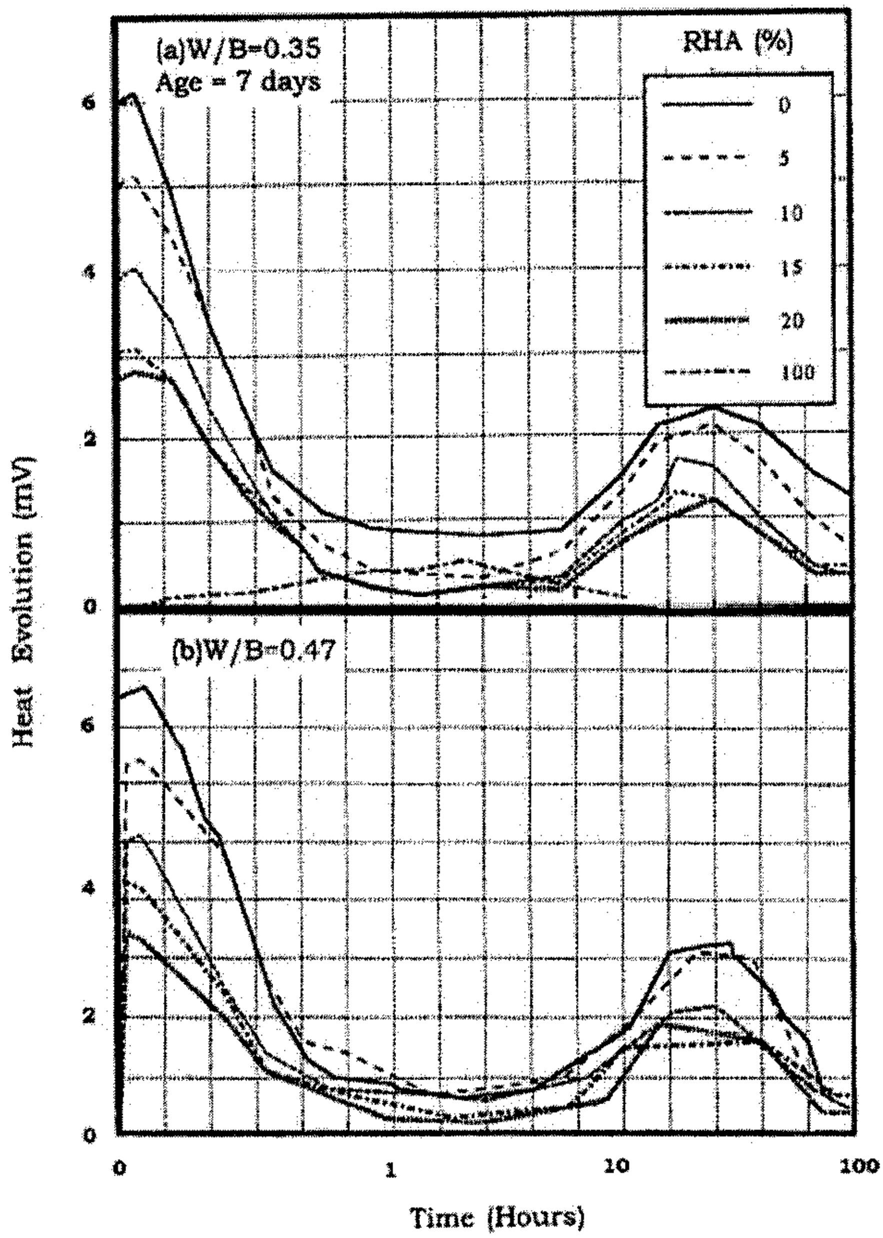


Fig 2.2. Heat Evolution of Cement Paste with MIRHA. (Adapted from Hwang and Wu)[3].

The first eight hours for hydration process in MIRHA/OPC paste is similar to the behavior of OPC paste with the growth of calcium hydroxide (CH). Hwang and Chandra [1] indicates that the penetration resistance during this period maybe primarily due to the formation of CH crystal and the formation of CH at the surface of MIRHA may be due to the adsorption by cellular structure of MIRHA. In such case the bleeding water will be significantly reduced. The adsorbed water enhances the pozzolanic reaction inside the inner cellular spaces and gain significant strength. After 40 hours the pozzolanic reaction further binds Si in MIRHA with CH to form C-S-H gel and solid structures (see figure 2.3). This means that MIRHA fills the finer pores and reduces the permeability, which may be beneficial to the durability [1].

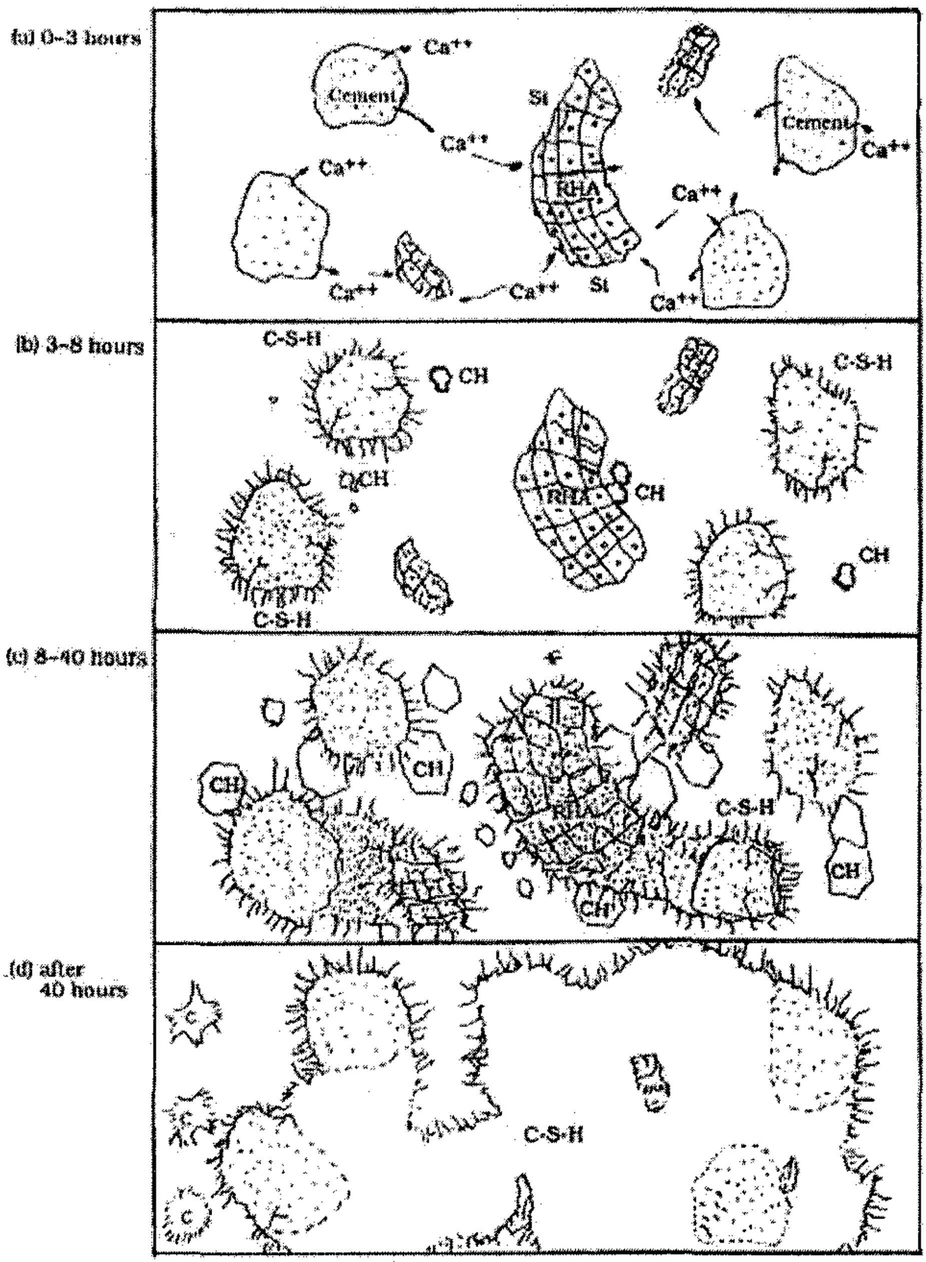


Fig 2.3: Schematic Drawing of the Hydration of Cement Paste with MIRHA Adapted From Hwang, Peng, and Lin [8]

2.5 Compressive Strength and Permeability

The addition of pozzolanic materials can affect both strength and permeability by strengthening the aggregate-cement paste through pozzolanic reaction. This phenomenon is shown in Figure 2.4. It is known that the pozzolanic reaction modifies the pore structure. Products formed due to the pozzolanic reactions occupy the empty space in the pore structures which thus becomes densified. The porosity of cement paste is reduced, and subsequently the pores are refined. Mehta [15] has shown significant reduction in the porosity of cement paste with MIRHA additions and refinement in the pore structure. Pozzolanic reaction is a slow process and proceeds with time [5].

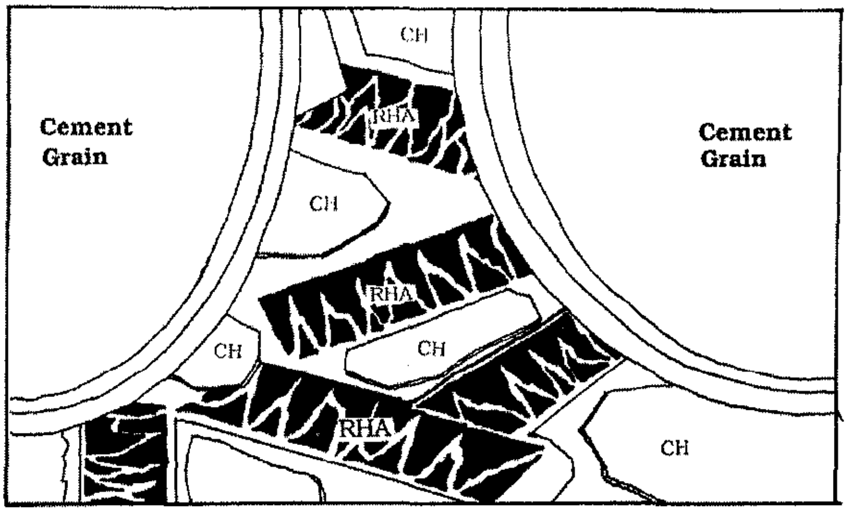


Figure 2.4 Mechanism of void filling and transition zone strengthening effect of MIRHA. Adapted from Hwang and Chandra [5]

In order to evaluate the effect of the conditioning temperature on strength and permeability properties of concrete a series of compressive, indirect tensile and permeability tests were performed on concretes (designed to have 28-day compressive strengths).

2.5.1 Compressive Strength Test

Compressive strength development of the concrete sample was measured according to BS EN 12390-3:2002 using Digital Compressive Testing Machine. The compressive strength machine is shows in figure 2.5. Since it was a destructive test, Compressive strength test was done after all none destructive tests were done. The measurement was taken for three concrete cubes per mix at ages 3, 7 and 28 days. During the test, concrete cube was loaded with 6.8kN/s constant loads without any sudden shock loads. Compressive strength value was taken from ultimate load that can be sustained by the concrete cube divided by surface area of the cube.

$F = P / A$

Where F : Compressive strength (N/mm^2)

P : ultimate load (N)

A : applied load surface area (mm^2)

Fig 2.5: Compression Machine

2.5.2 Split Cylinder Test

This test uses type of cylinder. Instead of standing up in the loading machine, the cylinder lays on its side. The machine pushes down on the free side of the cylinder. The cylinder will split in two halves. Figure 2.6 shows when the machine is going to pushes the cylinder. Based on the load at which the cylinder split, can compute a tensile strength, fct, of the concrete. The equation is:

$fct=2P/(\pi)dL$

Where P : the load at which the cylinder failed

d : the diameter of the cylinder

L : is the length of the cylinder

Fig 2.6 : Tensile Test

2.5.3 Ultrasonic Pulse Velocity (UPV)

Ultrasonic pulse velocity (UPV) technique is based on the ability to measure the propagation velocity of a pulse of vibration energy, which passes through a concrete medium. Knowing the direct path length between the transducers and the time of travel, the pulse velocity through the concrete can be obtained. Relationship between pulse velocity and strength are determined by calibration tests. UPV measurement techniques are totally non-destructive and have the advantage that they are quick and easy to perform. Also, because of the nature of the test, all the concrete located between the transmitter and the receiver affects the measured property. Therefore, if an experienced operator performs the test, then a considerable amount of useful information can be gained about the interior of a concrete element. See figure 2.7, UPV was measured with the portable ultrasonic non-destructive digital indicating tester [5].

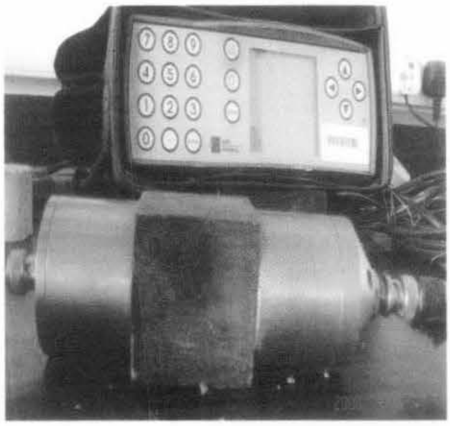


Fig 2.7: Ultrasonic Pulse Velocity

2.6 Investigating mix proportions of high strength self compacting concrete by using Taguchi method

In this study, mix proportion parameters of high strength self compacting concrete (HSSCC) are analyzed by using the Taguchi's experiment design methodology for optimal design. For that purpose, mixtures are designed in a L18 orthogonal array with six factors, namely, ''water/cementations material (W/C) ratio'', ''water content (W)'', ''fine aggregate to total aggregate (s/a) percent'', ''fly ash content (FA)'', ''air entraining agent (AE) content'', and ''super plasticizer content (SP)''. The mixtures are extensively tested, both in fresh and hardened states and to meet all of the practical and technical requirements of HSSCC. The experimental results are analyzed by using the Taguchi experimental design methodology. The best possible levels for mix proportions are determined for maximization of ultrasonic pulse velocity (UPV), compressive strength, and splitting tensile strength and for the minimization of air content, water permeability, and water absorption values.

2.7 Application of Taguchi

Design of experiments is a power analysis tool for modeling and analyzing the influence of process variables over some specific variable [15]. The most important stage in the design of experiment lies in the selection of the control factors. As many as possible should be included, so that it would be possible to identify non-significant variables at the earliest opportunity [16]. Table 2.5 shows the detail of the variables used in the experiment. It is noted that there is parameters at 4 levels. Only 16 experiments are needed to study the entire experimental parameters using the L16 (45) orthogonal array.

Table 2.5: Levels of the variable used in the experiments

Variable	Level 1	Level 2	Level 3	Level 4
Heating degree, H (°C)	20	200	400	800
Fly ash, A (%)	0	10	20	30

2.8 Taguchi method

The objective of the ''Taguchi method'' is to obtain products (or processes) more robust under varying environmental conditions and to consider the variability in the products' components (sub-products). The Taguchi method after bringing the mean performance of products to some targeted values has shown that experimental designs could be used to make the variability around the targeted value minimum. According to Taguchi, the performance of a product (i.e. optimum working conditions) may be affected by environmental conditions in which it is going to be used and components used in its production. Thus, when determining the optimum working conditions, environmental conditions in which the product will be used and details of its components should be taken into account. Parameters affecting the product may be divided into two groups which are controllable and uncontrollable [27].

CHAPTER 3

METHODOLOGY

3.1 Experimental Detail

The experiments conducted in this research are basically compressive strength test, split tensile test and UPV. The experimental detail is shown in Table 3.1.

Table 3.1: Experimental details

Test	Sample			Dimension	Measurement	Standard	Equipment
	No.of sample	Size (mm)	Age (day)				
Compressive	6 for each age	50x50x50	3,7 &28	N/mm^2 or Mpa	Compressive	BS1881:Part 116:1983	Compression testing machine 3000KN
Split	1 for each age	200x100D	28	N/mm^2 or Mpa	Tensile	BS1881:Part 117:1983	Compression testing machine 3000KN
UPV	6 for each age	50x50x50	7 & 28	km/s	Integrity	BS1881:Part 201:1986	UPV testing machine

3.2 Taguchi Method

Taguchi's approach to parameter design provides the design engineer with a systematic and efficient method for determining near optimum design parameters for performance and cost. The first concept of Taguchi that must be discussed is what he refers to as ''noise factors''. Noise factors are viewed as the causes of variability in performance, including why products fail. A noise factor is anything that causes a measurable product or process characteristic to deviate from its target value.

The purpose is to select the best combination of control parameters so that the product or process is most robust with respect to noise factors. The Taguchi method utilizes orthogonal arrays from design of experiments theory to study a large number of variables with a small number of experiments. Using orthogonal arrays significantly reduces the number of experimental configurations to be studied.

In this study, the following parameters are considered in the mix proportions: MIRHA content; Water to cementitious materials ratio (W/C); sand to cementitious materials ratio (s/c); Superplasticizer content (SP); Foam agent content (FC). The variation levels for the considered parameters are shown in Table 3.2.

Table 3.2: Parameters and their variation levels

Variable	unit	Level 1	Level 2	Level 3	Level 4
MIRHA	(%)	0	5	10	15
w/c	ratio	0.3	0.35	0.4	0.45
s/c	ratio	0.25	0.5	0.75	1
SP	(%)	1	1.5	2	2.5
FC	(%)	20	25	30	35

According to the parameters in Table 3.2 and their variation levels, orthogonal array is devised. In this study, L16 orthogonal array (OA) is used. The standard L16 OA is shown in Table 3.3.

Table 3.3: Standard L_{16} orthogonal array

Exp. no	Independent variables					Dependent Variable (s)
	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Performance parameter
1	1	1	1	1	1	P1
2	1	2	2	2	2	P2
3	1	3	3	3	3	P3
4	1	4	4	4	4	P4
5	2	1	2	3	4	P5
6	2	2	1	4	3	P6
7	2	3	4	1	2	P7
8	2	4	3	2	1	P8
9	3	1	3	4	2	P9
10	3	2	4	3	1	P10
11	3	3	1	2	4	P11
12	3	4	2	1	3	P12
13	4	1	4	2	3	P13
14	4	2	3	1	4	P14
15	4	3	2	4	1	P15
16	4	4	1	3	2	P16

Levels and L16 OA, the mix proportions are defined as shown in Table 3.4 by using the defined parameters.

Table 3.4: Mixture proportion of concrete

Code	Cement (kg/m³)	Sand (kg/m³)	Water (kg/m³)	MIRHA (kg/m³)	Vol Foam (liter/m³)	SP (kg/m³)
LWFC-1	930	233	419	0	203	23
LWFC-2	950	475	285	0	238	19
LWFC-3	770	578	270	0	272	12
LWFC-4	620	620	248	0	324	6
LWFC-5	893	223	282	47	333	13
LWFC-6	703	352	333	37	298	7
LWFC-7	732	549	308	39	239	18
LWFC-8	703	703	259	37	240	18
LWFC-9	900	225	350	100	239	9
LWFC-10	810	405	360	90	194	12
LWFC-11	572	429	286	64	345	11
LWFC-12	648	648	216	72	305	16
LWFC-13	748	187	352	132	284	15
LWFC-14	663	332	273	117	342	17
LWFC-15	774	580	273	137	206	8
LWFC-16	565	565	299	100	267	8

Binder properties of the cementitious materials are given in Table 3.5.

Table 3.5: Binder Properties

Oxide composition	Weight %	
	MIRHA	OPC "Tasek"
Na_2O	0.02	0.02
MgO	0.63	1.43
Al_2O_3	0.75	2.84
SiO_2	90.75	20.44
P_2O_5	2.50	0.10
K_2O	3.77	0.26
CaO	0.87	67.73
TiO_2	0.02	0.17
Fe_2O_3	0.28	4.64
SO_3	0.33	2.20
MnO	0.08	0.16

3.3 Equipment

Portafoam Model TM-2 that the equipment that will be produced stable aqueous foam for the production of foamed concrete. Foam output volume – 100 to 150 lit / min. The Portafoam generators work by the uptake of premixed (diluted) chemicals from a pressurized tank which is delivered to a main unit (tank delivery). Tank delivery means that the premix solution (chemical concentrate + water) is placed in pressure tanks which deliver the premix to the main generating unit. Pressure tanks have limited capacity and therefore foam volume and delivery is limited to their size. The main unit consists of several gauges and valves (all pneumatic) and is responsible for the generation of stable foam. The stable foam is then delivered to a lance unit which further stabilizes the foam before it exits into the concrete mixer

3.4 Constituent Materials

The constituent materials used to produce foam concrete are given in Table 3.6 and Chemical Composition of RHA at table 3.7.

Table 3.6: Constituent materials used to produce foamed concrete

Materials	Remarks
Cement	Ordinary Portland Cement BSEN 197-1
Sand	a maximum grain size of 2 mm, with 60-95 % passing 600 mm sieve (David Bennett, 2002 & BS EN 12620)
RHA	In order to produce MIRHA with high reactive silica content, controlled combustion of rice husk (Kusbiantoro A, 2007 & BS EN 450)
Foam	Preformed foam by palm oil based, a ratio of 1:30 (by volume), aerated to a density of 70-80 kg/m3, ASTM C 869-91 (reapproved 1999), ASTM C 796-97

Table 3.7 Chemical Composition of RHA

Oxide	Percentage
SiO_2	88.4 %
MgO	0.866 %
SO_3	0.495 %
CaO	0.998 %
K_2O	5.18 %
Al_2O_3	0.106 %
Fe_2O_3	0.114%

3.5 Mixing Process

Chemical liquid those are diluted with water and aerated forming the foaming agent. The foaming agent used was palm oil base and manufactured in Malaysia. Foamed concrete is produced in the laboratory with standard inclined rotating drum mixer according to BS 1881-125.1986 by the adding of pre formed foam to mortar. The Plastic density measured in accordance with BS EN 12350-6, weighing a foamed concrete sample in pre weigh container of known volume. A tolerance on plastic density was set at 70-80 kg/m3 of the target.

The compositions (Kearsley and Wainwright, 2001) by mass of the different mixtures cast are shown in Table 3.4 a total of 16 mixes were made as summarized below:

- Cement pastes with water/cement ratios of 0.3
- Foamed concrete mixtures of different casting densities (1400, 1600, 1800 kg/m3) with different percentages of RHA replacement

3.6 Health and Safety

3.6.1 Activity

- Grinding Rice Hush Ash
- Concrete mixing
- Testing concrete cubes

3.6.2 Hazard

Concrete laboratory

1) Staggered objects on the floor

- Equipments that are used by students are normally placed carelessly on the floor along the walking path of other students.

  Example: concrete cubes, hammer, reinforcement bars, concrete moulds.

2) Sharp objects

- The area next to the concrete mixer has scattered nails and other broken objects.
- Concrete cubes which have failed under compression test have to be disposed at the designated area.

Example: damaged concrete cubes (compression test), nails, shovel.

3) Machinery

- The lid of the concrete mixer has to be manually held down while being used due to problems with the lever.

Example: concrete mixer

i. Electricity

- The wire connecting the concrete mixer to the plug point hangs 0.4m above the ground.
- Some students handle electrical equipments and plug points with out cleaning or drying their hands.

Example: wires, plug points, electrical equipment

ii. Noise Machine

- The grinding machine noise loudly while working.

iii. Slipped Area

- Working area messy with ash occurred slipped floor

3.6.3 Prevention

Staggered objects on the floor

- If possible, students should wear safety boots or shoes that completely cover the foot.

Sharp objects

- Always use protective gloves.

Machinery

- When handling heavy machinery, make sure not to work alone.

Electricity

- Do not operate electrical equipment and plug points with dirty or wet

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

After the experiments, all the results were tabulated as shown in Table 4.1.

Table 4.1 Test Result of Hardened Concrete

MIX ID	Dry Density (kg/m3)	SSD Density (kg/m3)	3-day compressive strength (Mpa)	7-day compressive strength (Mpa)	28-day compressive strength (Mpa)	28 day UPV (m/s)	28-day Splitting tensile strength (Mpa)
M1	1,856	2,119	31.2	28.6	61.3	2,633	5.0
M2	1,899	2,145	54.9	43.0	76.5	2,183	4.9
M3	1,541	1,834	19.6	21.6	25.2	2,644	2.9
M4	1,340	1,621	12.4	11.0	13.8	2,821	1.9
M5	1,400	1,647	25.5	26.1	29.7	2,764	1.4
M6	1,504	1,860	22.8	24.5	26.6	2,368	3.0
M7	1,918	2,365	36.6	39.2	54.8	4,471	3.1
M8	1,886	2,196	45.0	56.3	63.9	4,743	3.4
M9	1,409	1,769	21.0	24.4	30.0	2,588	1.4
M10	1,517	1,888	24.6	30.3	37.5	2,776	1.6
M11	1,208	1,588	8.6	13.6	18.2	2,643	0.9
M12	1,668	1,958	23.3	30.2	40.1	3,123	2.0
M13	1,249	1,671	16.1	20.9	27.8	2,713	1.9
M14	1,412	1,777	26.6	25.2	30.8	2,940	2.4
M15	1,703	2,059	6.9	7.5	10.2	2,742	1.3
M16	1,374	1,671	15.7	20.1	25.5	3,002	1.6

In Table 4.1, each compressive strength, split tensile strength and water permeability values are an average of six 50 mm cube specimens. The compressive strength, split tensile strength and UPV of high strength self compacting concretes were in the range of 10.2–76.5, 0.9–5.0, and 2,183–4,743 respectively. The highest compressive and split tensile strength and the lowest UPV were measured M2, M1 and M8, respectively.

The best possible testing conditions of the foamed concrete properties can be determined from the main effect plot graphs from Figures 4.1 to 4.5 for compressive strength, splitting tensile strength and UPV, respectively. According to the Figures 4.1 to 4.5, the best mix proportions of the target properties are tabulated in Table 4.3.

The response data given in Table 4.1 was analyzed using analysis of variance (ANOVA) technique using a commercial software at a 0.05 level of significance to examine the variation in the measured properties of the high strength self compacting concretes. Mix proportions in Table 3.4 were selected as factors, whereas fresh and hardened properties of the concretes were dependent variables. A statistical analysis was performed to determine the statistically significant factors and data analysis are presented in Table 4.2. Finally, degree of contribution of the each significant factor was obtained so as to determine the level of its statistical importance in the model. The contribution percentage in Table 4.2 gives an idea about the degree of contribution of the factors to the measured response. If the contribution percent is high, the contribution of the factors to that particular response is more. Likewise, lower the contribution percent lower the contribution of the factors on the measured response.

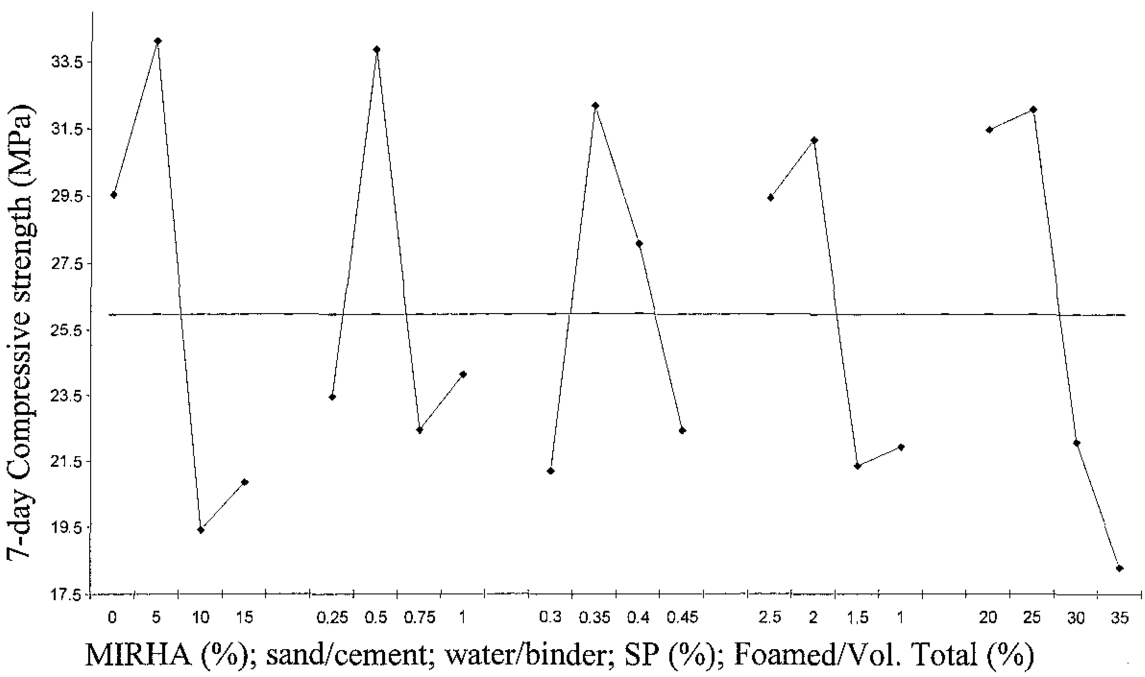


Fig 4.1 Main effect plot for 3-days compressive strength

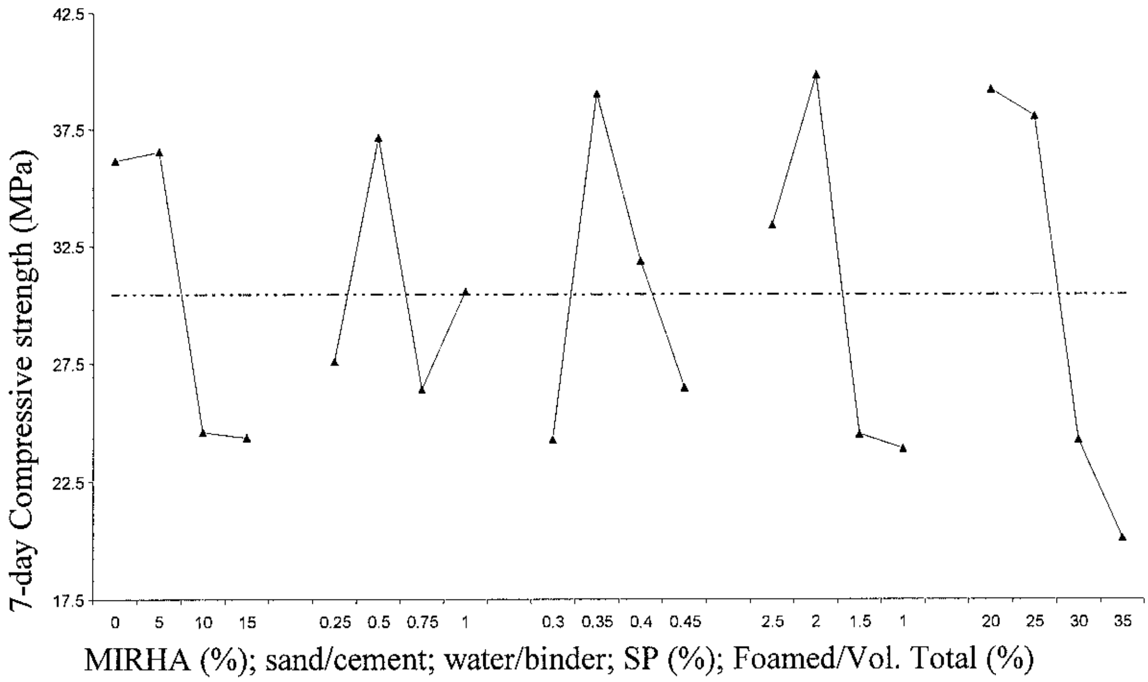


Fig 4.2 Main effect plot for 7-day compressive strength

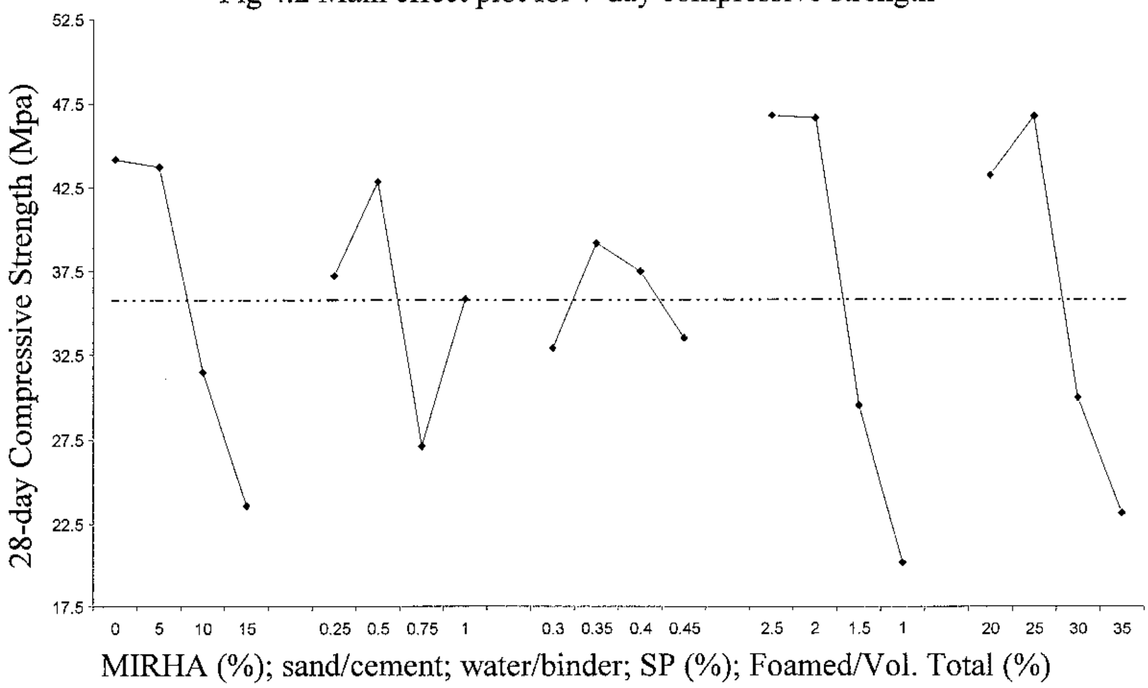


Fig 4.3 Main effect plot for 28-day compressive strength

When foamed agent content is increased in the concrete mix, the 28 days normal compressive strength of foamed concrete is decreased (see Fig. 4.3). However, increasing of MIRHA content increased the normal 28 days compressive strength. There is a contradiction in the comparison of optimum mix proportions of maximization of

UPV and compressive strength properties. Normally, there must be approximately same mix proportions for both of these properties but according to Table 4.3, the mix proportions are very different form each other. According to the analysis of variance results in Table 4.2, the SP content is the most effective parameter on the compressive strength with 39% contribution.

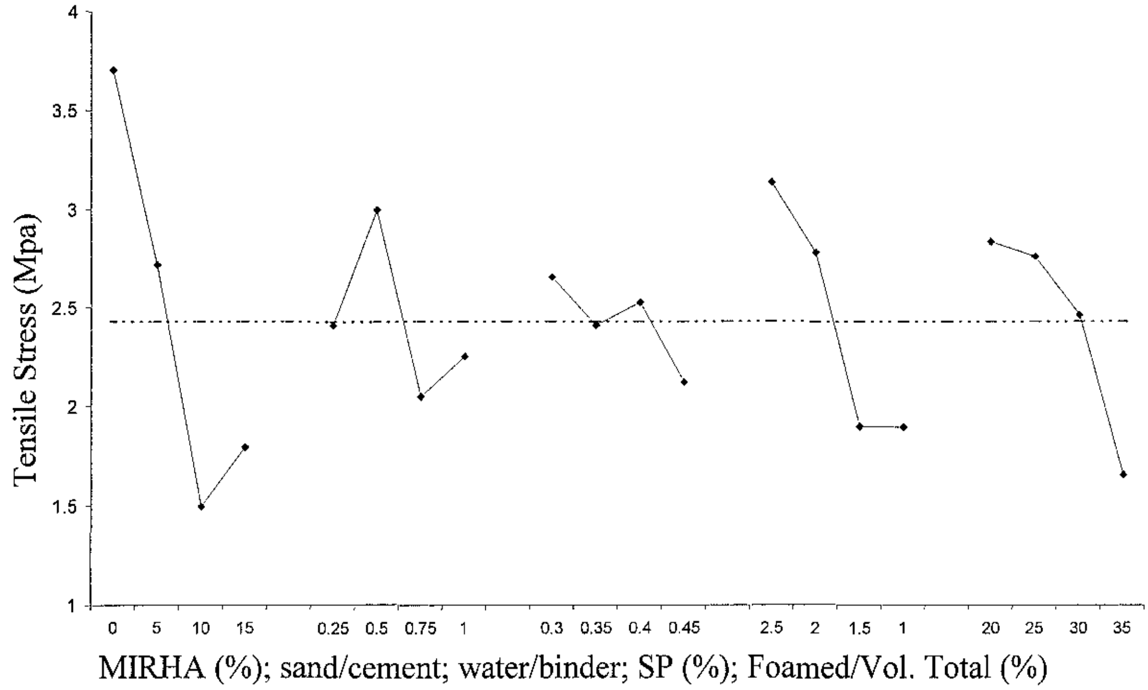


Fig 4.4 Main effect plot for 28-day Splitting tensile strength

As it can be seen from Fig. 4.4, decreasing of W/C and SP parameters decreases the splitting tensile strength but decreasing the content of foamed parameter value increases the splitting tensile strength. The contribution rank of the parameters on the splitting tensile strength can be seen in Table 4.2.

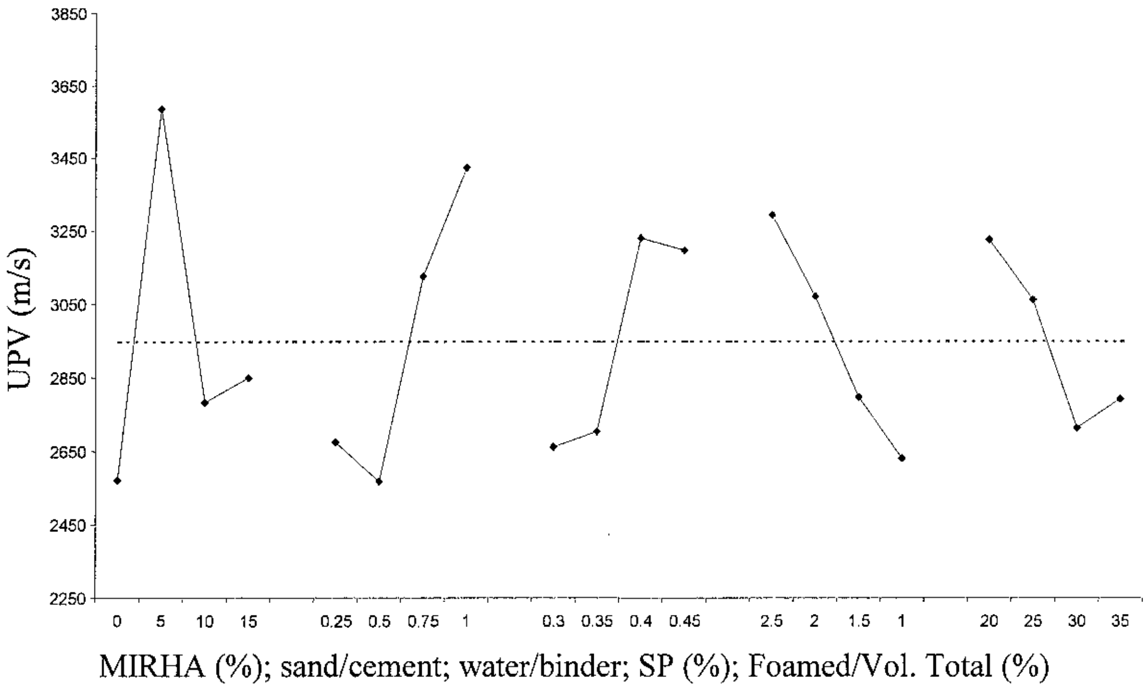


Fig 4.5 Main effect plot for 28-day ultrasonic pulse velocity

A general suggestion for the classification of quality of concrete by UPV technique is proposed by Whitehurst for 2400 kg/m3 density concretes. Concretes are classified as excellent, good, doubtful, poor, and very poor for 4500 m/s and above, 3500–4500 m/s, 3000–3500 m/s, 2000–3000 m/s and 2000 m/s and below UPV values, respectively. By using these proposed classification techniques, all produced concretes in this research are doubtful and poor quality. According to Fig. 4.5, the UPV values of produced concretes are decreased with the decreasing of foamed content but decreased with increasing of water content.

Table 4.2: Analysis of variance results of Lightweight Foamed Concrete Properties

Parameter	statistical parameters	3-day compressive strength	7-day compressive strength	28-day compressive strength	28-day UPV	28-day Splitting tensile strength	Porosity	Water Absoprtion	Dry Density
MIRHA	DF[a]	3	3	3	3	3	3	3	3.00
	SSS[b]	593	564	1,207	2,348,883	11.93	41	38.37	204,558.27
	ASS[c]	593	564	1,207	2,348,883	11.93	41	38.37	204,558.27
	MS[d]	198	188	402	782,961	3.98	14	12.79	68,186.09
	Contribution (%)	28%	18%	22%	33%	52%	7%	22%	24%
sand/cement	DF	3	3	3	3	3	3	3	3.00
	SSS	337	278	509	1,905,597	2.00	98	23.73	32,772.57
	ASS	337	278	509	1,905,597	2.00	98	23.73	32,772.57
	MS	112	93	170	635,199	0.67	33	7.91	10,924.19
	Contribution (%)	16%	9%	9%	27%	9%	16%	14%	4%
water/binder	DF	3	3	3	3	3	3	3	3.00
	SSS	314	520	111	1,128,635	0.63	87	73.60	79,573.33
	ASS	314	520	111	1,128,635	0.63	87	73.60	79,573.33
	MS	105	173	37	376,212	0.21	29	24.53	26,524.44
	Contribution (%)	15%	16%	2%	16%	3%	14%	42%	9%
superplasticizer	DF	3	3	3	3	3	3	3	3.00
	SSS	305	700	2,090	1,029,303	4.79	102	25.06	156,036.02
	ASS	305	700	2,090	1,029,303	4.79	102	25.06	156,036.02
	MS	102	233	697	343,101	1.60	34	8.35	52,012.01
	Contribution (%)	14%	22%	39%	15%	21%	17%	14%	18%
foamed	DF	3	3	3	3	3	3	3	3.00
	SSS	565	1,119	1,477	675,254	3.50	290	13.51	374,984.89
	ASS	565	1,119	1,477	675,254	3.50	290	13.51	374,984.89
	MS	188	373	492	225,085	1.17	97	4.50	124,994.96
	Contribution (%)	27%	35%	27%	10%	15%	47%	8%	44%

[a] Degree of freedom

[b] Sequential sum of square

[c] Adjusted sum of square

[d] Meand square (variance)

Table 4.3 Optimal mix design properties for properties of Lightweight Foamed Concrete

Optimal mix Proportional	MIRHA/ cement (%)	sand/cement	water/binder	superplasticizer/cement (%)	Foam/Total Vol (%)
Ultrasonic pulse Velocity	5	1	0.4	2.5	20
3-day compressive strength	5	0.5	0.35	2	25
7-day compressive strength	5	0.5	0.35	2	20
28-day compressive strength	0	0.5	0.35	2.5	25
28-day Splitting Tensile Strength	0	0.5	0.3	2.5	20
Dry Density	15	0.25	0.3	1.5	35

According to the analysis of variance results, the MIRHA is the most effective parameters on the UPV, and compressive strength. These tests measure the compressive strength of concrete, obtaining the same parameters as the most effective on these three tests is very meaningful and important.

4.2 DISCUSSION

Foamed concrete is consisting of many components; it is critical to use a systematic approach for identifying optimal mixes and investigate the most effective factors under a set of constraints [22]. Due to this reason Taguchi method with L16 orthogonal array is used in this study to investigate ranking of the effective parameters and best possible mix proportions of fresh and hardened properties of foamed concrete. At the end of this research, it is seen that Taguchi method is a promising approach for optimizing mix proportions of foamed concrete to meet several fresh and hardened concrete properties. Taguchi method can simplify the test protocol required to optimize mix proportion of foamed concrete by reducing the number of trial batches. This study has shown that it possible to design self compacting concrete with satisfying the criteria of high strength concrete. As it can be seen in the results of fresh and hardened concrete properties of produced concrete samples, they satisfied the expected properties of foamed concrete. Some of the result has achieved the target result which is the strength is above 17 Mpa. All the optimum design properties can be seen in table 4.3. A total of 16 test specimens were cast and tested at 3, 7 and 28 days. Compressive and split tensile strengths of the test specimens were determined. Test results indicated that strength is decreased when cement was partially replaced by MIRHA for maintaining same level of workability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objectives of this research are to determine the optimum of MIRHA on the engineering properties of foamed concrete that is required to improve the quality of foamed concrete with simply curing in foamed concrete. Second objectives are to establish the effect MIRHA on the porosity and permeability of foamed concrete. The MIRHA was obtained by burning rice husk, an agro-waste material which is abundantly available in the developing countries.

As the conclusion, an effort was made to evaluate the usefulness of using an agro-waste, known as microwave incinerated rice husk ash (MIRHA) (where an appreciable amount of silica is present) as part replacement of cement with locally available ingredients. Based upon the properties of materials determined, mix proportions were established with and without the replacement of cement by MIRHA. A durability study are made with part replacement of cement by MIRHA should be conducted along with its economic aspects.

5.2 RECOMMENDATIONS

Here, some of the studies that could be conducted in the future would be recommended. These studies would greatly help to elevate the potential of MIRHA as a cement material in the future.

- More studies especially in the usage of MIRHA need to be conducted in order to improve the strength.
- In doing this project, lot of time is needed. Time frame given is quite tide. In order to come out with better result, in term of accuracy and detail, longer time is needed.

REFERENCES

[1] Coutinho, J.Sousa. *The Combined Benefits of CPF and RHA in Improving The Durability of Concrete Structures.* Cement & Concrete Composites 25, pp 51-59. 2003.

[2] Mehta, P.K, *Mineral Admixture for Concrete – An Overview of Recent Developments. Advance in Cement and Concrete.* In : Proceedings of an Engineering Foundation Conference, University of Newhampshire, Durham. ASCE, pp 243 – 56.1994.

[3] Abdullahi, M. *Characteristic of Wood Ash/OPC Concrete*, 2006

[4] Bui, D.D, Hu. J, Stroeven, P. *Particle size effect on the strength of rice husk ash blended gap-graded Portland Cement concrete*, 2004

[5] Hwang, Chao Lung and Chandra, Satish. *The use of Rice Husk Ash in concrete*

[6] International Rice Research Institute. *Rough Rice Production by Country and Geographical Region 1961-2004.* 2005

[7] Hernandez, Martirena.J.F., Middendorf, B., Gehrke, M., and Budelmann, H. *Use of Waste of The Sugar Industry as Pozzolana in Lime-Pozzolana Binders : Study of The Reaction.* Cement and Concrete Research 28. pp 1525-1536. 1998.

[8] Suthar, Surendra. *Nutrient Changes and Biodynamics of Epigeic Earthworm Perionyx Excavatus (Perrier) during Recycling of some Agriculture Wastes.* Bioresource Technology.2006

[9] Mittal, Alok., Kurup, Lisha,, and Gupta, Vinod. *Use of Waste Materials-Bottom Ash and De-Oiled Soya, as Potential Adsorbents for the Removal of Amaranth from Aqueous Solutions.* Journal of Hazardous Materials B117. pp 171-178. 2005

[10] Khedari,J., Rawangkul, R., Chimchavee, W., Hirunlabh, J., Watanasungsuit, A. *Feasibility Study of using Agriculture Waste as Desiccant for Air Conditioning System.* Renewable Energy 28. pp 1617-1628. 2003.

[11] Ballesteros, I. Olivia, J.M., Negro, M.J., Manzanares, P., Ballesteros, M. *Enzymic Hydrolis of Steam Exploded Herbaceous Agricultural Waste (Brassica Carinata) at Different Particle Sizes.* Process Biochemistry 38. pp 187-192. 2002.

[12] Ozturk, T., Bayrakl, M. *The Possibilities of Using Tobacco Wastes in Producing Lightweight Concrete.* Agricultural Engineering International : the CIGR Ejournal. Vol VII. Manuscript BC 05 006. 2005

[13] Alabadan, B.A., Njoku, C.F., and Yusuf, M.O. *The Potential of Groundnut Shell Ash as Concrete Admixture.* Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 05 012, Vol. VII. 2006

[14] Ajiwe, V.I.E., Okeke, C.A., Akigwe, F.C. *A Preliminary Study of Manufacture of Cement from Rice Husk Ash.* Bioresource Technology 73. pp 37-39 2000.

[15] Hwang, C. L., and Wu, D. S., *Properties of Cement Paste Containing Rice Husk Ash, ACZ SP-114* (Editor: V. M.Malhotra), pp. 733-765. 1989

[16] Sensale, G.R. *Strength Development of Concrete with Rice Husk ash.* Cement and Concrete Composites 28. pp158-160. 2006.

[17] Tashima, M.M., Silva, C.A.R., Akasaki, J.L., Barbosa, M.B. *The Possibility of Adding The Rice Husk Ash (RHA) to the Concrete.*

[18] Mehta, P. K., Rice Husk Ash-A Unique Supplementary Cement Material, *Advances in Concrete Technology, Ed.* By Malhotra, CANMET, Ottawa, Canada, 1992

[19] Ankra, K. *Studies of Black Silica Produced Under Varying Conditions*, PhD Dissertation, University of California at Berkeley, 1975

[20] Hwang, C. L., Peng, T. F., and Lin, L. K., *The Hydration Mechanism of the Rice Husk Ash Cement Paste, Journal of the Chinese Institute of Civil and Hydraulic Engineering,* Taipei, Republic of China (To be published), 1995

[21] Bentech. *Operation & Maintenance manual for Microwave Incinerator.*

[22] Limnological Research Center Core Facility. *X-Ray Diffraction.* 2004

[23] Arehart, Greg. *Introduction to X-Ray Diffraction.* Department of Geological Sciences MS 172, University of Nevada-Reno.

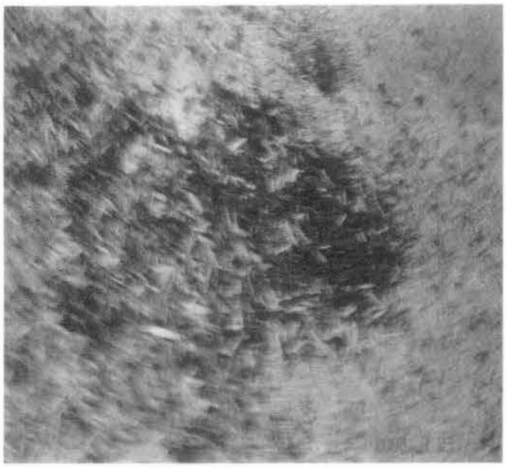
[24] Amptek. *X-Ray Fluorescence Spectroscopy.* Bedforf, MA.USA. 2002

[25] Neville, A.M., *Properties of Concrete*, Great Britain, 1990

[26] Shideler, J.J and Chamberlin, W.H. *Early Strength of Concretes as Affected by Steam Curing Temperatures.* J. Amer Concr. Inst. 46. pp 273-83. 1949

[27] Ibrahim Turkmena, Rustem Gula, Cafer Celikb, *A Taguchi approach for investigation of some physical properties of concrete produced from mineral admixtures,* Ataturk University, Turkey, 2007

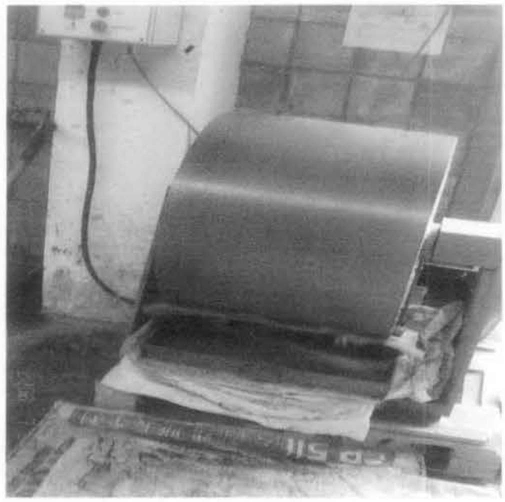
APPENDICES



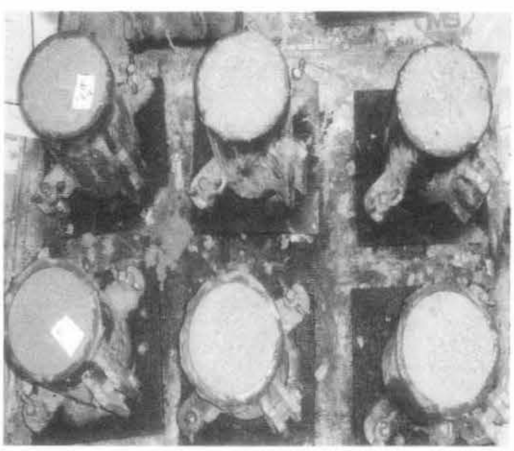
Rice Husk

Foamed Machine motor

Foam agent entered into foamed machine



LA Abrasion Machine for grinding MIRHA



Split Sample

Mixing the concrete