STUDY ON THE PERFORMANCE OF RICE HUSK ASH AS A CEMENTING MATERIAL

By

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Declaration

This is to certify that the thesis work entitle "Study on the Performance of Rice Husk Ash as a Cementing Material" has been carried out by Md. Azad Hossain Khan in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above research work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

Utilization of rice husk has become subject of growing interest. The possibilities of its utilization of rice husk in various ways have evoked much interest due to its high silica content. Particularly in the developing countries of South-east Asia where the production of rice is more than half of the production of entire world. Most important among various methods suggested for the utilization, is the development of construction materials from rice husk as such and from its ash. For every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of rice husk ash (RHA) is obtained. Rice husk ash is a great threat to environment causing damage to the land and surrounding area in which it is dumped. Rice husk burnt at 450°C have been found to produce a pozzolana conforming to the requirements of the ASTM standard C618-72. Therefore, valuable product from this rice hush ash (RHA) is possible.

The rice husk for the study was collected from rice husking mill and was burnt in muffle furnace in laboratory (at 450°C) for 60 minutes. Rice husk is found to contain about 76.53 % organic volatile matter and the balance 23.47 % as ash (Table 3.7). The rice husk ash was grounded in laboratory by using Industrial Ball Mill to the form of powder. The particles finer than 200 meshes was collected for further test.

The new product of RHA cement sample was tested for properties like Ordinary Portland Cement. RAH cement made in this study contains ash, lime and clay in different ratio. For this purpose a typical samples at the beginnin was made with RHA (60%) mixed with finely grounded lime (30%) and un-burnt clay (10%). Similar samples were made with burnt (800 ^{0}C) clay. The result between two are found to agree. Rest of the cement samples were made with Un-burnt clay and burnt clay. Results of these samples are shown in table no. 4.1, 4.2, 4.3, 4.4, 4.5. By discussion the test results we find that, (a) in case of un-burnt clay, average water-cement ratio required for cement paste of normal consistency (CPNC) was found to be 0.56, initial setting time was found to be 96 minutes, final setting time was found to be 6 hrs. 58 minutes. and 3 days compressive strength for cement mortar cube was found to be 171 psi. respectively. (b) in case of burnt clay, average water- cement ratio required for cement paste of normal consistency (CPNC) was found to be 0.56, initial setting time was found to be 96 minutes, final setting time was found to be 7 hrs.13 minutes and 3 days compressive strength for cement mortar cube was found to be175 psi respectively. These values when compared with those of Ordinary Portland Cement, it was found that in case of un-burnt clay, CPNC varied only 7%, initial setting time was double than OPC, final setting time was increased by one

hour than OPC. (b) in case of burnt clay, CPNC was found to be 0.56, initial setting time was found to be more than double than OPC, final setting time was increased by one and half hour than OPC and 3 days compressive strength was found to be 175 psi. It is clear from the study that RHA can be attributed cementing property when combined with lime and clay. The properties of this cement resembles with those of OPC with compromise of higher setting time and lower strength. However this may be recommended for the cases where lower strength can be used (e.g., boundary walls, normal load bearing residential buildings, partition walls, surface drains etc.)

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Abbreviation

CPNC	Cement Paste Normal Consistency
C_3S	Tricalcium Silicate
C_2S	Dicalcium Silicate
C_3A	Tricalcium Aluminate
C_4AF	Tetra Calcium Aluminoferrite
OPC	Ordinary Portland Cement
RHA	Rice Husk Ash

CHAPTER 1

INTRODUCTION

1.1 General Remarks

The history of cementing material is as old as the history of engineering construction. An analysis of mortar from great Pyramid showed that it contained 81.50% Calcium Sulphate and only 9.50% Carbonate. The early Greeks and Romans used cementing materials obtained by burning limestone. The Greeks and Romans later became aware of the fact that certain volcanic ash and tuff when mixed with lime and sand yield mortar possessing superior strength and better durability in fresh or salt water [1]. The use of Pozzolanic material is as old as that of the art of concrete construction. It was recognized long time ago that the suitable pozzolana used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes. [1]

Pozzolana is a natural or artificial material containing silica in a reactive form.[2] According to ASTM specification-C618-78 Pozzolana is a siliceous or siliceous aluminous material which itself possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration at ordinary temperature to form compounds possessing cementitious properties.[2] Certain pozzolana natural or artificial improve their activity by calcinations in the temperature range of 550°C to 1100°C, depending on their materials. [3]

Rice milling generates a by product known as husk. This surrounds the paddy grain. During milling of paddy about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight of the paddy is received as husk. This husk is used as fuel in the rice mills and in some alternative way. The husk contains about 75% organic volatile matter and 25% weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85% - 90% amorphous silica. So for every 1000 kgs of paddy milled, about 220 kgs (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kgs (25%) of rice husk ash is obtained. The particle size of the cement is about 35 microns. There may be formation of void in the concrete mixes, if curing is not done in properly. This reduces the strength and quality of the concrete. A commercial product known as "Silpozz" which is made out of this RHA is finer than cement having very small particle size of 25 microns, so much so that it fills the interstices in between the cement in the aggregate. That is where the strength and density comes from. And that is why it can reduce the amount of cement in the concrete mix. Since Silpozz (made from rice husk ash) contain Silica (SiO_2) $\geq$ 85% rice husk ash can be a good raw material to produce cementing material and/or a good admixture for concrete mix. Amorphous silica occupies majority (85% - 90%) of volume of RHA. Rice husk ash is a great threat to environment causing damage to the land and surrounding area in which it is dumped. But valuable product from this RHA is possible [4]. Almost 28.00 million metric tones of paddy grown per year in our country [5]. It is also noted that rice husk burnt at 450°C have been found to produces a pozzolana conforming to the requirements of the ASTM standard C618-72 [6]. The above discussion indicates that this huge quantity of rice husk ash (RHA) can be used in construction industries if it is improved by proper investigation.

1.2 Background of the Study

It is reported that, same farmer without knowing the effects of RHA rarely uses RHA as fertilizer in crop field, latter they found RHA reduces productivity. As a result there seems no user of this RHA, and gradually it is becoming a burden for the mill owner and to the environment. It is also known that, when rice husks burnt in high temperature (above 450°C), it produces ash that possess chemical properties resemble to pozzolana. Pozzolana is a good building material. By mixing calcium oxide and if needed lime, gypsum and clay in a required proportion and finely grounded it is possible to get pozzolanic cement. It can also be used cement admixture. It will help us to reduce environmental pollution as well as gives us a method to produce low cost and moderate strength cement/cement admixture.

1.3 Objective of the Study

1. To determine the burning temperature which renders cementing properties to rice husk ash.
2. To determine the appropriate ratio of RHA and lime which will provide maximum cementing properties.
3. To study the compressive and tensile strength of the RHA cement mortar.
4. To study the compressive and tensile strength of mortar made of normal Portland cement using RHA cement as admixture.

1.4 Statement of the Problem

Study on the Performance of Rice Husk Ash as a Cementing Material.

1.5 Scope of the Experimental Study

The rice husk has to be collected from rice husking mill and burnt in furnace in laboratory to produce rice husk ash. Muffle furnace of maximum temperature up to1100$^{o\ C}$ which is available in the civil engineering department. The ash that produced by burning rice husk is to be grinded to fine powder. For this purpose a pulverizer (ball mill) will be procured from thesis budget. Rice husk ash mixed with lime (calcium oxide) and if needed gypsum and dried clay in required proportion and to be grounded finely to get cement/ admixture from rice husk ash. To investigate the properties of cement/admixture made from rice husk ash, (a) Standard consistency test (b) Setting time test (c) Cement-sand mortar cube test will be performed in the civil engineering laboratory.

1.6 Methodology /the Research Outlines of the Study:

Steps to be followed are chronologically given below:

1) Burning rice husk in muffle furnace raising temperature above 450$^{o\ C}$ for making ash.
2) The produced ash to be mixed with lime and if needed gypsum and dried clay in different proportion and to be grounded finely by using ball mill to get RHA cement/ or admixture from rice husk ash.
3) At last the test for engineering properties, that is (a) Standard consistency test (b) Setting time test (c) Cement-sand mortar cube test will be performed in the laboratory.
4) Normal Portland cement will be compared with the product obtained from rice husk ash.
5) Appropriate proportion of different ingredient will be proposed for preparation of cement/or cement admixture made from rice husk ash.

CHAPTER 2

LITERATURE REVIEW

2.1 General Remarks

M.S.Shethy [11] gave the history of development of cement and its composition reviewed in the following Para:

The history of cementing material is old as the history Engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient construction. It is believed that the early Egyptians mostly used cementing materials, obtained by burning gypsum. An analysis of mortar from great Pyramid showed that it contained 81.50% Calcium Sulphate and 9.50% Carbonate. The early Greeks and Romans used cementing materials obtained by burning limestones. The remarkable hardness of the mortar used in early Roman brickworks, same of which still exist, is presenting sufficient evidence of the perfection which the art of cementing materials had attained in ancient time. The Greeks and Romans latter become aware of the fact that certain volcanic ash and tuff, which mixed with lime and sand yield mortar possessing superior strength and better durability in fresh or salt water. Roman builders used volcanic ash and tuff found near Pozzuoli village near Mount Vesuvius in Italy. This volcanic ash and tuff mostly siliceous in nature, thus acquired the name "Pozzolana". Later on the name Pozzolana was applied to any other materials, natural or artificial, having nearly same composition as that of volcanic ash and tuff found in Pozzuoli village. The Romans, in the absence of natural volcanic ash, used powdered tiles or pottery as pozzolana. In India, powdered bricks or brick dust named Surki has been used in mortar. The Indian practice of thorough mixing and long continued ramming of lime mortar with or without the addition of Surki yield strong and impervious mortar which confirmed the secrete of superiority of Roman mortar. It is understood that the Romans added blood, milk and lard to their mortar and concrete to achieve better workability. Haemoglobin is a powerful air-entraining agent and plasticer, which perhaps is yet another reason for the durability of Roman structures. The cementing material made by the Romans using lime and natural or artificial pozzolana retained its position as the chief building material for all work, particularly, for hydraulic construction, recommended an intimate mixture of tiles, stone chips, and scales from a blacksmith's forge, carefully ground, washed free from coal and drift, dried, sifted and then mixed with fresh slack lime for making good concrete. In 1796 hydraulic cement was made by calcining nodules of argillaceous lime-stones. In about 1800 the product thus obtained was called Roman Cement. This type of cement was in use till about 1850 after which this was outdated by Portland cement. The story of the invention of Portland cement is however attributed to Joseph Aspdin, a Leads builder and bricklayer. Joseph Aspdin took the patent of Portland cement on 21st October 1824. The fancy name of Portland was given owing to the resemblance of this hardened cement to the natural stone occurring at Portland in England. In this process Aspdin mixed and ground hard lime stones and finely divided clay in the form of slurry and calcined it in a furnace similar to a lime kiln till the CO_2 was expelled. The mixture so calcined was then grounded to a fine powder. Perhaps, a temperature lower than the clinkering temperature was used by Aspdin Later in 1845 Isaac Charles Johnson burnt a mixture of clay and chalk till the clinkering stage to make better cement and established factories in 1851. Association of Engineers, consumers, and cement manufacturers has been established to specify standard for cement. The German standard specification for Portland cement was drawn in 1877. The British standard specification was first drawn up in 1904. The first ASTM specification was issued in 1904. The raw materials used for manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln form more complex compound. The relative proportion of these oxides is responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding. In addition to the four major compounds, there are many minor compounds formed during clinker production in the kiln. The influence of these minor compounds on the properties of cement or hydrated compounds is not significant. Two of the minor compounds namely K_2O and Na_2O referred to as alkalis in the cement are of some importance. Because K2O and Na_2O are responsible alkali-aggregate reaction in concrete. The use of Pozzolanic material is as old as that of the art of concrete construction. It was recognized long time ago that the suitable pozzolana used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes. Ancient Greeks and Romans used certain finely divided siliceous materials which when mixed with lime produced strong cementing materials having hydraulic properties and such cementing materials were used in the construction of aqueducts, arch bridges etc. Specimens of concrete made by lime and volcanic ash from Mount Vesuvius were used in the construction of "Caligula Wharf" built in the time of Julius Caesar nearly 2000 years ago is now existing in a fairly good condition. A number of structures stand today as evidence of the superiority of pozzolanic cement over lime [1].

2.2 Portland Cement

In spite of the modern concrete roads and buildings everywhere around us, it is difficult to realize the tremendous growth of the cement industry during the past century. Humans had early discovered certain natural rocks which, through simple calcination, gave a product that hardened on the addition of water. Yet the real advance did not take place until physiochemical studies and chemical engineering laid the basis for the modern efficient plants working under closely controlled conditions with a variety of raw materials. Cement dates back to antiquity, and one can only speculate as to its discovery. A cement was used by Egyptians in constructing the Pyramids. The Greeks and Romans used volcanic tuff mixed with lime for cement, and a number of these structures are still standing. In 1824 an Englishman, Joseph Aspdin, patented artificial cement made by the calcination of an argillaceous limestone. He called this "Portland" because concrete made from it resembled a famous building stone obtained from the Isle of Portland near England. This was the start of the Portland cement industry of today. The hard clinker resulting from burning a mixture of clay and limestone or similar materials is known by term Portland cement to distinguish it from natural or pozzolan and other cements [9].

2.2.1 Types of Portland Cements[9]

Hydraulic calcium silicates possess the ability to harden without drying or by reaction with atmospheric carbon dioxide, thus differentiating them from other inorganic binders such as plaster of Paris. The reactions involved in the hardening of cement are hydration and hydrolysis. Five types of Portland cement are recognized as follows:

Type-I: *Regular* Portland cements are the usual products for general construction. There are other types of this cement, such as white, which contains less ferric oxide, oil-well cement, quick-setting cement, and others for special uses.

Type-II: *Moderate-heat-of-hardening and sulfate-resisting* Portland cements are for use where moderate heat of hydration is required or for general concrete construction exposed to moderate sulfate action. The heat involved from these cements should not exceed 295 and 335 J/g after 7 days and 28 days, respectively.

Type-III: *High-early-strength* (HES) cements are made from raw materials with a lime-to-silicate ratio higher than that of Type-I cement and are ground finer than Type-I cements. They contain a higher proportion of tricalcium silicate (C_3S) than regular Portland cements. This, with the finer grinding, causes quicker hardening and a faster evolution of heat.

Type-VI: *Low-heat* Portland cements contain a lower percentage of tricalcium silicate (C_3S) and tricalcium aluminate (C_3A), thus lowering the heat evolution. Consequently, the percentage of tetra-calcium aluminoferrite (C_4AF) is increase because of the addition of iron oxide (Fe_2O_3) to reduce the amount of tricalcium aluminate (C_3A). Actually, the heat evolved should not exceed 250 and 295 J/g after 7 days and 28 days respectably, and 15 to 35 percent less than the heat of hydration of regular or High-early-strength (HES) cements.

Type-V: *Sulfate-resisting* Portland cements are whose which, by their composition or processing, resist sulfate better than other four types. Type-V is used when high sulfate resisting is required. These cements are lower in tricalcium aluminate (C_3A) than regular cements. In consequence of this, the tetra-calcium aluminoferrite (C_4AF) content is higher.

According to A.M.Neville, the name Portland cement, given originally due to the resemblance of the color and quality of the set cement to Portland stones- a limestone quarried in Dorset - has remained throughout the world to this day to describe a cement obtained by intimately mixing together calcareous and argillaceous, or other silica-, alumina-, and iron oxide-bearing materials, burning them at a clinkering temperature, and grinding the resulting clinker. The definition of the current British Standard (BS 12:1987) is on these lines; the standard stipulates also that no materials other than gypsum and water may be added after burning [2]. According to M.S.Shetty, the story of the invention of Portland cement is however attributed to Joseph Aspdin, a Leeds builder and bricklayer, even though similar procedures had been adopted by other inventors. Joseph Aspdin took the patent of Portland cement on 21st. October 1824. The fancy name of Portland given owing to the resemblance of this hardened cement to the natural stone occurring at Portland in England [1].

2.2.2 Chemical Composition of Portland Cements

The raw materials used for manufacture of Portland cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln (burning at a temperature of about 1300^{oC} to $1500^{oC)}$ to form more complex compound (clinker). The relative proportion of these oxides is responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding. The approximate oxide composition limits of Ordinary Portland Cement listed below [1]:

Approximate Oxide Composition limits of Ordinary Portland Cement

Oxide Composition	Percent Content
Calcium oxide CaO	60 - 67
Silica SiO_2	17 - 25
Alumina Al_2O_3	3.0 - 8.0
Iron oxide Fe_2O_3	0.5 - 6.0
Magnesium oxide MgO	0.1 - 4.0
Potasium & Sodium oxide K_2O, Na_2O	0.4 - 1.3
Sulphuric Anhydride SO_3	1.0 - 3.0

2.2.3 Bogue's Compounds

The oxides present in the raw materials used in cement manufacture when subjected to high clinkering temperature combine with each other to form complex compounds. The identification of the major compounds is largely based on R.H.Bogue's work and hence termed as "Bogue's Compounds". The four compounds usually regarded as major compounds. The four compounds regarded as major compounds are listed [1]:

Name of Compound	Formula	Abbreviated Formula
Tricalcium silicate	3 CaO, SiO_2	C_3S
Dicalcium silicate	2 CaO, SiO_2	C_2S
Tricalcium aluminate	3 CaO, Al_2O_3	C_3A
Tetra calcium aluminoferrite	4 CaO, Al_2O_3, Fe_2O_3	C_4AF

The equations suggested by **Bogue** for calculating the percentages of major compounds are given below:

$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85(SO_3)$

$C_2S = 2.87(SiO_2) - 0.754(3\ CaO, SiO_2)$

$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$

$C_4AF = 3.04(Fe_2O_3)$

2.2.4 The Oxide Composition of Typical Portland Cement

The oxide Shown within the brackets represents the percentage of the same in the raw materials. In addition to the four major compounds, there are many minor compounds formed during clinker production in the kiln. The influence of these minor compounds on the properties of cement or hydrated compounds is not significant. Two of the minor compounds namely K_2O and Na_2O referred to as alkalis in the cement are of some importance. Because K_2O and Na_2O are responsible Alkali-Aggregate Reaction in concrete. The oxide composition of typical Portland cement and the corresponding calculated compound composition is shown below [1]:

2.2.5 Hydration of Portland cements

Oxide Composition		Calculated Compound Composition (Using Bogue's Equation) percent	
Oxide	Composition Percent	Bogue's Compound	Composition Percent
CaO	63	C_3S	54.10
SiO_2	20	C_2S	16.60
Al_2O_3	6.0	C_3A	10.80
Fe_2O_3	3.0	C_4AF	9.10
MgO	1.5		
SO_3	2.0		
K_2O	1.0		
Na_2O	1.0		

Tricalcium silicate (C_3S) and Dicalcium silicate (C_2S) are the most important compounds responsible for cement's or concrete's strength. Together they constitute 70% to 80% of cement. Tricalcium aluminate (C_3A) and Tricalcium aluminoferrite (C_4AF) that is, the hydrated aluminate do not contribute anything to the strength of cement past. On the other hand, their present is harmful to the durability of concrete particularly where the concrete is likely to be attacked by sulphates. Tricalcium aluminate (C_3A) and Tricalcium aluminoferrite (C_4AF) hydrates e.i, hydrated aluminate very fast it may contribute a little to the early strength of cement past. The average content of Tricalcium Silicate (C_3S) and Dicalcium silicate (C_2S) in modern cement is about 45% and 25% respectively. The sum of the contents Tricalcium aluminate (C_3A) and Tricalcium aluminoferrite (C_4AF) decreased slightly in modern cement [1].

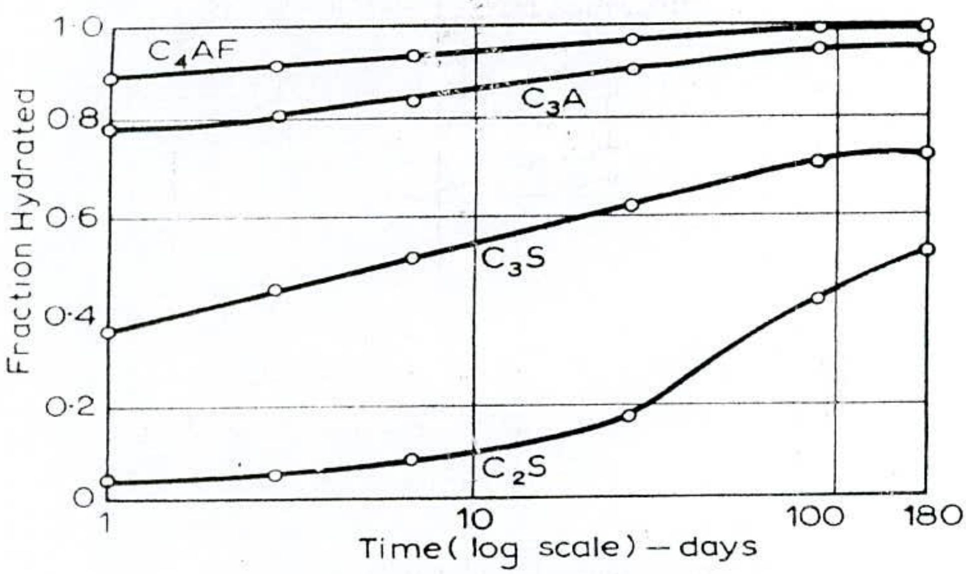

Fig.2.1 Hydration of Pure Compounds

2.3 Pozzolana

2.3.1 Introduction

Pozzolana is a siliceous or siliceous aluminous material which itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration at ordinary temperature to form compounds possessing cementitious properties [2]. Pozzolana is normally used as cement admixture in concrete. Generally, pozzolanic materials are economic, most abundant and widely available than ordinary port-land cement. Careful use of pozzolana is enormously useful in countering problems such as reactive aggregate, high sulfate soils, freeze-thaw conditions, and exposure to salt water, deicing chemicals, and acids [7].

2.3.2 Historical Development of Pozzalana

The use of Pozzolanic material is as old as that of the art of concrete construction. It was recognized long time ago that the suitable pozzolana used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes. Ancient Greeks and Romans used certain finely divided siliceous materials which when mixed with lime produced strong cementing materials having hydraulic properties and such cementing materials were used in the construction of aqueducts, arch bridges etc [1]. Specimens of concrete made by lime and volcanic ash from Mount Vesuvius were used in the construction of "Caligula Wharf" built in the time of Julius Caesar nearly 2000 years ago is now existing in a fairly good condition. A number of structures stand today as evidence of the superiority of pozzolanic cement over lime. [1]

2.3.3 Use and Future Prospect of Pozzolana

Bruce King P.E [7] stated that, the modern use of pozzolana as a cement replacing or enhancing admixture in concrete began many decades ago, and it is not new or alternative to the construction industry, but a trend in the past decade toward greater usage is now redefining acceptable practice. Often restricted by building codes to small fraction of cementitious material in a concrete mix, pozzolana has a relatively minor role in the concrete industry. But three trends are now active that would change that minor role to a much bigger one:

(a) Economy: Portland cement, the primary "glue" for structural concrete, is expensive and unaffordable to a large portion of the world's population. Some pozzolans, for various reasons, are also expensive, but the most abundant and widely available, fly ash, is not, and typically costs about half as much by weight as cement. Blended cements that replace up to 60% of the Portland cement with fly ash have now been successfully used in structural applications. Since Portland cement is typically the most expensive constituent of concrete, the implication is greatly improved concrete affordability.

(b) Durability: A wide variety of environmental circumstances are deleterious to concrete, such as reactive aggregate, high sulfate soils, freeze-thaw conditions, and exposure to salt water, deicing chemicals, and acids. Typically these problems have been countered, with partial success, by utilizing special cements, increasing strength, and/or minimizing water/cement ratios. But there now exists an overwhelming body of laboratory research and field experience showing that a careful use of pozzolans is enormously useful in countering all of these problems (and others); the pozzolana is not just a "filler", as many engineers think, but a strength and performance-improving additive. (A discussion of the pozzolanic reaction by which all this magic happens is readily available in the cited source. Very generally, it could be described as the siliceous pozzolans reacting with the (non-cementitious) calcium hydroxide in the hydrated cement paste to produce (highly cementitous) calcium silicate hydrates (CH + S + H —> CSH), yielding higher strength and dramatically reduced permeability.)

(c) Environment: Portland cement requires enormous heat in its manufacture, making it expensive not just to the consumer, but to the atmosphere as well. For every ton of cement produced, roughly 1/2 of a ton of CO_2 (greenhouse gas) is released by the burning fuel, and an additional 1/2 ton is released in the chemical reaction that changes raw material to clinker, making the production of cement responsible for more than 8% of all the greenhouse gases released by human activity. High-volume use of pozzolans is (or can be) not just an effective use of "waste" material, and not just an economic savings, but makes possible a noticeable reduction in greenhouse gas buildup. Seen from another perspective, high volume pozzolana usage in blended cements is a way for the cement industry to supply the ever-growing world market without having to build new production facilities. Some pozzolans are manufactured to augment concrete mixes in some specific way, others are ground from fired clay soils (such as the surki of India, made by grinding fired clay bricks), and others are volcanic tuffs or diatomaceous soils mined directly from the earth

2.3.4 Cementitious and Pozzolanic Materials

High-calcium fly ash (class C): HCFA is the residue collected from the smokestacks of coal-fired power plants generally using lignite and sub-bituminous coals. Class C fly ashes are in themselves mildly cementitious, and have been combined with lime or even calcium carbonate soils to produce moderately strong concretes.

Ground Granulated Blast Furnace Slag: GGBFS is the ground residue from iron smelters, and is also mildly cementitious in itself, but hugely pozzolanic in combination with water and cement. Its usage dates back 200 years, is widely used in Europe, and is currently restricted by the 1997 UBC to 50% of the cementitious material in a concrete mix.

2.3.5 Highly Active Pozzolana

Condensed Silica Fume: CSF is a waste product of the silicon metal industry, and is a super-fine powder of almost pure amorphous silica. Though difficult (and expensive) to handle, transport, and mix, it has become the chosen favorite for very high-strength concretes (such as for high rise buildings), often in combination with both cement and fly ash

Rice Hull (or Husk) Ash: RHA is the least known of the four pozzolans discussed, but enormously promising on a global scale. The world's primary staple crop is rice, the milling of which generates 100 million tons of hulls, or chaff, annually. Like the straw, hulls have historically been burned in the fields, but the resulting pollution is increasingly causing health problems. Research in India and the United States has found that if the hulls (or straw) are burned at a controlled low temperature, the ash collected can be ground to produce a pozzolan very similar to (and in some ways superior to) silica fume. Simultaneously, rice farmers have found that their biomass wastes can be burned to produce electrical power; several such power plants are now operational in the rice-growing regions of the USA, and more are planned in the USA, Brazil, the Philippines, and Japan. It is now known to be easy to burn the hulls (or straw) in such a way as to produce power and also generate the desired quality of ash for pozzolanic use. The implication, then, is that the hull/straw disposal problem worldwide can be ameliorated by building small (one to five MW) plants in rice-growing regions that could cleanly dispose of the crop waste, generate electricity for the area, and provide high quality cement.)

2.3.6 Normal Pozzolana

Low-calcium fly ash (class F, generally less than 10% CaO): LCFA is the residue collected from coal-fired power plants generally using anthracite and bituminous coals. Though generally less effective than the class C fly ashes, class F fly ash is nevertheless an abundant and useful pozzolan; note that the referenced structure in Nova Scotia, using 60% fly ash, was utilizing class F material. Both classes of fly ash are restricted by the 1997 UBC to 25% of cementitious material "in special exposure conditions" (section 1904), but this restriction is widely interpreted to apply to concrete in all conditions.

2.3.7 Types of Pozzalana

Pozzolanic materials can be divided into two group that (a) Natural Pozzolana which are clay and shales, opaline shales, diatomaceous earth, volcanic tuff & ash and pumicites. (b) Artificial Pozzolana which are fly ash, surki [1]. It is essential that pozzolana be in finely divided state as it only then that silica can combine with calcium hydroxide in presence of water to form stable calcium silicate which has cementitious properties[2]. Certain pozzolanas natural or artificial improve their activity by calcinations in the temperature range of 550 °C to 1100 °C, depending on their materials [3]. Rice Husks burnt at 450 °C have been found to produce a pozzolana confirming to the requirements of ASTM standard C618-72 [6].

2.3.8 Chemical Composition of Pozzolana [1]:

As per Indian Standard IS-1344-1968 the pozzolana shall conform to the following chemical requirements:

Oxides Composition	Percent Content
Silica (SiO_2)	$\geq$ 40%
Calcium Oxide (CaO)	$\geq$ 10%
Magnesium Oxide (MgO)	$\geq$ 3%
Sulphuric Anhydride (SO_3)	$\geq$ 3%
Soda and Potash (Na_2O, K_2O)	$\geq$ 3%
Water Soluble Alkali	$\geq$ 0.1%

2.4 Rice Husk and Rich Husk Ash

2.4.1 Introduction

Rice husk is a major agricultural by-product obtained from the food crop of paddy. For every 4 tones of paddy produced 1 tone is husk, i.e., about 20% of total paddy crop. On account of its typical physical and chemical characteristics like low bulk density (0.12 gm/cc), harshness, slow rate of biodegradation and high silica content it has but a little traditional use value in the countryside as cattle fodder, fuel or a source of manure. So far it has been totally a waste material posing difficult problems of disposal wherever it is produced, but recently the possibilities of its utilization in various ways have evoked much interest particularly in the developing countries of South-east Asia where the production of rice is more than half of the production of entire world.

Interesting development has taken place of utilizing rice husk in burnt form. Rice husk contains 16 to 18 percent pure silica by weight and on burning the rice husk yields 20 to 25 per cent ash with more than 90% amorphous silica. Since silica is an important and essential component of most of the present day building materials, like bricks and cements, and of varieties of lime-pozzolanas and sand-lime bricks, rice husk silica has been an interesting subject of investigations as a building material. Although most of the work has been done on the rice husk ash produced in the laboratory under controlled conditions, earlier attempts in this direction consisted in making building units from rice husk ash and hydrated lime by hydrothermal treatments. Development of technologies for the utilization of rice husk appropriate to those areas, not only will solve the problem of its disposal, but may also, help in providing a cheap source of new product in may ways. Research in the use of rice husk in the recent past suggest several ways of its utilization and those relating to the development of materials of construction are very important. Based on typical physical and chemical characteristics of rice husk (table-A) many applications of the material have been examined. A brief mention can be made here, among others, of the use of rice husk as such as an aggregate in lightweight concrete, bricks or blocks for wall construction, particle boards with or without binder and as a component in materials for insulation.

2.4.2 Use and Development of RHA

Arjun Dass and Mohan Rai of Central Building Research Institute (CBRI), Roorkee, India [11] discussed various aspect of rice husk and its ash in their paper which has been summarized as follows: Utilization of rice hush has become a subject of growing interest, particularly in the developing countries of South-east Asia. Most important among various methods suggested for the utilization, is the development of construction materials from rice as such and from its ash.

Use of rice husk has been examined as an aggregate in lightweight concrete, bricks and blocks for walls, particle boards, insulation materials, etc. High amount of silica present in the rice husk has been found to possess good pozzolanic reactivity. The ash can be used making Portland-pozzolana cement or lime-pozzolana cement. These products may conform to relevant standard specifications satisfying compressive strength value of Portland cement.

Rice husk ash obtained from boiler furnaces is generally variable in carbon content and hence reactivity. Rice husk ash produced by controlling burning in special furnaces may possess excellent properties but the process may be highly capital intensive.

In their paper describes the details of two simple processes developed at the Central Building Research Institute, Roorkee, India, for the controlled burning of rice husk as well as utilizing the resulting heat energy to convert waste calcium carbonate into lime in producing lime-rice husk ash cementitious material. These processes are potentially labour-oriented and can be adopted for rural areas.

The first process consists of making rice husk ash pozzolana by burning rice husk balls or cakes bonded with clay. Almost carbon-free ash of fairly consistent quality is obtained which is grounded with a fixed quantity of hydrated lime to produce a cementitious material. The balls or cakes burn quickly and completely as against the heap of husk which burns very slowly and produces ash with an appreciable quantity of unburnt carbon. The same is also the case with the furnaces where rice husk is commonly used as fuel.

The second process of CBRI is a further extension of the above approach. In place of dry clay, waste powdery calcium carbonate (known as lime sludge of sugar, paper and other industries) has been used. As a result of burning, fuel value of rice husk is used to convert calcium carbonate to lime and resulting ash is mixture of lime and rice husk silica which possesses hydraulic properties.

Among the means of utilization of the rice husk for constructional purposes the CBRI processes make best use of rice husk silica showing good promise for reasons of potentialities they possess. Looking from the point of view of the distributed occurrence and locations of the paddy cultivation and large and small rice mills scattered in the countryside these technologies can be adopted easily at the place where small or large quantities of rice husk and cheap source of lime exist.

Subsequent work by Dr. P.K. Mehta of California University showed that sufficient good quality product comparable to Portland cement can be made by combination of hydrated lime and rice husk ash produced at optimum temperature of burning under controlled conditions. He has developed a specially designed furnace for burning the rice husk to get the reactive type of rice husk ash. Dr. P.K. Mehta is of opinion that rice husk ash obtained from the boiler furnaces is not sufficiently reactive.

Dr. Narayan P.Singhania [8] discussed various aspect of rice husk ash which has been summarized as follows: Their is an increasing importance to preserve the environment in the present day world. Rice Husk Ash (RHA) from the parboiling plants posing a serious environmental threat and ways are being thought of to dispose them. This material is actually a super pozzolana since it is rich in silica and has about 85% to 90% silica content. A good way of utilizing this material is to use it for making 'High Performance Concrete' which means high workability and very high early strengths, or, consider high workability and long-term durability of the concrete. Each tone paddy produces about 200 kg of husk, which on combustion; yield approximately 40 kg of highly siliceous ash, and release 3800 kcal/kg of heat energy. In the conversion of rice husk to ash, combustion process removes the organic matter and leaves the silica rich residue. However, such thermal treatment of the silica in the husk results in structural transformations that influence both the pozzolanic activity of the ash and its grind ability. The silica is still in an amorphous form below 600°C. Lots research has been carried out in this context and it has been proved beyond doubt that by utilizing these Super-Pozzolanic materials even in small amount (5% to10% cement replacements) can dramatically enhance the workability, strength and impermeability of concrete mix, as a result the concretes are highly durable to chemical attacks, abrasion and reinforcement corrosion. From the standpoint of durability a better way to improve the workability of a concrete mixture is through the incorporation of fine particles of a material, which are less reactive, then the Portland cement. The mechanism by which RHA particles improve workability is as follows: if well in the cement paste, the particles of RHA segment the bleed-water channels and subsequently is able to prevent bleeding and segregation. The physical effect, followed by the chemical effect involving the pozzolanic reaction (in which the calcium hydroxide formed during hydration of cement in concrete reacts with the silica present in the admixture to form calcium hydride silicate), fill up the empty spaces and cause densification (pore refinement) and strengthening of the microstructure, particularly in high porous and least cracking-resistant interfacial zone which exit in the vicinity of coarse aggregate particles. Studies have shown that 10% cement replacement with RHA can reduce large pores. Note that the transformation of an open-pore system into a close-pore system, through the process of pore refinement has a much greater effect on the permeability than on the strength of the materials. Compressive strength can be increased up to 30%. Water permeability can be reduced up to 60%. Chloride penetration can be reduced by up to 60% and Heat of Hydration up to 25%, with 10% replacement of cement in concrete [8].

2.4.3 Source of Rice Husk Ash

Rice milling generates a by product know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85 % - 90 % amorphous silica. So for every 1000 kg of paddy milled, about 220 kg (22 %) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25 %) of RHA is generated. The husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and/or by gasification. Rice husk ash is supper Pozzolana. It contained 85%-90% reactive silica, so RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of this RHA [4].

2.4.4 Future Prospect of RHA:

The particle size of the cement is about 35 microns. There may be formation of void in the concrete mixes, if curing is not done in properly. This reduces the strength and quality of the concrete. A commercial product known as "Silpozz" which is made out of this RHA is finer than cement having very small particle size of 25 microns, so much so that it fills the interstices in between the cement in the aggregate. That is where the strength and density comes from. And that is why it can reduce the amount of cement in the concrete mix [4]. Since Silpozz (made from rice husk ash) contain Silica (SiO_2) $\geq$ 85% rice husk ash can be a good raw material to produce cementing material and/or a good admixture for concrete mix. Amorphous silica occupies majority (85% - 90%) of volume of RHA. Rice husk ash is a great threat to environment causing damage to the land and surrounding area in which it is dumped. But valuable product from this RHA is possible. It is also noted that rice husk burnt at 450°C have been found to produces a pozzolana conforming to the requirements of the ASTM standard C618-72[6]. Bangladesh produces about 35 million metric tons of paddies per annum. 80% of the paddy produced is parboiled [10]. After husking this huge amount of paddy, it produces about 6.16 million metric tones of rice husk per year. By burning of this husk produces 1.54 million metric tones of rice husk ash per year. The above discussion indicates that this huge quantity of rice husk ash (RHA) can be used in construction industries if it is improved by proper investigation.

CHAPTER 3

LABORATORY INVESTIGATION

3.1 General Remarks

Interesting development has taken place of utilizing rice husk in burnt form. Rice husk contains 16 to 18 percent pure silica by weight and on burning the rice husk yields 20 to 25 per cent ash with more than 90% amorphous silica. Since silica is an important and essential component of most of the present day building materials, like bricks and cements, and of varieties of lime-pozzolanas and sand-lime bricks, rice husk silica has been an interesting subject of investigations as a building material. Although most of the work has been done on the rice husk ash produced in the laboratory under controlled conditions, earlier attempts in this direction consisted in making building units from rice husk ash and hydrated lime by hydrothermal treatments. Laboratory-burnt rice husk ash has been investigated as a pozzolana in the form of an additive in cement mortar and concrete. Primary aim has been to look into the possibility of saving cement through replacement by rice husk ash without losing the advantage of compressive strength and other properties in the mortar or concrete. It has been shown that replacement of cement up to 20% by this ash can be accommodated to produce Portland-pozzolana cement [11].

Rice Husks burnt at 450 °C have been found to produce a pozzolana confirming to the requirements of ASTM standard C618-72 [6]. Rice milling generates a by product know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. Each tone paddy produces about 200 kg of husk, which on combustion; yield approximately 40 kg of highly siliceous ash, and release 3800 kcal/kg of heat energy. In the conversion of rice husk to ash, combustion process removes the organic matter and leaves the silica rich residue. However, such thermal treatment of the silica in the husk results in structural transformations that influence both the pozzolanic activity of the ash and its grindability [8]. The silica is still in an amorphous form below 600°C. Rice husk contains about 75 % organic volatile matter and the balance 25 % of the weight of husk is converted into ash during the firing process. This RHA in turn contains around 85 %-90 % amorphous silica. So for every 1000 kg of paddy milled, about 220 kg (22 %) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. The husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and/or by gasification.

Rice husk ash is supper Pozzolana. It contained 85%-90% reactive silica, so RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of RHA [4].

3.2 Burning of Rice Husk and Clay:

The rice husk was collected and burnt in furnace in laboratory to produce ash. Muffle furnace of maximum temperature up to1100 °C was used which is available in the civil engineering department. By burning rice husk in controlled temperatures which are below 700 °C, almost carbon-free ash of fairly consistent quality is obtained. Here, the burning temperature has been maintained at 450 °C. Duration of burning was 60 minutes. The ash produced that collected for grinding.

Fig.3.1: Muffle Furnace

Clay was used in two ways i.e., as un-burnt form and burnt form. In second case clay was separately burnt at 800 °C for 60 minutes.

3.3 Grinding of Rice Husk Ash, Clay and Lime:

The rice husk ash that obtained then grounded by using industrial ball mill to produce powder or dust and then sieving it by a 200 mesh sieve. Industrial ball mill (fig.-3.2) is a steel made special type grinding machine that fitted with a steel barrel of 6 flat sided interior surface rotated by an electric motor. The barrel designed to maximize the milling action by forcing the grinding media (50 no of $^{1}/_{4}$" dia. steel ball) to fall and impact on itself during rotation. The particles that pass through sieve then collected and stored in air tight container for further use. Similarly, lime and clay (both un-burnt and burnt) were also grounded to produce powder or dust and then sieving it by a 200 mesh sieve.

Fig.3.2: Industrial Ball Mill

Fig.-3.3 200Mesh Sieve

3.4 Preparation of Cement

The grounded rice husk ash, clays (either bunt or un-burnt) and lime then thoroughly mixed in definite proportions to get homogenous mixture of RHA cement and was collected for further test. Mix ratio for the preparation of cement using burnt and un-burnt clay with rich husk ash (RHA) and lime are selected for planned experiments shown in table 3.1 & 3.2.

Table- 3.1 Mix ratio for preparation of cement using burnt clay, rice husk ash (RHA) and lime in laboratory.

Ingredients	Weight in % (B_1)	Weight in % (B_2)	Weight in % (B_3)
Treatment-A			
Lime	55	60	65
Rice Husk Ash (RHA)	35	30	25
Clay (Burnt)	10	10	10
Treatment-B			
Lime	55	60	65
Rice Husk Ash (RHA)	40	35	30
Clay(Burnt)	5	5	5
Treatment-C			
Lime	55	60	65
Rice Husk Ash (RHA)	30	25	20
Clay (Burnt)	15	15	15
Treatment-D			
Lime	55	55	55
Rice Husk Ash (RHA)	30	35	40
Clay (Burnt)	15	10	5
Treatment-E			
Lime	60	60	60
Rice Husk Ash (RHA)	25	30	35
Clay (Burnt)	15	10	5

Table-3.2 Mix ratio for preparation of cement using un-burnt clay, rice husk ash (RHA) and lime shown in table below:

Ingredients	Weight in % (U_1)	Weight in % (U_2)	Weight in % (U_3)
Treatment-A			
Lime	55	60	65
Rice Husk Ash (RHA)	35	30	25
Clay (Un-burnt)	10	10	10
Treatment-B			
Lime	55	60	65
Rice Husk Ash (RHA)	40	35	30
Clay (Un-burnt)	5	5	5
Treatment-C			
Lime	55	60	65
Rice Husk Ash (RHA)	30	25	20
Clay (Un-burnt)	15	15	15
Treatment-D			
Lime	55	55	55
Rice Husk Ash (RHA)	30	35	40
Clay (Un-burnt)	15	10	5
Treatment-E			
Lime	60	60	60
Rice Husk Ash (RHA)	25	30	35
Clay (Un-burnt)	15	10	5
Treatment-F			
Lime	65	65	65
Rice Husk Ash (RHA)	20	25	30
Clay (Un-burnt)	15	10	5

3.5 Testing of Cementing Properties

3.5.1 Standard Consistency Test (CPNC)

For finding out initial setting time, final setting time and soundness of cement, a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the Vicat mould 80 mm diameter and 40 mm high.

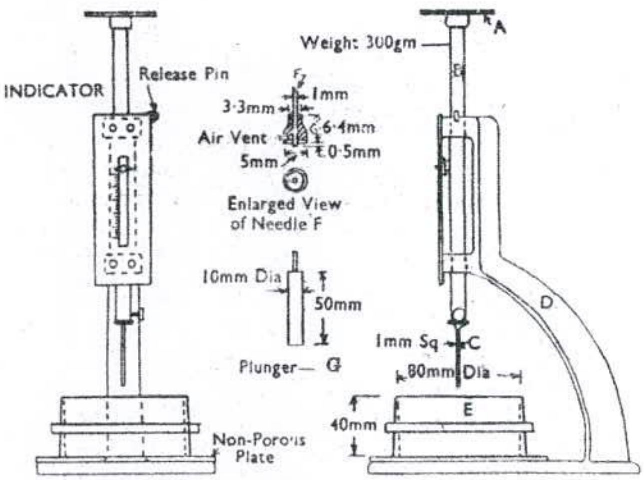

Fig.3.4 Vicat Apparatus

The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is same time called cement paste normal consistency (CPNC). The following procedure is adopted to find out standard consistency. Take about 500 gms of cement and prepare paste with a weighed quantity of water (say 24% by weight of cement) for the first trial. The paste must be prepared in a standard manner and filled into the Vicat mould within 3-5 minutes. After completely filling the mould, shake the mould to expel air. A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink in to paste by its own weight. Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trail (say 25% by weight of cement) and find out the depth of penetration of plunger. Similarly, conduct trail with higher and higher water/cement ratios till such time the plunger penetrates for a depth 33-35 mm fro the top of Vicat mould. The particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as 'P'. The standard consistency test that has been performed in our experiments. Results show in the tables 4.1 & 4.2

3.5.2 Setting Time

An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions. For convenience, initial setting time is regarded as the time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moments that the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. This test method conforms to the ASTM standard requirements of specification C 191. As per ASTM C150, ordinary Portland cement should have the initial setting time not less than 45 minutes and final setting time not more than 375 minutes. Results show in the tables 4.1 & 4.2.

3.5.2.1 Initial Setting Time

The Vicat Apparatus is used for setting time test. The following procedure is adopted. Take 167 gm of cement sample and gauge it with 0.56P (water/cement ratio) times the water required to produce cement paste of standard consistency (0.56P). The paste shall be gauged and filled into the Vicat mould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement. The temperature of the water and that of the test room, at the time of gauging were within $27^0C \pm 2^0C$. Lower the needle (C) of the Vicat apparatus gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle wills completely piers through the test block. But after same time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time that was 90 minutes. Results show in tables 4.1 & 4.2.

3.5.2.2 Final Setting Time

Release the needle (C) of the Vicat apparatus by a circular attachment (F). The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm. In our test final setting time was 7 hours. Results show in tables 4.1 & 4.2.

3.5.3 Compression Test of Cement Mortar

The mechanical strength of hardened cement is the property of this material which is, perhaps, the most important one for its structural use. Tests for strength are not made on a neat cement paste because of difficulties in the molding and testing with a consequent large variation in results. The strength of cement is usually determined from test on mortars. Several tests are performed to determine the tensile, compressive and shear strength of cement mortar of a certain proportion. Cement mortar of concrete gives a compressive strength of about ten times its tensile strength. Our test method covers determination of compressive strength of cement made from Rice Husk Ash. using 2-in or 50 mm cube specimens. The test method conforms to the ASTM standard requirement of specification C 109. The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for the strength at the laboratory before the cement is used in important works. Strength test are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportions. The standard sand is used for finding the strength of cement. In our test it was used OTTAWA sand in specified mix proportion of $1:2^3/_4$. We have taken 460 gm of OTTAWA sand, 167 gm of cement in a non-porous enamel try and mix them with a trowel for one minute, then add water of quantity P/4 + 3.25 percent of combined weight of cement and sand (e.i., 106.43 gm) and mix the three ingredients thoroughly until the mixture is of uniform color. The time of mixing was 4 minutes. Immediately after mixing, the mortar is filled into a cube mould of size 2 inch-cube. The area of the face of the cube was 4 sq. inch. Compacting the mortar by hand compaction in a standard specific manner. The compacted cube was kept in mould and covered with wet gunny bag to simulate 90 percent relative humidity. After 24 hrs. the cube were removed from the mould and immersed in clean fresh water until taken out for testing. Three cubes were tested for compressive strength. The periods being recorded from completion of compaction. The compressive strength were the average of the three cubes for each period respectively were maximum of 300 psi (using burn clay) and 295 psi (using Un-burn clay) for 3 days. Results show in tables 4.3 & 4.4.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

Different selective experiments and tests are done for this research. Results of initial setting time, final setting time and cement paste normal consistency (CPNC) of different samples using burnt clay and un-burnt clay found in laboratory test shown in tables 4.1, 4.2, 4.3, 4.4 & 4.5.

Table 4.1 Results of initial setting time, final setting time and cement paste normal consistency (CPNC) of different samples using burnt clay found in laboratory test shown in table below:

Treatment	Sample No.	Initial Setting Time (Minutes)	Final Setting Time (Minutes)	CPNC
A	B_{1-A}	90	450	0.56
	B_{2-A}	95	455	0.57
	B_{3-A}	90	455	0.58
B	B_{1-B}	100	440	0.55
	B_{2-B}	100	450	0.57
	B_{3-B}	100	450	0.58
C	B_{1-C}	90	450	0.53
	B_{2-C}	90	455	0.55
	B_{3-C}	90	450	0.56
D	B_{1-D}	90	450	0.58
	B_{2-D}	95	455	0.57
	B_{3-D}	100	455	0.56
E	B_{1-E}	95	450	0.57
	B_{2-E}	95	455	0.56
	B_{3-E}	100	450	0.55
F	B_{1-F}	98	455	0.57
	B_{2-F}	100	460	0.56
	B_{3-F}	105	460	0.55
	Average	**96**	**433**	**0.56**

Table 4.2 Results of initial setting time, final setting time and cement paste normal consistency (CPNC) of different samples using un-burnt clay found in laboratory test shown in table below:

Treatment	Sample No.	Initial Setting Time (Minutes)	Final Setting Time (Minutes)	CPNC
A	$U_{1\text{-}A}$	93	415	0.55
	$U_{2\text{-}A}$	95	420	0.56
	$U_{3\text{-}A}$	94	425	0.58
B	$U_{1\text{-}B}$	105	410	0.54
	$U_{2\text{-}B}$	100	415	0.56
	$U_{3\text{-}B}$	105	420	0.58
C	$U_{1\text{-}C}$	95	415	0.53
	$U_{2\text{-}C}$	95	420	0.54
	$U_{3\text{-}C}$	90	425	0.57
D	$U_{1\text{-}D}$	95	415	0.57
	$U_{2\text{-}D}$	95	420	0.55
	$U_{3\text{-}D}$	100	420	0.57
E	$U_{1\text{-}E}$	100	415	0.58
	$U_{2\text{-}E}$	105	415	0.55
	$U_{3\text{-}E}$	105	410	0.55
F	$U_{1\text{-}F}$	100	420	0.58
	$U_{2\text{-}F}$	105	420	0.55
	$U_{3\text{-}F}$	105	420	0.55
	Average	**99**	**418**	**0.56**

Table 4.3 Results of 3 days compressive strength for cement mortar cube of different samples using burnt clay of different water-cement ratios found in laboratory test shown in the table below:

Sample No.	Water Cement Ratio	3 days Compressive Strength (psi)
$B_{1\text{-}A}$	0.56	283
$B_{2\text{-}A}$	0.57	300
$B_{3\text{-}A}$	0.58	192
$B_{1\text{-}B}$	0.55	267
$B_{2\text{-}B}$	0.57	296
$B_{3\text{-}B}$	0.58	233
$B_{1\text{-}C}$	0.53	229
$B_{2\text{-}C}$	0.55	188
$B_{3\text{-}C}$	0.56	158
$B_{1\text{-}D}$	0.58	229
$B_{2\text{-}D}$	0.57	120
$B_{3\text{-}D}$	0.56	167
$B_{1\text{-}E}$	0.57	46
$B_{2\text{-}E}$	0.56	29
$B_{3\text{-}E}$	0.55	167
$B_{1\text{-}F}$	0.57	71
$B_{2\text{-}F}$	0.56	83
$B_{3\text{-}F}$	0.55	88
Average	**0.56**	**175**

Table 4.4 Results of 3 days compressive strength for cement mortar cube of different samples using un-burnt clay of different water-cement ratios found in laboratory test shown in the table below:

Sample No.	Water Cement Ratio	3 days Compressive Strength (psi)
$U_{1\text{-}A}$	0.55	278
$U_{2\text{-}A}$	0.56	295
$U_{3\text{-}A}$	0.58	188
$U_{1\text{-}B}$	0.54	262
$U_{2\text{-}B}$	0.56	291
$U_{3\text{-}B}$	0.58	229
$U_{1\text{-}C}$	0.53	225
$U_{2\text{-}C}$	0.54	184
$U_{3\text{-}C}$	0.57	155
$U_{1\text{-}D}$	0.57	224
$U_{2\text{-}D}$	0.55	117
$U_{3\text{-}D}$	0.57	163
$U_{1\text{-}E}$	0.58	43
$U_{2\text{-}E}$	0.55	28
$U_{3\text{-}E}$	0.55	164
$U_{1\text{-}F}$	0.58	69
$U_{2\text{-}F}$	0.55	80
$U_{3\text{-}F}$	0.55	85
Average	**0.56**	**171**

Table 4.5 Weight of ash left as residue and loss of volatiles materials after burning of rice husk obtained from different variety of paddy found in laboratory shown in the table below:

Variety of Paddy (Rice)	**Weight of Raw Husk (gm)**	**Weight of Volatiles materials loss after burning (gm)**	**Weight of Ash obtained after burning (gm)**	**Percentage of volatile materials loss**	**Percentage of Ash obtained**
BR-27	200	153.04	46.96	76.52	23.48
Minicate	200	153.07	46.93	76.55	23.46
Paizam	200	153.05	46.95	76.53	23.47
IRRI-8	200	153.04	46.96	76.52	23.48
Nazir Sail	200	153.06	46.94	76.53	23.47
Average	**200**	**153.05**	**46.95**	**76.53**	**23.47**

4.2 Discussion

The new product of RHA cement sample was tested for properties like Ordinary Portland Cement. RAH cement made in this study contains ash, lime and clay in different ratio. For this purpose a typical samples at the beginning was made with un-burnt clay. Similar samples were made with burnt (800 ^{0}C) clay. The result between two are found to agree. Rest of the cement samples were made with burnt clay. Results of these samples are shown in tables no. 4.1, 4.2, 4.3, 4.4 & 4.5. By discussion the test results we find that, (a) in case of un-burnt clay, average water- cement ratio required for cement paste of normal consistency (CPNC) was found to be 0.56, initial setting time was found to be 99 minutes, final setting time was found to be 6 hrs.58 minutes and 3 days compressive strength for cement mortar cube was found to be 171 psi respectively. (b) in case of burnt clay, average water- cement ratio required for cement paste of normal consistency (CPNC) was found to be 0.56, initial setting time was found to be 96 minutes, final setting time was found to be 7 hrs. 13 minutes and 3 days compressive strength for cement mortar cube was found to be 175 psi respectively. These values when compared with those of Ordinary Portland Cement, it was found that in case of un-burnt clay, CPNC varied only 7%, initial setting time was double than OPC, final setting time was increased by one hour than OPC. For burnt clay, CPNC was found to be 0.56, initial setting time was found to be more than double than OPC, final setting time was increased by one and half hour than OPC and 3 days compressive strength was found to be 175 psi. It is clear from the study that RHA can be attributed cementing property when combined with lime and clay. The properties of this cement resembles with those of OPC with compromise of higher setting time and lower strength. However this may be recommended for the cases where lower strength can be used (e.g., boundary walls, normal load bearing residential buildings, partition walls, surface drains etc.)

CHAPTER 5

CONCLUSSION AND RECOMMANDATION

5.1 Conclusion

The above laboratory investigations indicates that rice husk ash (RHA) can be used in construction industries if it is improved by proper investigation.

5.3 Recommendation

The recommendations for the study are as follows:

1. Chemical composition of RHA of different temperature should be studied
2. Rate of hydration and heat of hydration of such new product (RHA cement) should be studied.
3. Behavior with concrete, that is long term strength and short term strength should be studied.

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