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Partial Replacement of Cement Using Rice Husk Ash in Concrete

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ABSTRACT

Concrete usage worldwide is second only to water. OPC is conventionally used as the main binder in the production of concrete. The environmental issues mixed with the production of OPC. In addition, the energy required to produce OPC is only slightly more than that of steel and aluminum. Portland cement concrete is a combined substance of Portland cement, aggregates, and water. Concrete is the most commonly used construction material. Due to an increase in infrastructure development, the demand for concrete is expected to rise in the future demand. The production of Portland cement releases carbon dioxide, the highest level of contributor to greenhouse gas emissions in the atmosphere. The manufacture of every ton of Portland cement contributes approximately about one ton of CO2. Globally, the world's Portland cement production contributes six percent of the global loading of carbon dioxide into the atmosphere. By 2012, the world's cement consumption rate had reached approximately 4,425 million tons, meaning that about 265.5 million tons of CO2 would be released.
To address the environmental effects associated with Portland cement, there is a need to utilize alternative binders in the production of concrete. Globally, approximately 850 million tonnes of rice are harvested annually, with India producing around 160 million tonnes. On average of 30% of the rice crop is husk, presenting an annual total production of 160 million tonnes. This rice husk, when burnt, produces 32 million tonnes of Rice Husk Ash (20% approx.). In the majority of rice-producing countries, most of the husk produced during rice processing is either burned or discarded as waste. The specific objectives of this study were to compare the performance characteristics of concrete made with the partial replacement of cement by four different materials, as mentioned below.
Different combinations of RHA mixtures, to levels of 10%, 15%, 20%, and 25%, with that of concrete made with no cement replacement at all.

1.Introduction

1.1 General

Concrete usage worldwide is second next to the water. Ordinary Portland cement (OPC) is conventionally used as the primary binder in the production of concrete. The environmental problems associated with the production of OPC are well known. The quantity of carbon dioxide produced during the manufacture of OPC, due to the calcination process of limes and the burning of fossil fuels, is approximately one ton for every ton of OPC produced. Additionally, the energy required to produce OPC is in addition to that required for steel and aluminum. Portland cement concrete is a combined mixture of Portland cement, aggregates, and water. Concrete is the most often used construction material. Due to the growth in infrastructure development, the demand for concrete is expected to increase in the future. The production of Portland cement releases carbon dioxide (CO2), a primary contributor to greenhouse gas emissions in the atmosphere. The manufacture of every ton of Portland cement contributes approximately about one ton of CO2.

Globally, the world's Portland cement production contributes 6% of the global loading of carbon dioxide in the atmosphere. By 2012, the world's cement consumption rate had reached approximately 4,425 million tons, meaning that about 265.5 million tons of CO2 would be released into the atmosphere. To address the environmental effects associated with Portland cement, there is a requirement to use alternative binders in the production of concrete. Several efforts have been made to reduce the use of Portland cement in concrete, aiming to lower CO2 emissions and mitigate global warming. These include the use of supplementary cementing materials (SCMs) such as fly ash, silica fume, granulated blast furnace slag, rice husk ash, and metakaolin, as well as the development of alternative binders to Portland cement.

The use of SCMs dates back to the ancient Greeks' historical period when they incorporated volcanic ash with hydraulic lime to create cementitious mortar. The Greeks passed on this valuable knowledge to the Romans, who constructed engineering marvels such as the Roman aqueducts and the Colosseum, which still stand today. Early SCMs consisted of natural, readily available materials such as volcanic ash or diatomaceous earth. More recently, stringent air pollution controls and regulations have generated an abundance of industrial by-products that can be utilized as supplementary cementing materials, including fly ash, silica fume, and blast furnace slag. The use of such by-products in concrete construction not only prevents these products from being landfilled but also enhances the properties of concrete in both its fresh and hardened states.

SCMs can be classified into two categories based on their type of reaction: hydraulic or pozzolanic. Hydraulic materials react directly with water to become cementation compounds. In contrast, pozzolanic materials chemically react with calcium hydroxide (CH), a soluble byproduct of the chemical reaction, in the presence of moisture to form compounds possessing cementing properties.

The word "pozzolan" is derived from a deposit of volcanic ash from Mt. Vesuvius, situated near the town of Pozzuoli, Italy. Pozzolanic SCMs can be used as an addition to the cement or as a replacement for some portion of the cement. Most often, an SCM will be used to replace a portion of the cement composition for economic or property improvement reasons.

Globally, approximately 850 million tons of rice are harvested annually, with approximately 160 million tons produced in India alone. The rice paddy yields husk, resulting in an annual total production of 160 million tons, equivalent to approximately 30% of the Rice crop. This rice husk, when burnt, produces 32 million tons of Rice Husk Ash (20% approx.). In the majority of rice-producing countries, much of the husk produced during rice processing is either burned or discarded as waste.

The solution for the treatment of rice husks as a 'resource' for energy generation is a departure from the assumption that husks current disposal problems. The concept of producing energy from rice husks has good potential. Rice husks are one of the most significant and most readily available biomass resources, making them an ideal fuel for electricity generation.

Rice husk contains a significant amount of ash, approximately twenty percent, compared to other biomass fuels. The ash is composed of 93 to 96% silica, is large, porous, and lightweight, with a very high outer surface area. Its absorbent and insulating properties are beneficial for industrial uses. If a long-term, sustainable market and cost for rice husk ash (RHA) can be developed, then the viability of rice husk power or cogeneration plants can be substantially improved. Many more plants in the 3-5 MW range can become commercially viable worldwide, and this biomass resource can be utilized to a significantly greater extent than it is currently.

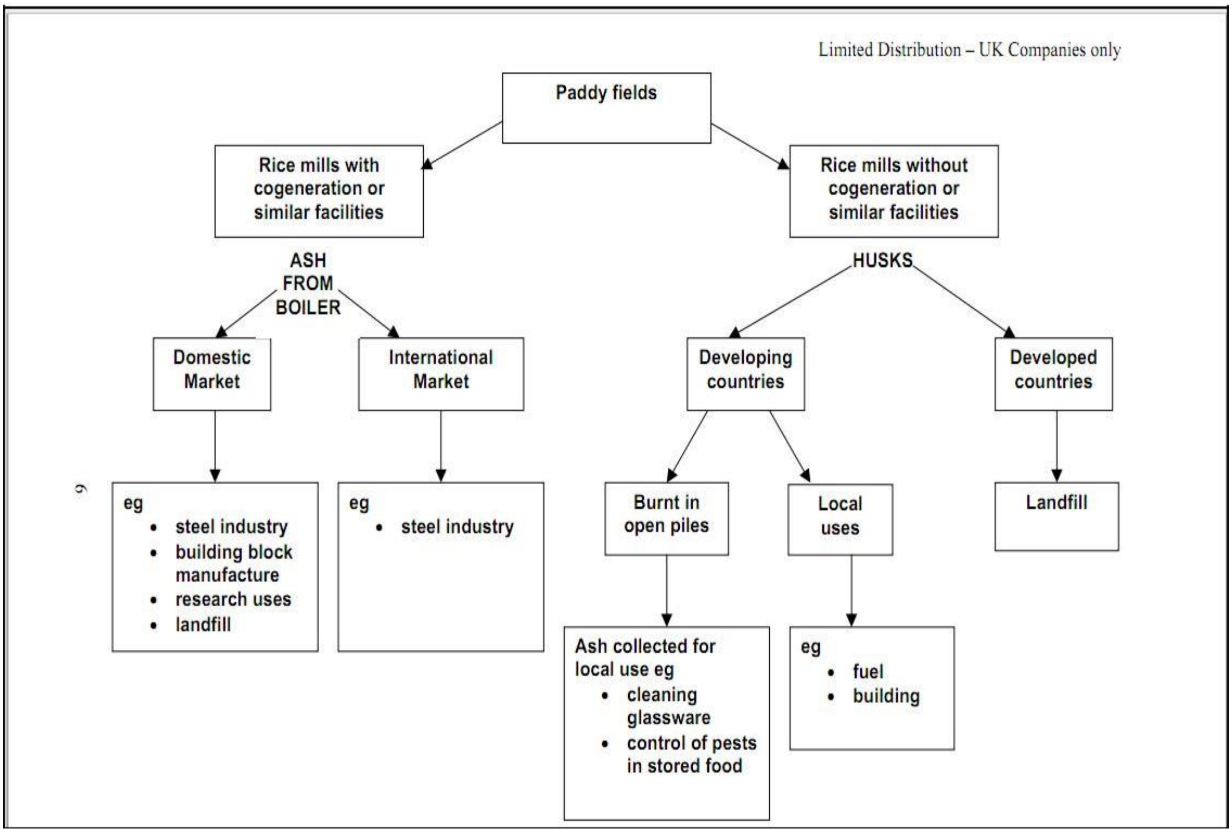

Figure 2.1: Flowchart showing movement of rice husk ash under two scenario mills.

1.2 Aims of study

The specific objectives of this study were to compare the performance characteristics of concrete made with partial replacement of cement by four different combinations of RHA mixtures at levels of 10%, 15%, 20%, and 25% with those of concrete made with no cement replacement at all.
To know and study the effect of salient parameters that affect the properties of rice husk ash concrete.

1.3 Production of Rice Husk Ash (RHA)

The rice plant is one of the crops that most absorb silica from the soil and assimilate it into its structure during growth. Rice husk is the surface covering of the grain of rice crop. Rice husk is produced in millions of kilo tons every year as a waste material in agricultural and industrial processes. It constitutes about 21% of the weight of rice. It contains approximately 50% cellulose, 25–30% lignin, and 15–20% silica.

When rice husk is burnt, rice husk ash (RHA) is generated. On burning, cellulose and lignin are removed from the rice husk, leaving behind silica ash. The stable temperature and environment of burning yield better quality rice husk ash, as its particle size and specific surface area are primarily determined by the burning conditions. For every 1000 kg of paddy milled, approximately 300 kg (30%) of husk is produced, and when this rice husk is burnt in the boilers, about 50 kg (25%) of Rice husk ash is generated. Completely burnt rice husk turns from grey to white, while partially burnt RHA remains blackish.

The form of silica obtained after the combustion of the rice husk depends on the temperature and duration of combustion of the rice husk. At 400◦C, polysaccharides begin to depolymerize.

Above approximately 400 °C, dehydration of sugar units occurs. Around 700◦C, the sugar units decompose. At temperatures above 700 °C, the unsaturated products collectively reacted to form a highly concentrated, reactive carbonic residue as the product. The X-ray data and chemical analysis of RHA produced under different burning conditions revealed that the higher the burning temperature, the greater the percentage of silica in the ash, with K, S, Ca, Mg, and several other components identified as volatile.

Rice husk ash is a naturally excellent pozzolanic material. The use of rice husk ash as a pozzolanic material in cement concrete offers several advantages, including improved compressive strength and durability properties of the concrete, reduced material costs due to savings in cement, and environmental benefits related to the disposal of agricultural waste materials and reduced atmospheric emissions. The reactivity of Rice husk ash is due to its high content of amorphous silica and its vast surface area, which is managed by the porous structure of the particles. Generally, reactivity is also favored by increasing the fineness of the pozzolanic material. However, grinding Rice husk ash to a high degree of fineness should not be considered, as its pozzolanic activity originates mainly from the inner surface area of the particles.

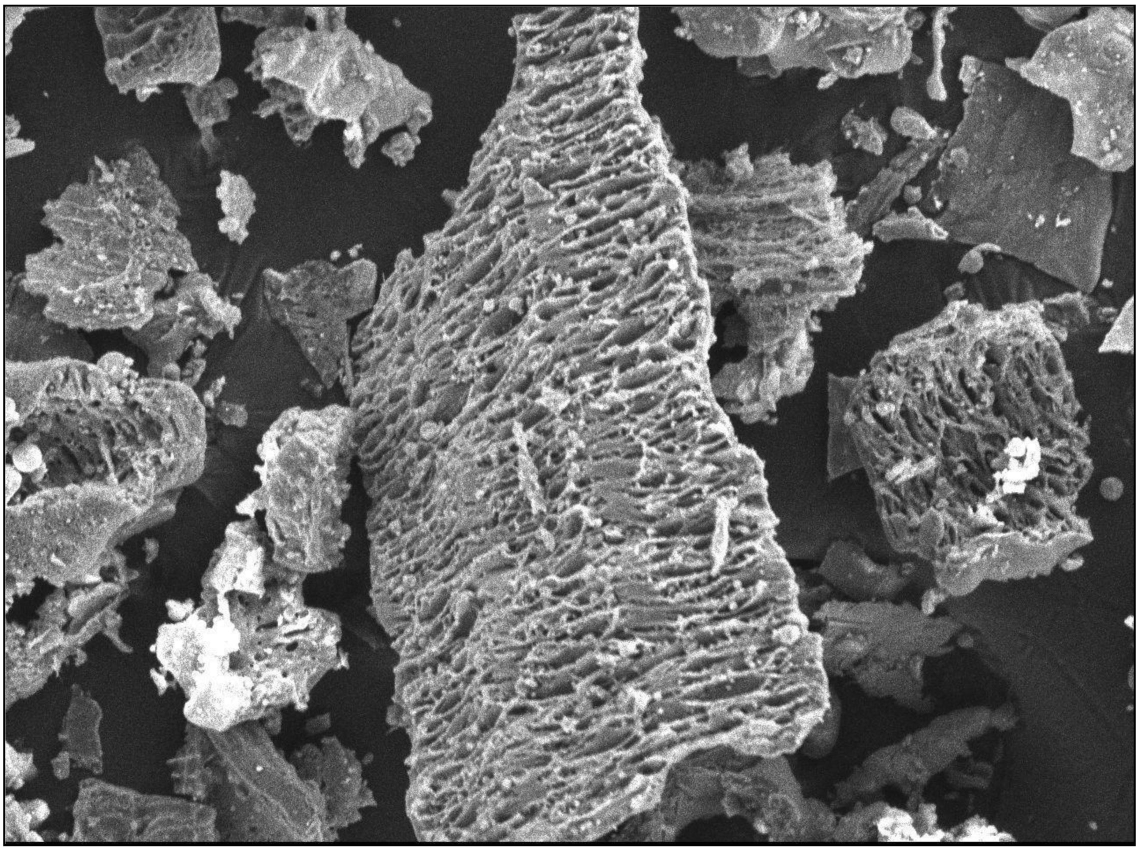

Figure 1.2: Cellular Structure of Rice Husk Ash.

1.4 Properties of RHA

1.4.1 Physical properties

RHA is a very fine material. The average particle size of rice-husk ash ranges from 5 to 10 µm. The specific gravity is in the range of 2.05 to 2.10.

1.4.2 Chemical properties

Rice husk ash is very rich in silica content. The silica content in RHA is generally more than 80–85%. For RHA to be used as a pozzolana in cement and concrete, it must meet the chemical composition requirements specified in ASTM C618 for pozzolanas. The combined proportion of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3) in the rice husk ash should not be less than 70%, and the loss on ignition (LOI) should not exceed 12%, as mentioned in the ASTM requirement.

1.5 Reaction Mechanism

1.5.1 Pozzolanic reaction

A pozzolanic reaction occurs when a siliceous or aluminous material reacts with calcium hydroxide in the presence of humidity to form a compound exhibiting cementitious properties. During the cement

hydration process, calcium silicate hydrate (C-S-H) and calcium hydroxide (Ca (OH) 2), also known as CH, are released from the hydration of the two main components of cement: tricalcium silicate (C3S) and dicalcium silicate (C2S), where C and S represent CaO and SiO2, respectively.
Hydration of C3S, C2S, C3A, and C4AF (where A and F represent Al2O3 and Fe2O3, respectively) is essential. Upon wetting, the following reactions occur.

$$2(3CaO\text{-}SiO_2) + 6H_2O \rightarrow 3Cao.2SiO_2.3H_2O + 3CaOH_2 \quad (1)$$

$$2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + CaOH_2 \quad (2)$$

$$3CaO.Al_2O_3 + 31\ H_2O + 3CaSO_4 \rightarrow 3CaO.\ Al_2O4.\ 3CaSO_4.\ 31\ H_2O \quad (3)$$

$$4\ CaO.Al_2O_3.Fe_2O_3 + 10\ H_2O + 2\ CaOH_2 \rightarrow 6\ CaO.\ Al_2O_3.\ Fe_2O_3.12\ H_2O \quad (4)$$

The C-S-H gel generated by the hydration of C3S and C2S in equations (1) and (2) is the principal strengthening constituent. Calcium hydroxide and Ettringite (3CaO · Al2O3 ·3CaSO4 · 32H2O, equation 3), which are crystalline hydration products, are randomly distributed and form the framework of the gel-like products. Hydration of C4AF (Equation 4) consumes calcium hydroxide and generates a gel-like product. Excess calcium hydroxide can be detrimental to concrete strength due to its tendency to promote crystalline growth in one direction.
It is known that by adding pozzolanic material to a mortar or concrete mix, the pozzolanic reaction will only start when CH is released and a pozzolan/CH interaction exists. In the pozzolan-lime reaction, OH- and Ca2+ react with the SiO2 or Al2O3-SiO2 framework to form calcium aluminate ferrite hydrate, calcium silicate hydrate (C-S-H), and calcium aluminate hydrate (C-A-H)

Tobermorite gel:

$$SiO2 + CaOH2 + H2O \rightarrow CaO.SiO2.H2O \quad (5)$$

Calcium aluminate hydrate:

$$CaOH2 + H2O + Al2O3 \rightarrow CaO.Al2O3.CaOH2.H2O \quad (6)$$

Calcium aluminate ferrite hydrate:

$$CaOH2 + Fe203 + Al2O3 + H2O \rightarrow CaOH.Al2O3.Fe203.H2O \quad (7)$$

The crystallized compound of C-S-H and C-A-H, known as cement gel, hardens with age to form a continuous binding matrix with a large surface area, which is responsible for the development of strength in the cement paste. Pozzolan-lime reactions are typically slow, often commencing after one or more weeks have passed. The behavior of the delay in pozzolanic responses will result in more permeable concrete at an early age, becoming denser than plain concrete over time. This behavior is due to two reasons: Firstly, pozzolanic particles become the precipitation sites for the early hydration of C-S-H and CH, which hinders the pozzolanic reaction. Next, the strong dependency of the breakdown of the glass phase on the alkaline nature of the pore water, which can only attain a high pH after a particular time of hydration.

Pozzolana can partially replace cement in a mortar or concrete mix without affecting the strength development of the material. The effect of the pozzolanic reaction produces more cement gel (i.e., C-S-H and C-A-H), which reduces the pore size, blocks capillaries, and produces denser concrete, thereby making it stronger and more durable.

1.5.2 Pozzolanic reaction of RHA

The cement paste of CH with a 30% RHA amount starts to decrease substantially after 3 days, and by 91 days, it reaches zero, whereas in the control paste, it is considerably enlarged with hydration time. The addition of pozzolana reduces the amount of CH formed through the pozzolanic reaction, enabling the production of more C-S-H gel, which can enhance the compressive strength and durability of concrete. Amorphous silica that is found in some pozzolanic materials reacts with lime more eagerly than those of crystalline form.

The most essential asset of RHA that identifies pozzolanic activity is the amorphous phase substance. The production of rice husk ash can result in approximately 85% to 95% of the material being amorphous silica by weight. As a consequence of this characteristic, RHA is a highly reactive pozzolanic substance suitable for use in lime-pozzolanic mixes and as a substitute for Portland cement.

The reactivity of RHA associated with lime depends on two primary factors: the non-crystalline silica content and its specific surface area. Cement replacement by rice husk ash accelerates the early hydration of C3S. The increase in the early hydration rate of C3S is attributed to the high specific surface area of the rice husk ash. This phenomenon is especially noticeable with fine particles of RHA. Although the small particles of pozzolanas are less reactive than Portland cement, they produce a larger number of nucleation sites for precipitation, typically of hydration products, by dispersing widely in fine cement pastes.

Consequently, this mechanism creates a more homogenous and denser paste for the distribution of the finer pores due to the pozzolanic reactions among the amorphous silica of the mineral's addition and the CH.

1.6 Temperature effect

Exothermal reactions occur during cement hydration. Hydration heat is an essential aspect that influences the setting and characteristic behavior of Portland cement. This temperature variation, from the initial setting moment until the hardening of the cement, may cause shrinkage, resulting in the formation of cracks that can be observed in some constructions. Cement blended with pozzolanic materials usually has decreased heat of hydration compared to pure cement during the period of C3S hydration. The rate of hydration heat of the cement added with pozzolanic material mainly depends on three factors: C3S hydration, aluminates hydration, and pozzolanic reaction.

2.Literature Review

2.1 Strength Development of Concrete with Rice-Husk Ash

AUTHOR: - Gemma Rodrıguez de Sensale;

This paper presents a study on how the development of compressive strength to 91 days of concrete with rice-husk ash took place, in which residual RHA from a rice paddy milling industry in Uruguay and Rice hush ash produced by stabled incineration from the USA were used for comparison. Two different scenarios of replacement percentages of cement by RHA, namely 10% and 20%, and three different water-to-cement ratios (0.50, 0.40, and 0.32) were employed. The results are compared with those of concrete without Rice husk ash in terms of splitting tensile strength and air permeability.

The details of the Experimental program conducted are as follows:

Concrete specimens were prepared using fine aggregate with a maximum aggregate size of 4.75 mm, coarse aggregate (crushed granite) with a maximum aggregate size of 12.5 mm, Portland cement type I, and a superplasticizer based on a sulfonated naphthalene formaldehyde condensate. Two sources of ash were considered for comparison. First is a residue of RHA from the special rice paddy milling industry in Uruguay (UY RHA), and next is a homogeneous ash generated by stabled incineration from the United States (USA RHA) for comparison. The residual RHA used in this work was a treated waste dry-milled for the necessary time to obtain a medium particle size of 8 μm, with a defined specific surface area as determined by nitrogen adsorption, and a maximum activity index as per ASTM C311-98b. Chemical analysis indicates that both the ashes are mainly composed of SiO2. They have the same particle size and an activity index that is similar. X-ray diffraction tests revealed that the USA RHA could be considered non-crystalline rice husk ash. Still, the UY rice husk ash indicated the presence of crystalline materials, which were identified as cristobalite. The percent of relative silica contained in the UY RHA was 39.55%. And in the USA, RHA was 98.5%

A total of 15 concrete mixes were made for the study, with six mixes for each RHA and three mixes without RHA for comparison. The replacement of cement by RHA was made by volume, as RHA has a lower specific gravity than Portland cement.

A superplasticizer was used in a very low percentage, approximately to achieve the results obtained in the slump, allowing for consistency adjustment (slump = 60 ± 20 mm) without altering the proportion of the other materials. A superplasticizer was used at a very low percentage, as indicated by the results obtained in the slump, to ensure consistency in casting cylindrical concrete test specimens. They were compacted by external vibration and kept protected after casting to avoid water evaporation. After 24 h, they were remolded and stored in a moist room until the testing date. 100 × 200-mm cylinders were used to monitor compressive strength at 7, 28, and 91 days. Splitting tensile tests and air permeability tests on cylinders of 100 × 200 mm and 150 × 300 mm, respectively, with lower and higher water/cementation materials ratios at the age of 28 days, were analyzed. Air permeability for concrete was determined with the ‘‘Torrent permeability tester’’ method.

The RHA concrete exhibits higher compressive strength at 91 days compared to the concrete without RHA; however, at 7 and 28 days, a different behavior is observed between the concrete with the two types of Rice husk ash considered. The increase in compressive strength of concrete with RHA is better validated by the filler effect than by the pozzolanic effect (chemical and physical). The increase in compressive strength of concrete with RHA produced by controlled incineration is primarily due to the pozzolanic effect. It is determined that residual rice husk ash has a net positive impact on the compressive strength of concrete at an early age. Still, in the long term, the behavior of the concrete with RHA produced by controlled incineration was more critical

2.2 A Preliminary Study of Manufacture of Cement from Rice Husk Ash

AUTHOR: - AshV.I.E. Ajiwe, C.A. Okeke, F.C. Akigwe;

This study aimed to establish a technological foundation for the production of building materials in the cement sector by utilizing local raw materials, thereby enabling the manufacture of prefabricated reinforced-concrete products. The environmental problems created by the underutilization of rice husks from rice produced in Nigeria and other developing countries led to the innovation of substituting rice husk ash (RSA) for silica in cement manufacture. This idea differs from the usual sources of producing cement.

In this research, 24.5% rice husk ash was mixed with other raw materials to produce white Portland cement, which was then used to make a concrete slab. Formulated cement slab elements, commercial cement, and slab were tested in the laboratory for their physical characteristics and chemical composition.

Methods include three basic steps:

Sampling and preparation of the sample: A sample of rice husk was collected from Achalla, Awka North Local Government Area, Anambra State, Nigeria. The sample was burnt to give a white ash in two steps. It was pre-carbonized using an improvised stove to reduce the high electricity expenditure. The precarbonized sample was then fully decarbonized in an electric furnace at a temperature of 650°C to obtain a white ash.

Cement formulation (manufacture): For this purpose, cement was formed from 24.5% rice husk ash and locally sourced raw materials. The theoretical percentage fraction of tricalcium silicate was found to be 26.3%; it was on this basis that rice husk ash was used to substitute for the silica in the tricalcium silicate. The other raw materials were equally varied based on their theoretical values in cement composition. These were then ground and fused using the dry synthesis process. After that, white Portland cement was formulated using the general methods. The product was then stored and packaged in a screw-capped container. Here, water was also used.

Formulation of the Slab: In the formulation of the slab, the formulated white Portland cement and commercial cement were weighed separately and mixed with sand in a 1:2 ratio (cement to sand). 40 mL of water was added to each mixture (50:100 g) with thorough mixing, and the cement was poured into a mold measuring $10:5 \times 8:2 \times 10$ cm^3 to obtain a slab. The setting time of the slab was noted.

The silica, calcium oxide, loss on ignition, insoluble residue, and iron oxide contents are determined by the prescribed method of analysis outlined in the AOAC (AOAC, 1990) and the method described by Basset et al. (1978). The compressive test was conducted using the American Society for Testing and Materials (ASTM) method outlined by Ryder (1965). The results showed that comparable economical cement could be made from rice husk (ash) as a significant raw material or from clay and limestone. The loss on ignition, insoluble residue and iron oxide

content, calcium oxide, and silica results in formulated and commercial cement were quite close. A significant aspect of the project was to determine the extent to which rice husk ash could be used as a substitute for silica in cement formulations, thereby reducing its environmental impact as a farm waste. The production of cement from rice husk was relatively inexpensive, with a cost comparable to that of traditional raw materials.

Test results confirmed that the produced cement met the same standards as commercial cement. Based on the report, replacement of cement by rice husks has been suggested for use in developing countries, as it would help reduce the problems associated with rice husks as farm waste.

2.3 Effect of RHA on the Strength and Durability Characteristics of Concrete

AUTHOR: - Hwang Chao-Lung, Bui Le Anh-Tuan, Chen Chun-Tsun;

This work investigates the effects caused by residual rice husk ash from South Vietnam, generated during the burning of rice husk pellets in boilers to produce cement. To improve pozzolanic reactivity, RHA was ground for one hour. The non-ground RHA and ground RHA were used to test the strength activity index according to ASTM C311. Properties of the concrete were investigated, including its compressive strength, electrical resistivity, and ultrasonic pulse velocity.

Materials used:

RHA characteristics: The residual RHA was collected at Saigon Ve Wong Co., Ltd., Ho Chi Minh City, Vietnam. Rice husk pellets were burned in a boiler at temperatures varying from 600 to 800 °C. The average particle size of RHA is 87 µm in diameter, as measured using a Master Sizer 2000. To increase the finesses, RHA was ground by a ball mill for one hour. In this way, the average particle size of RHA can be decreased to 12 µm. Therefore, chemical analysis was performed on the ground rice husk ash (RHA). High silica content and loss on ignition can be observed. To assess the pozzolanic reactivity of the ashes, a strength activity index test was prepared according to ASTM C311. RHA particles, in the 10–75 µm range, exhibit satisfactory pozzolanic behavior.

Materials used in concretes: In the type I Portland cement produced by Taiwan Cement Company. Crushed coarse aggregate (19 mm maximum size, density 2.67, and absorption capacity 1.4%) and natural sand (modulus of fineness 3.0, density 2.65, and absorption capacity 1.2%) were provided from local quarries. The mixing water was local tap water. Type-G superplasticizer, with a 43% solid content and a specific gravity of 1.18, was used to achieve the desired workability for all concrete mixtures. All materials comply with the relevant ASTM standards.

The ground RHA was used as a pozzolanic material in concrete. Durability properties were evaluated through compressive strength testing. Mixture proportions of concrete were based on the ACI 211.1. Three water-to-binder ratios (w/b) of 0.23, 0.35, and 0.47, with the same 10% replacement of RHA by weight of cement, were investigated in this study. To check the effect of RHA replacements on concrete properties, a w/b ratio of 0.35 was selected. The mixtures were prepared by replacing 0%, 10%, 20% and 30% of cement with RHA. The slump of concrete was measured according to ASTM C143. The slump of concrete was controlled in the 80–100 mm range. The preparation of concrete specimens for cylinder compressive strength, concrete electrical resistivity, and the ultrasonic pulse velocity test followed ASTM C192. Those specimens were cured in saturated lime water at a temperature of 23 ± 2.0 °C. As per ASTM C39, concrete cylinders with dimensions of 100 mm in dia. × 200 mm in long were tested for compressive strength. A concrete electrical resistivity meter, manufactured by the CNS Company in the

UK, is used in this study to conduct the concrete electrical resistivity test, measuring the concrete electrical resistivity under saturated conditions. The ultrasonic pulse velocity test was performed by ASTM D597. The tests for hardened concrete done for 1, 3, 7, 14, 28, 56, and 91 days after the age of the concrete.

Strength efficiency of cement:

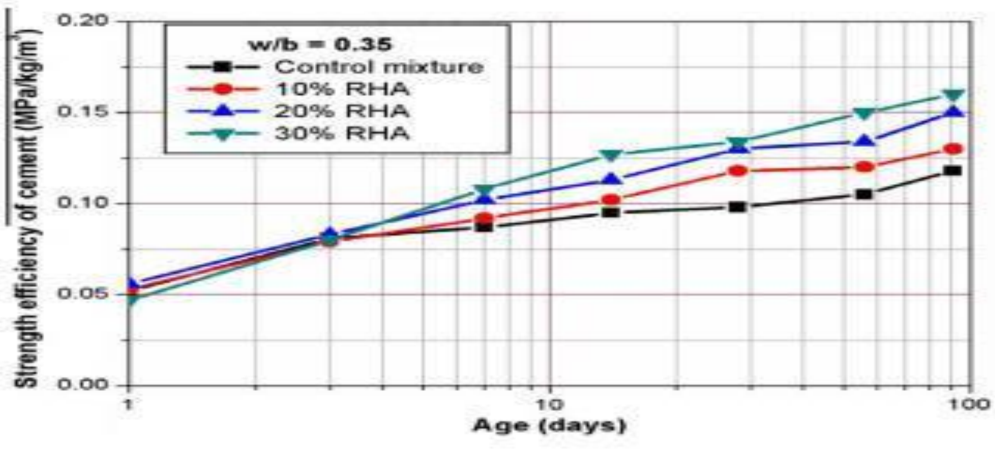

Figure 2.1: Effect of RHA content on Strength Efficiency of Cement.

The compressive strength of concrete with up to 20% ground RHA added reaches values equivalent to those of control concrete after 28 days, indicating the potential use of ground RHA as a partial substitute for Portland cement. After 91 days of curing, the electrical resistance of all RHA concrete exceeds 20 kX-cm. Similarly, for all RHA concrete samples, the UPV is higher, at 3660 m/s, after 91 days of curing. The strength efficiency of cement in-ground RHA concrete is much higher than that of the control concrete.

The results demonstrate that it is possible to obtain RHA concrete with comparable or superior properties to those of the control specimen (without RHA) while reducing cement consumption, thereby lowering CO2 emissions during cement production.

2.4 Reduction in Environmental Problems Using Rice-Husk Ash in Concrete

AUTHOR: - RawaidKhana, Abdul Jabbar , IrshadAhmada, WajidKhana, AkhtarNaeemKhana, JahangirMirza;

The production of cement (a key binding component of concrete) is costly, consumes high energy, depletes natural resources, and emits enormous amounts of greenhouse gases (1 ton of cement production emits ~1 ton of CO2). Consequently, environmental degradation, severe pollution, and health hazards associated with the cement and concrete industries have come under intense scrutiny from environmentalists and governments. Developed and some developing nations are already using industrial and agricultural wastes in concrete. These wastes also pose several environmental problems. Partial inclusion of garbage instead of 100% cement is environmentally safe, stable, durable, and economical.

The present study used rice-husk ash (RHA) as a partial replacement of cement in concrete. X-ray diffraction analysis, scanning electron microscopic examination, compressive strength (with and without superplasticizers), flexural strength, resistance to aggressive chemicals, and cost analysis were carried out.

Materials Used:

- Cement, a locally available Ordinary Portland Cement (OPC) conforming to ASTM C150, was used.
- Rice-husk ash- Rice-husk from the Province of Punjab, Pakistan, was selected to evaluate its suitability as ash for OPC replacement in concrete. Rice husk was burned in a controlled atmosphere at 800 °C in the laboratory. The ash thus produced was cooled both rapidly and slowly. Rapid cooling was carried out at an ambient temperature of 21 ± 10 °C. Slow cooling, on the other hand, was achieved by leaving the ash, as is, in the incinerator after the required burning temperature was reached. Only 22% of the ash was obtained after burning the rice husk. It was ground through a rod mill and sieved through a 200- or 325-μm mesh. It shows that the amount of chemical constituents differs significantly between the rapidly and slowly cooled RHA samples.
- Aggregates - The fine aggregate used was natural silica river sand with a fineness modulus of 2.3. The coarse aggregate used was crushed limestone. It had a maximum aggregate size of 19 mm and a bulk specific gravity of 2.66.
- Superplasticizer - A superplasticizer (SP) was used to control the water-to-cement or water-to-binder (OPC + RHA) ratio (W/B) to achieve the desired workability of the concrete mixture.

Tests Conducted:

Tests carried out on RHA and RHAC concrete included its reactivity with sodium hydroxide (NaOH), X-ray diffraction analysis (XRD), scanning electron microscopic analysis (SEM), compressive strength (with and without SP), flexural strength, and chemical resistance, among others.

Results and the discussion:

- Reactivity of Rice husk ash:

One gram of RHA was solubled in 200 mL of 0.5 M NaOH solution and leave to stay for 48 hour with constant stirring. The filtrate was then titrated against a 0.5 M HCl solution. The amount of NaOH neutralized by the dispersed ash (reactivity) was estimated from the difference in the concentration of NaOH solution before and after this treatment. It was observed that the reactivity value of the slowly cooled ash sample was 2.34 m mol/g, whereas it was 2.90 m mol/g for rapidly cooled ash. These values indicated several moles of NaOH reacted by one gram of RHA.

X-ray diffraction analysis

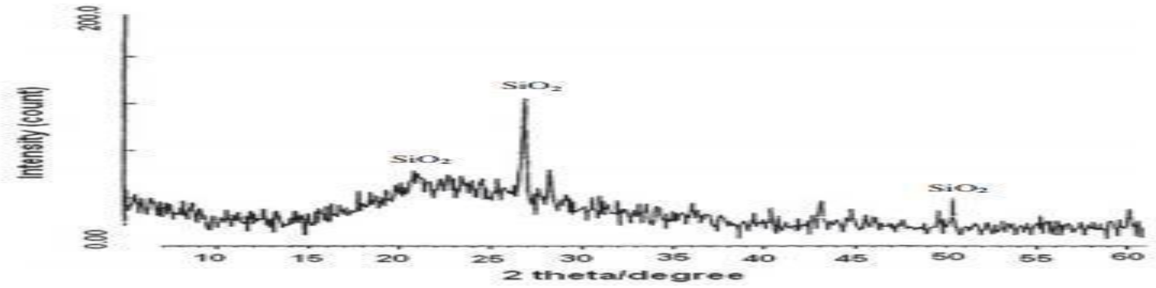

Figure 2.2: XRD Patterns Of Rapid Cooled RHA.

• Scanning Electron Microscopic Analysis:

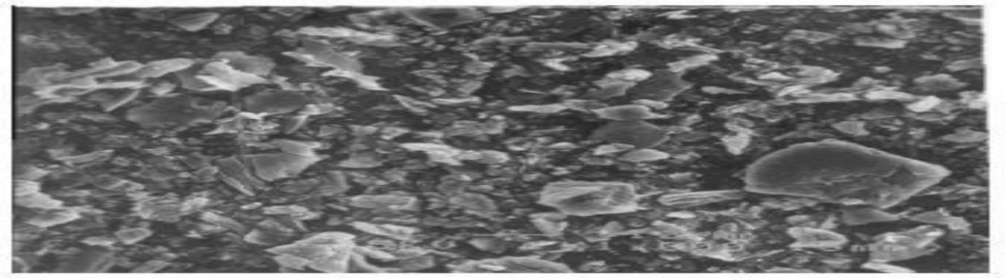

Figure 2.3: Scanning Electron Micrograph Of RHA.

• Compressive Strength:

Concrete Cylinders, 150 mm × 300 mm in size (cement: sand: coarse aggregates ratio = 1:2:4), were prepared using a W/B of 0.70 to achieve a workable concrete with a slump of 65 mm. Therefore, two types of concrete mixtures were prepared for a constant slump of 65 mm: one without SP at different water-to-binder (W/B) ratios and the other with SP at a constant W/B ratio. All the concrete specimens were kept in potable water to cure at an ambient laboratory temperature of 21 ± 1°C and relative humidity of 100% until the time of testing.

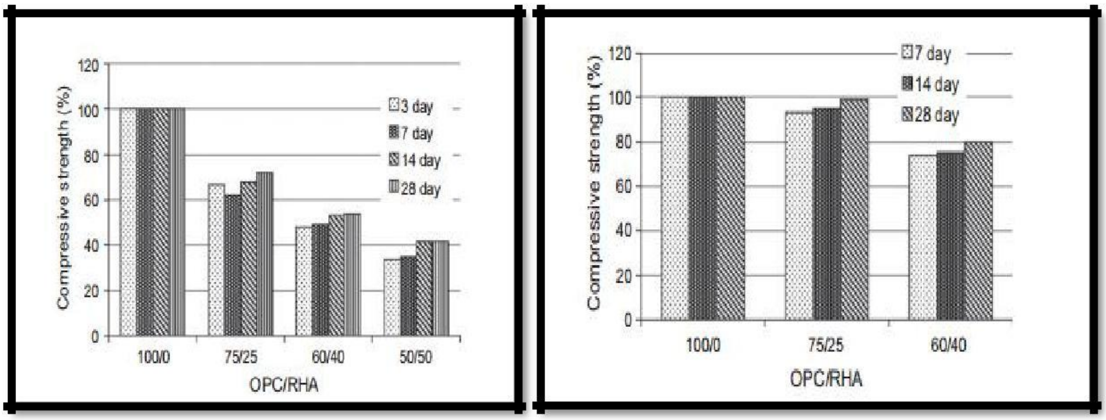

Figure 2.4: Compressive Strength Of RHAC For 3, 7, 14 & 28 Days With SP and Without SP.

• Flexure strength:

RHAC concrete beams tested for Flexural strength test containing 0%, 25%, 30%, and 40% of RHA as a replacement of OPC. All the concrete beams were cast using a 1:2:4 mixture design ratio of cement, sand, and coarse aggregate, respectively. A midpoint loading was applied. The mid-span deflection was recorded at the first crack and ultimate load for all beams.

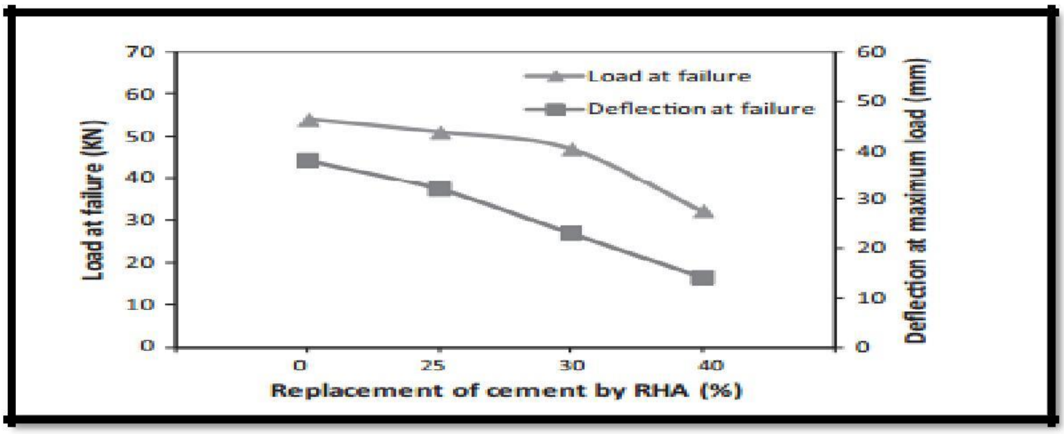

Figure 2.5: RHA Cement concrete In RHAC Cemant Beam.

Chemical Resistance of RHAC Mortars:

Experimental work on chemical resistance was conducted by ASTM C722. To study the behavior of RHA concrete in various environments, including dampness, salts, and acids, different chemical solutions were prepared. Two types of aggressive salt solutions were used: one containing chloride and the other containing sulfates. The chloride solutions included 5% ammonium chloride and 5% magnesium chloride, whereas sulfate solutions were prepared with 2% calcium sulfate and 2% magnesium sulfate. The acidic solution used for the chemical resistance of RHAC mortars was 0.1 Normal (0.1 N) sulphuric acid.

Mortar specimens, 25 mm × 25 mm in cross-section and 150 mm long, were prepared using a 1:1 equivalent cement-to-sand ratio for immersion in salt solutions. For immersion in acid solution (0.1 N sulphuric acid), 50 mm mortar cubes were prepared. After casting and curing for 28 days, the mortars containing 0%, 25%, 30%, and 40% RHA as replacements for OPC were immersed in separate solutions for 70 days. After 70 days, the mortar specimens were tested for compressive strength.

The rice husk yielded 22% of its total weight as ash. It would, therefore, seem logical to make arrangements for incineration in rural areas near the primary source of husk to reduce transportation costs.

SEM shows that the RHA sample is multi-dispersed with micro-porous surface and irregular-shaped particles.

Water demand was high for concrete mixtures containing RHA, resulting in a decrease in compressive strength. To achieve more workable and higher strength, SP should, therefore, be added to the concrete mixtures incorporating RHA.

The rate of strength gain at early ages is lower in RHAC concrete as compared to OPC concrete. It may be due to the slow reaction rate of RHA.
A concrete mixture containing 25% RHA as a partial replacement of OPC produced the same strength as the concrete containing 100% OPC. Therefore, this concrete could be used to reduce environmental problems associated with OPC production and RHA dumping.

Higher proportions (40%) of RHA could be used for non-structural works where strength is not critical.

The RHAC mortar containing RHA has more resistance to chemical attacks than OPC concrete without RHA. The RHAC mortars placed in different salt solutions for 70 days showed satisfactory results compared to OPC mortars. However, in an acidic solution, both the OPC and RHAC mortars were deformed and disintegrated.

2.5 Study on Strength Characteristics of High-Strength Rice Husk Ash Concrete

AUTHOR: - Ravande Kishore, V. Bhikshma, and P. jeevanaPrakash;
The study is to investigate the mechanical properties of high-strength concrete with different replacement levels of ordinary Portland cement by Rice Husk Ash. The standard cubes (150 mm × 150 mm × 150 mm), cylinders (150 mm × 300 mm), and prisms (100 mm × 100 mm × 500 mm) were cast in test cubes. M40 and M50 grade concrete mix cubes were cast and tested. The strength effect of High-strength concrete with various quantities of replacement of cement, like 0%, 5%, 10%, and 15%, with Rice Husk Ash of both grades, was compared with that of high-strength concrete without Rice Husk.

Rice Husk is a waste material generated in rice-growing regions. This not only facilitates the Purposeful utilization of agricultural waste but also reduces the energy consumption used in cement production. Therefore, Rice Husk is an agro-based product that can be used as a substitute for cement without sacrificing strength and durability. Generally, rice husk ash is used when burning raw clay bricks in brick kilns. Until recently, it was also used in Hotels for cooking, but now it has been replaced by LPG Gas. Rice Husk has a negligible protein composition, which makes it helpful for animal feeding. Rice Husk Ash is produced from the burning of Rice Husk in any method, which is a by-product of rice milling. It has been verified that 1,000 kg of rice grain produces 300 kilograms of rice husk. After the rice husk is burned, approximately 30 percent of the Rice Husk, or 40 kilograms, becomes RHA. Rice Husk Ash consists of as much as 80-85% silica, which is more reactive, depending upon the temperature of incineration. Due to relatively high water demand, the lime Rice Husk Ash cement developed low compressive strength.

However, the strength characteristics are considered required for general masonry work. Portland Rice Husk Ash cement contains up to 50% Ash by weight, demonstrating a higher compressive strength of concrete than the controlled Portland cement at early ages of 3 and 7 days. The cement containing Rice Husk Ash gives excellent resistance to dilute organic and mineral acids. The water requirement for normal consistency tends to increase with increasing ash content of the finely mixed cement. However, this can be adjusted by the application of certain water-reducing admixtures. The investigations, as outlined above, point towards an encouraging trend. Typically, fly Ash may be used to partially replace cement to the extent of about 25% of the cement. Chemical reactions that occur during the preparation of Rice Husk Ash concrete are: Silicon is burned in the presence of oxygen, yielding Silica.

$Si + O_2$ --------SiO_2

C_3S (Cement) + H_2O ----------- CSH + $CaOH_2$

The reactive Silica reacts with Calcium hydroxide released during the hydration process of cement, resulting in the generation of Calcium Silicates, which are the primary reason for the strength of the cement.

SiO_2 + $Ca(OH)_2$ ----- CSH + SiO

Compressive Strength of Concrete of M40 grade concrete with content of 15% replacement, the percentage increase in strength from 7 days to 28 days is recorded to be 42%. At 90 days, the maximum compressive strength of M40 grade mix cubes with a 15% replacement was 45.04 MPa. At 90 days, the max. The compressive strength of M50 concrete grade mix cubes with 15% replacement was 52.50 MPa, which was 16% less than the maximum strength compared to that of M50 concrete grade mix cubes with 0% replacement.

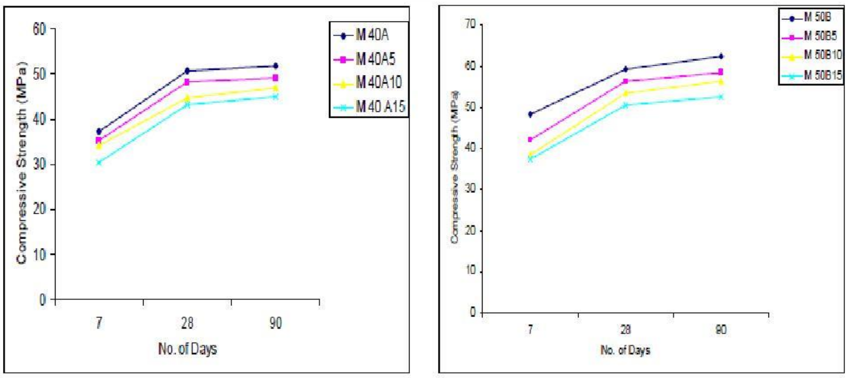

Figure 2.6: Splitting Tensile Strength Of Concrete.

As the replacement level increases, there is a reduction in splitting tensile strength for 28 days of curing for both M40 and M50 concrete grades by 5 to 10%. The splitting tensile strength of both M40 and M50 grades of concrete was 3.98MPa and 4.19MPa, respectively. It indicates that the splitting tensile strength at 15% replacement was reduced to 5.1% and 9.1%, respectively, for M40 and M50 grades of concrete, compared to that of conventional concrete.

Test results of the parameters of flexural strength and the modulus of elasticity of concrete show that for both grades of concrete, flexural strengths were reduced at a 15% replacement of RSH with cement, but they achieved the target strength at a 10% replacement. The modulus of elasticity obtained is consistent with the target strength values for all replacements.

2.6 Rice husk ash mixed cement: Assessment of optimum level of Replacement for strength and permeability properties of concrete.

AUTHOR: - K. Ganesan, K. Rajagopal, K. Thangavel;

In this study, rice husk ash prepared from the boiler-burnt husk residue of a particular rice mill has been evaluated for the optimal level of replacement as a finely mixed component in cement. The physical, chemical, and mineralogical characteristics of Rice husk ash were first tested for analysis. The properties of concrete observed include compressive strength, splitting tensile strength, water absorption, sorptivity, total charge passed derived from a rapid chloride permeability test (RCPT), and the rate of chloride ion penetration, as determined by the diffusion coefficient. This particular RHA consists of 87% silica, primarily in an amorphous form, and has an average specific surface area of 36.47 m^2/g. Test results obtained in this study indicate that up to 30% of RHA can be advantageously finely mixed with cement without significantly affecting the strength and permeability properties of concrete. Boiler-fired rice husk residue was collected from a modern rice mill located in Puduvayal, Sivaganga district, Tamil Nadu, India. The uncontrolled fired husk residue ash was black, obviously due to an excess amount of carbon content. The mill-fired husk residue ash was further burned in an industrial furnace at approximately 650 °C for one hour, as described below. The uncontrolled fired husk residue collected from the mill was placed in the stove for testing. The temperature of the furnace was increased at a rate of 2000 °C per hour until it reached the required temperature of 6500 °C over a period of three hours and 15 minutes. At 6500 °C, the temperature was maintained at a constant level for a 1-hour burning period under controlled conditions, and then cooled. The material was pulverized to a mean grain size of 3.8 lm before it was used as a cement replacement material. Eight different proportions of concrete mixes (RHA ranging from 5% to 35% by weight of cement, including the control mix) were prepared, with a water-to-binder W/(C + RHA ratio of 0.53, to achieve a design cube compressive strength of 25 MPa. These mixes were designated as R0 for control and R1–R7 for RHA concretes.

In this study, we have concluded that rice husk ash obtained from Indian paddy, when re-fired at a temperature of 650 °C for one hour, converts into an efficient pozzolanic material rich in amorphous silica content (87%) with a relatively low loss of ignition value (2.1%). This practical transformation enables the replacement of up to 30% by weight of OPC with burnt rice husk ash without any severe effect on strength and permeability properties. Replacing 30% of burnt rice husk ash leads to a significant improvement in the permeability properties of finely mixed concrete compared to those of unblended OPC concrete. In terms of compressive strength and chloride permeation properties, the standard practice of curing for 28 days is found to be adequate. Prolonged curing, up to 90 days, is found to be beneficial only from the perspective of improving resistance to water absorption.

2.7 A structural investigation relating to the pozzolanic activity of rice husk ashes

AUTHOR: Deepa G Nair et al

In this paper, we determine:

Different factors determine the applicability of rice husk ash as a pozzolanic material. The amount and accessibility of reactive sites are considered key factors in assessing the effectiveness of a catalyst. A structural study of RHA samples has been conducted to investigate their chemical reactivity. Silica in RHA is formed by burning rice husk in a laboratory furnace under a continuous air supply. It has been characterized as a function of incineration temperature, time, and cooling regime. The characterization methods include chemical analysis, conductivity parameter readings, microscopic analysis, X-ray diffraction (XRD), and 29Si magic-angle spinning (MAS) nuclear magnetic resonance (NMR). In conjunction with earlier observations, the studies indicate that the highest amounts of amorphous Silica develop in samples burnt in the range of 550 °C–750 °C. The 29Si NMR data enable the direct identification of reactive silanol sites in the RHA samples. Deconvolution of the NMR spectra indicates that the RHA, which was shortly cooled after burning rice husk for 12 hours at 500 °C, has the highest amount of silanol groups. This sample also induced the most significant reduction in conductivity when added to a saturated calcium hydroxide liquid, demonstrating its reactivity towards lime. Hence, this RHA is a favorable specimen to use as a pozzolanic cement additive.

Conclusion-

The characterization of rice husk ash has been conducted to identify the optimal conditions for producing reactive ash from rice husk. The amount of soluble Silica and loss on ignition in the different RHA samples indicated that incineration at 300 °C is unsuitable, as not all carbon is expelled from the samples. These analyses furthermore indicate the reactivity of samples burnt at 500 °C or 700 °C. This agrees with the earlier investigations of Mehta and Hamad et al., who have identified a temperature range of 500 to 700 °C as optimal for reactive ash formation. However, very different processing times have been suggested. Electrical conductivity tests verify the good pozzolanic activity of the RHA500 and RHA700 samples, with uniformly higher values for the samples incinerated at 500 °C. XRD and microscopic analysis stipulated the amorphous character of both the RHA500 and RHA700 samples, with the first crystalline material appearing at processing temperatures of 900°C and above. 29Si MAS NMR proved to be a very effective tool to get insight into the formation of reactive material on a local structural level. First of all, it can accurately determine at which temperature significant amounts of crystalline material begin to form. At lower incineration temperatures, the broad Gaussian line shapes in the spectra of the different RHA samples support the amorphous nature of the Silica in samples burnt at temperatures of 500 °C and 700 °C. At higher temperatures, a gradual conversion to crystalline material is observed, in agreement with the XRD results. Optimal incineration temperatures are those at which all carbon content is expelled at the end of the process. NMR also allows one to directly observe the surface silanol sites in the amorphous phase, which are thought to relate to the sample's activity in the pozzolanic reaction with lime. The amount of Q3 sites in the amorphous phase of the RHA differs, with a clear maximum for RHA500-12Q, exhibiting a Q4:Q3 ratio of 4:1. This sample also showed the highest conductivity drop in the pozzolanic activity test. So, we conclude that the most reactive rice husk ash is generated after incineration for 12 hours at a temperature of 500 °C to 550 °C. C and subsequently quickly cooling the specimen down by directly removing it from the oven

2.8 The study of using rice husk ash to produce ultra-high-performance concrete

AUTHOR: Nguyen Van Tuan at el

The limited availability of resources and the high cost of silica fume (SF) in producing ultra-high-performance concrete (UHPC) motivate the search for substitutes with similar functions, particularly in developing countries. Rice husk ash is an agricultural waste, specified in a category as "a highly active pozzolan" because it contains a very high quantity of amorphous SiO2 and a large surface area. The feasibility of using RHA to produce UHPC was analyzed in this study. The results show that the compressive strength of UHPC incorporating RHA, with a mean size between 3.6 µm and nine µm, can be achieved at more than 150 MPa under regular curing conditions. The most important fact is that the effect of RHA on the increase of compressive strength of UHPC is higher than that of SF. Additionally, the sample incorporating a ternary blend of cement with 10% RHA and 10% SF exhibited better compressive strength than the control sample without RHA or SF. This blend demonstrates the proven results that it is the optimal combination for achieving a maximum synergistic effect.

Conclusion:

From the above study, the following conclusions can be drawn:

– RHA can be considered as a supplementary cementitious material used for producing UHPC.
– The addition of RHA does not result in a reduction in the required compressive strength of UHPC compared to that of SF when less than 30% Rice husk ash is added to concrete.
– Compared to SF, the fineness of RHA has a favorable effect on compressive strength when cured under normal conditions. The optimum mean RHA particle size for producing UHPC was 5.6 lm. The finer RHA can significantly improve the compressive strength of UHPC. The compressive strength of UHPC using the finest RHA with a mean particle size of 3.6 μm can reach 180 MPa and 210 MPa at ages of 28 and 91 days, respectively.
– The mixing of SF and RHA can predominantly increase the total cement replacement percentage up to 40% to produce UHPC.
– There is a synergic effect between Silica fume and RHA on the compressive strength. The sample made from a ternary blend of cement with 10% RHA and 10% SF exhibited better compressive strength than the control sample without RHA and SF. The combination of 10% RHA and 10% Silica fume proved that it is optimum for achieving maximum synergic effect.

2.9 Affecting of the use of RHA on the electrical resistivity of concrete:

Author: A.L.G. Gastaldini et al

This study investigated the behavior of the clearly non-visible electrical resistivity of concrete mixes with the addition of rice husk ash using Wenner's four-electrode method. Tests includes parameter compressive strength, porosity, and electrical conductivity of the pore solution. The contents of RHA tested were 10%, 20%, and 30%, and end results were compared with a basic reference mix with 100% Portland cement and two other mixes with 35% fly ash and 50% blast furnace slag. Higher contents of rice husk ash ended in higher electrical resistivity, which shut up limits that of all other specimen. However, for compressive strength ranges between 40 MPa and 70 MPa, the mix of 50% blast furnace slag showed the great combination of cost and performance.

Conclusion:

For the concrete tested in this study, it was found that:
_ For similar w/b and slump values, the mixes with 10%, 20%, and 30% RHA showed higher compressive strength values when compared with the reference mix (100% Portland cement) at 28 and 91 days. The same was true when they were compared with the mixes with 35% FA and 50% BFS. Because of their larger specific surface area, the mixes with RHA require higher additions of superplasticizer than the other mixtures in the study, which contributes to the higher cost in these mixtures. In the study, the best compressive strength behavior was
obtained in the mixture with 20% RHA.
_ For identical w/b ratios, all mixes with mineral additions displayed much higher electrical resistivity values than those of the reference sample. In the mixes with RHA, the increase in RHA content resulted in higher values of apparent electrical resistivity, as well as lower values of electrical conductivity, and a larger proportion of small pores. When the contents of RHA increased from 10% to 20% of RHA for a similar w/b ratio, there was an increase of almost 100% in the values of electrical resistivity.

_ For identical compressive strength values (from 40 MPa to 70 MPa), the mixes with 10% and 20% RHA showed lower costs per m^3 when compared with the reference sample, in addition to showing higher electrical resistivity values.
_ The mixes with 50% slag, 35% fly ash, 20%, and 30% RHA and w/ b = 0.65 showed higher electrical resistivity when compared to the reference mix with w/b = 0.35 (59%, 31%, 39%, and 104%, respectively). None of the applicable technical standards (NBR 12655, ACI [31] or CEB-FIP Model for Concrete Structures would rate as 'durable' a concrete with w/b = 0.65. It appears that using electrical resistivity values as a variable to estimate durability may be a risky approach.
_ Of all mixes with the same compressive strength value investigated, the one that offered the best combination of electrical resistivity and cost was the one with 50% BFS, followed by the mixture with 35% FA.

2.10 Incineration of Rice Husk For Use as a Cementitious Material: THE GUYANA EXPERIENCE

AUTHOR: A. A. Boateng et al

Guyana is a leading rice-producing country in the English-speaking Caribbean. While rice husk is considered waste in Guyana's rice milling industries, it is finding practical applications in other developing countries. The use of its silica-rich ash as a cementitious material for building projects in non-developed areas is one such application. Although houses made of wood are popular in Guyana, an initial study showed that the use of concrete in the building industry could expand if the foreign exchange rate on cement importation could be reduced drastically. The potential strength of RHA as an extender to imported Portland cement has been studied. A study of the availability of rice husks in Guyana has shown that quantities of the material are sufficient to support an undeveloped building industry. A prototype incinerator has been developed with special features to burn the husk and can maintain bed temperatures in the range of 800 - 900 °C. The ash generated is amorphous and highly reactive when it is mixed with lime and water. The concrete compressive strength of the mortars produced with the extended cement at a 1:1 blend ratio and cured for 3-28 days is in the range of 11.25-20.42 N/mm². These figures exceed 8-31% of the imported cement mix.

Conclusion:
The availability of husk in the rice milling industries in Guyana has been quantified and estimated to be sufficient to justify its use as a pozzolan of plant origin. Investigations into the technological development of the office husk ash as an extender to capital-intensive Portland cement have been carried out. The results substantiate the viability of implementing such technology under the prevailing conditions in Guyana.

2.11 Use of Rice Husk Ash in Concrete

AUTHOR: Moayad N. AI-Khalaf et al

Rice husk ash was produced as a pozzolana through a special process, ensuring the end product meets engineering requirements in terms of physical and chemical properties, with Silica remaining in an amorphous form and a minor quantity of unburnt carbon. Using different pozzolanic activity indices, depending on the degree of grinding and the burning temperature, pozzolana can be produced, and the results are consistent. The effect of RHA content as a partial replacement for cement on the concrete compressive strength and volume changes of different concrete mixes is studied. The 40% replacement can be made with no significant change in compressive strength compared with the control mix, and this is verified by the test results. However, the effect on volume changes is within the range specified in the American Standard.

Conclusion:
The convenient and economical burning conditions required to convert rice husk into a homogeneous and well-burnt ash, taking into consideration the quality of the produced ash and the energy used in its preparation, are 500°C for 2 hours. The relationship between grinding time and the fine of RHA burned at temperatures suggests that for a bound grinding time, there is a considerable reduction in the particular surface area of RHA as the burning temperature increases. Based on these studies, the RHA produced can be classified as an artificial pozzolana of siliceous material, which conforms to the chemical and physical requirements of Class N pozzolan (ASTM C618). It has a specific gravity of 2.14. For a mortar mix with a constant RHA quantity, the water consumption decreases as the fineness of the ash increases. The minimum pozzolanic activity of RHA required by class N can be obtained when the ash has a specific surface area of about 11,500 cm^2/g. The strength of cement-RHA mortar approaches the strength of the corresponding plain mortar of the same consistency when the particular surface of RHA is about 17 000 cm2/gm.

2.12 Rice Husk Ash-Lime-Cement Mixes for use in Masonry Units.

AUTHOR: DAVID J. COOK et al

This paper discusses the potential of rice husk ash as a low-cost cementitious material for use in the manufacture of masonry units. Evaluation of the material was based on its ability to replace cement in block-making practices currently employed in Thailand. Masoud et al.[7] have already demonstrated the suitability of lime rice husk ash bricks manufactured in an autoclave. Equipment such as an autoclave or low-pressure steam curing machinery and apparatus is generally not financially viable in the small-scale factories that produce blocks in Thailand or other developing countries. Accordingly, simple curing techniques were considered in the production of a block of suitable properties. Finally, in Thailand, the difference in cost between lime and cement is slight, and it was decided to investigate the behavior of cement rice husk ash mixes as well as lime-cement mixes.

Conclusion:
Rice husk ash 60 % (by weight) can be incorporated in a mortar to produce units that will, in general, satisfy the requirements for non-load-bearing masonry. A 23'~, increase in compressive strength (to a minimum of 6.9 MPa) is required before the mixes used in this study can be considered for the manufacture of load-bearing masonry. It is likely that this strength increase could be achieved most economically by additional curing beyond the 3 days used in this investigation.

2.13 Reduction in water demand of non-air-entrained concrete incorporating large volumes of fly ash

AUTHOR: L.H. Jiang, V.M. Malhotra*

Results of studies dealing with the reduction in water requirement of the non-air-entrained concrete, including large volumes of ASTM Class F and C fly ashes. The eight varieties of fly ash investigated were sourced from Canada and the United States, and the percentage replacement of fly ash in concrete was 50% by mass of Portland cement. No superplasticizer is used in the concrete mixtures. The lab test results indicate that the reduction in water demand in concrete incorporating fly ash ranged from a low percentage of 8.8% for fly ash from Lingan, Canada, Nova Scotia, to a high rate of 19.4% for Creek coal fly ash from the US. The one-day compressive strength of the concrete varies from 6.4 MPa for fly ash from Belews Creek, America, to a high of 13.9 MPa for fly ash from Thunder Bay, Canada. The 28-day concrete compressive strength varies from 30.7 to 55.8 MPa

Conclusion:

The results of this investigation show that a significant reduction in water demand can achieved due to the incorporation of fly ash in non-air-entrained, high-volume fly ash concrete. These reductions in water demand range from 8.8% for concrete made with fly ash from Lingan, Nova Scotia, to 19.4% for concrete incorporating fly ash from Coal Creek, the USA. The concrete mixtures investigated had slumps ranging from 57 to 70 mm. To achieve slumps exceeding 100 mm while maintaining the same strength as before, it will be necessary to use water-reducers or superplasticizers in the concrete.

2.14 Rice husk ash as an alternate source for active silica production

AUTHOR: V.P. Della et al.

The objective is to develop a procedure for obtaining an active Silica with a high specific surface location from rice husk ash. The relative amount of Silica was tremendously increased after burning out the carbonaceous material at different times and temperatures. 95% of silica powder could be produced after heat-treating at 700 °C for six hours. The specific surface area of the particles increased after moisture grinding, from 54 to 81 m^2/g.

Conclusion:

Within the limits of the present study, the following conclusions can be drawn: Rice husk ash is another source of high specific area silica. 95% silica powder could be produced after calcination at 700 °C for six hours. The specific surface area of the particles increased after moisture grinding from 54 to 81 m^2/g.
The thermal treatment of rice husk ash does not affect the structure of its ash-silica. It was possible to obtain high specific area silica from rice husk ash after heat-treating and milling processing by applying this simple technique, and it is possible to transform industrial residue into valuable raw materials, thereby avoiding environmental damage.

Table 2.1: Author and their work in a tabular form

Sr.No	Author	Title	Conclusion
1.	Gemma Rodrıguez de Sensale	Strength Development of Concrete with Rice-Husk Ash	The RHA concrete exhibited higher compressive strength at 91 days compared to the concrete without RHA. However, different behaviors were observed between the concretes with the two RHA considered at 7 and 28 days. The increase in compressive strength of concretes with residue RHA is justified by the filler effect than by the chemical and physical of pozzolanic effect . The significant developemnt in compressive strength of concrete with Rice husk ash produced by controlled incineration is mainly due to the pozzolanic effect. It is justified that residual RHA has a impact on the compressive strength of concretes on positive at early ages; however, in the long term, the behavior of concretes with RHA produced by controlled incineration was more significant.
2	AshV.I.E. Ajiwe, C.A. Okeke, F.C. Akigwe	Preliminary Study of *the* Manufacture of Cement from Rice Husk Ash	Preliminary Study of the Manufacture of Cement from Rice Husk Ash The test results confirmed that the produced cement met a same as standard to commercial cement. The production of cement from rice husk recommended for developing countries, as it would help alleviate the problems associated with rice husk as farm waste.
3	Hwang Chao-Lung, Bui Le Anh-Tuan, Chen Chun-Tsun	Causes of RHA on Strength and Durability nature of Concrete	According to the results of this study, several conclusions can be drawn. 1. The compressive strength of concretes with up to 20% ground RHA added attain values equivalent to those of control concrete After 28 days. On the other hand,

			although ground RHA presents high carbon content, the experiments in the current study found that the compressive strengths of the compounds and the References were similar after 28 days, which indicates a possible Use of the ground RHA as a partial Portland cement substitute. 2. After 91 days of curing, the electrical resistance of all RHA concrete becomes higher than 20 kX-cm. Similarly, for all RHA concrete samples, the UPV is higher than 3660 m/s after 91 days of curing. The strength efficiency of cement in-ground RHA concrete is much higher than that of the control concrete. The results prove that it is possible to obtain RHA concrete with better properties than those of the control specimen (No RHA) with a lower consumption of cement, like this reducing the CO_2 emissions during the production of cement. The final results will be able to substantiate the viability of the application of RHA in the concrete industry under the prevailing conditions in Vietnam, they are also trusted to be especially useful for next studies on RHA in a specific condition in this country.
4	RawaidKhana, Abdul Jabbar , IrshadAhmada, WajidKhana, AkhtarNaeemKhana, JahangirMirza	Reduction in Environmental issues Using Rice-Husk Ash in Concrete	The rice husk yielded 22% of the ash by weight of its total quantity burned. It seems logical to create facilities for incineration in village areas near the main source of husk to reduce

			transportation costs. – SEM shows that the RHA sample is multi-dispersed with micro-porous surface and irregular-shaped particles. – Water demand was high for concrete mixtures containing RHA, which decreased the compressive strength. To achieve more workable and higher strength, SP should, therefore, be added to the concrete mixtures incorporating RHA. The rate of strength gain at early ages is lower in RHAC concrete as compared to OPC concrete. It may be due to the slow reaction rate of RHA. – A concrete mixture containing 25% RHA as a replacement for OPC produced the similar strength as the concrete containing 100%
5	Ravande Kishore, V.Bhikshma and P.jeevanaPrakash	Feasable Study on Strength Characteristics of High Strength Rice Husk Ash Concrete.	The coefficient of permeability of modified ferrocement decreases with the increase in polymer cement ratio up to 12.5% and flyash replacement levels up to 30%. 2. The time taken for the initiation of crack for ordinary ferrocement specimens is less compared to that of polymer and flyash specimens. 3. The time taken for initiation of a crack in flyash-modified ferrocement is more in case the Replacement of cement by flyash is 0% to 30% when compared to the addition of polymer by 0% to 12.5% in polymer-modified ferrocement. 4. As the percentages of polymer (0% to 12.5%) and flyash (0% to 30%) increased, the resistance to the current of ferrocement elements

			increased. 5. The pH value of cement mortar at the specimen's top surface in fly ash-modified ferrocement is higher than in polymer-modified ferrocement. 6. The chloride content of the cement mortar at the top surface of the specimen in the beams cast with flash-modified ferrocement is less than that of beams cast with polymer-modified ferrocement and ordinary ferrocement.
6	K. Ganesan, K. Rajagopal, K. Thangavel;	Rice husk ash blended cement: Analysis of optimal level of Replacement for concrete strength and permeability properties.	(1) Rice husk ash obtained from Indian paddy when Returned at 650 _°C for a period of 1 h, it transforms itself into pozzolanic material rich in amorphous silica content (87%) with a relatively low loss on ignition value (2.1%). (2) As high as 30% by weight of OPC can be replaced With burnt rice husk ash without any adverse effect on strength and permeability properties. (3) Replacement with 30% of burnt rice husk ash leads to a improvement in permeability properties of blended concrete that compared to that of unblended OPC concrete, namely (a) About 35% reduction in water permeability. (b) About 28% reduction in chloride diffusion. (c) About 75% reduction in chloride permeation. These observations have a direct bearing

			on the durability of reinforced concrete constructions, leading to An enhanced design life. (4) A linear relationship is found to exist among three measured transport properties, namely sorptivity, chloride penetration in line with total charge passed In coulombs and the chloride diffusion coefficient. (5) In the case of compressive strength and chloride permeation properties, the standard practice of curing for 28 Days are found to be adequate. Prolonged curing up to 90 days is found to be beneficial only from the point of view of view of improving the resistance to water absorption. (6) When rice husk ash, which has a lower loss on ignition value compared to OPC is used to replace partially OPC resistance to chloride permeation is substantially improved. This may be probably because of reduction in electrical conductivity of concrete due to lowering of unburnt carbon content in RHA, in addition to pore structure refinement and conductivity of pore solution.
7	Deepa G Nair et al	A structural study relating to the pozzolanic activity of	An in-depth characterization of rice husk ashes has been conducted to identify the optimum conditions for

		rice husk ashes.	producing reactive ash from rice husk. The amount of soluble silica and loss on ignition in the different RHA samples showed that incineration at 300 °C is unsuitable, as not all carbon is expelled from the samples. These analyses furthermore indicate the reactivity of samples burnt at 500 °C or 700 °C. This agrees with the earlier investigations of Mehta and Hamad et al., who have identified a temperature range of 500 to 700 °C as optimal for reactive ash formation. However, very different processing times have been suggested. Electrical conductivity tests verify the good pozzolanic activity of the RHA500 and RHA700 samples, with uniformly higher values for the samples incinerated at 500 °C. XRD and microscopic analysis confirmed the amorphous character of both the RHA500 and RHA700 samples, with the first crystalline material appearing at processing temperatures of 900°C and above. 29Si MAS NMR proved to be a very effective tool for getting insight into the formation of reactive material on a local structural level. First of all, it can accurately determine at which temperature significant amounts of crystalline material start to be formed. At lower incineration temperatures, the broad Gaussian line shapes in the spectra of the different RHA samples support the amorphous nature of the silica in samples burnt at temperatures of 500 °C and 700 °C. A gradual conversion to crystalline material is observed at higher temperatures, which is in agreement with the XRD results. Optimal incineration temperatures are those at which all carbon content is

			expelled at the end of the process. NMR also allows one to directly observe the surface silanol sites in the amorphous phase, which are thought to relate to the sample's activity in the pozzolanic reaction with lime. The amount of Q3 sites in the amorphous phase of the RHAs varied with a clear maximum for RHA500-12Q with a Q4: Q3 ratio of 4:1. This sample also showed the highest conductivity drop in the pozzolanic activity test. So, we come to the conclusion that the most reactive rice husk ashes are produced after incineration for 12 h at 500 °C and subsequently quickly cooling the sample down by directly removing it from the oven.
8	Nguyen Van Tuan at el	The Investigation of using rice husk ash to produce ultra-high-performance concrete.	RHA can be considered a supplementary cementitious material used in the production of UHPC. – The addition of RHA does not significantly decrease the compressive strength of UHPC compared to that of SF when less than 30% RHA is added. – Compared to SF, the fineness of RHA has a favorable effect on compressive strength when cured under normal conditions. The optimum mean RHA particle size for producing UHPC was found to be 5.6 lm. The finer RHA can significantly improve the compressive strength of UHPC. The compressive strength of UHPC using the finest RHA with a mean particle size of 3.6 lm can reach 180 MPa and 210 MPa at the ages of 28 and 91 days. – The combination of SF and RHA can increase the total cement replacement percentage up to 40% to produce UHPC. – There is a synergic effect between SF

			and RHA on the compressive strength. The sample made from a ternary blend of cement with 10% RHA and 10% SF exhibited better compressive strength than the control sample without RHA and SF. The combination of 10% RHA and 10% SF proved to be optimum for achieving maximum synergic effect.
9	A.L.G. Gastaldini et al	effects of the use of RHS on the electrical resistivity of concrete:	For similar w/b and slump values, the mixes with 10%, 20%, and 30% RHA showed higher compressive strength values when compared with the reference mix (100% Portland cement) at 28 and 91 days. The same was true when they were compared with the mixes with 35% FA and 50% BFS. Because of their larger specific surface area, the mixes with RHA require higher additions of superplasticizer than the other mixtures in the study, which contributes to the higher cost of these mixtures. In the study, the best compressive strength behavior was obtained in the mixture with 20% RHA.
10	A. A. Boateng et al	Incineration of Rice Husk for use as a Cementitious Material: THE GUYANA EXPERIENCE	The availability of husk in the rice milling industries in Guyana has been quantified and estimated to be sufficient to justify its use as a pozzolan of plant origin. Investigations into the technological development of the office husk ash as an extender to capital-intensive Portland cement have been carried out. The results substantiate the viability of implementing such technology under the prevailing conditions in Guyana.
11	Moayad N. AI-Khalaf* et al	Use of Rice Husk Ash In Concrete.	The convenient and economical burning conditions required to convert rice husks

			into a homogenous and well-burnt ash, taking consideration the quality of the produced ash and the energy used in its preparation, are 500°C for 2 hours. The relationship between grinding period and fineness of RHA burned at various temperatures reffered that for a given grinding time, there is a enough reduction of specific surface area of RHA as the burning temperature increases. Based on these studies, the RHA produced can be classified as an artificial pozzolana of siliceous material, which conforms to the chemical and physical requirements of Class N pozzolan (ASTM C618). It has a specific gravity of 2.14. For a mortar mix with constant RHA content and the water requirement decreases as the fineness of the ash increases. The minimum pozzolanic reaction of RHA required by class N can found that the ash has a specific surface of about 11,500 cm2/gm. The cement strength-RHA mortar approaches the strength of the corresponding plain mortar of the same consistency when the particular surface of RHA is about 17 000 cm2/gm.
12	DAVID J. COOK et al	Rice Husk Ash-Lime-Cement Mixes for Use in Masonry Units.	60 % of rice husk ash (by weight) can be incorporated in a mortar to produce units that will, in general, satisfy the requirements for non-load-bearing masonry. A 23'~ increase in compressive strength (to a minimum of 6.9 MPa) is required before the mixes used in this study can be considered for the manufacture of load-bearing masonry. This strength increase could be achieved more economically through prolonged moist curing, extending

			beyond the 3 days used in this investigation.
13	L.H. Jiang, V.M. Malhotra*	Reduction in water demand of non-air-entrained concrete incorporating large volumes of fly ash.	The results of this investigation show that a reduction in water demand can be achieved because of the incorporation of fly ash in non-air-entrained, high-volume fly ash concrete. These reductions in water demand range from 8.8% for concrete made with fly ash from Lingan, Nova Scotia, to 19.4% for concrete incorporating fly ash from Coal Creek, the USA. The concrete mixtures investigated had slumps ranging from 57 to 70 mm. To achieve slumps exceeding 100 mm while maintaining the same strength as before, it will be necessary to use water-reducers or superplasticizers in the concrete.
14	V.P. Della et al	Rice husk ash as another source for active silica production.	Within the limits of the present studies, the following conclusions can be drawn: Rice husk ash is an another source for high specific area silica. A95% silica powder produced after calcination at 700 jC for six hours. The specific surface area of the particles increases after process wet milling from 54 to 81 m^2/g. The thermal treatment of rice husk ash does not affect the structure of its ash-silica. It was possible to obtain high specific area silica from the rice husk ash after heat-treating and milling processing by applying this simple technique, and it is possible to transform industrial residue into valuable raw materials, avoiding damage to the environment.

3.Material properties

3.1 Material procurement

3.1.1 Rice Husk Ash (RHA)

Rice Husk Ash was procured from the firm 'N K Enterprises (Silpozz)' in Orissa, which manufactures RHA under controlled conditions, allowing it to be used as a pozzolanic material in concrete production. Rice husk ash is a carbon-neutral, environmentally friendly product. The mean particle size of RHA was less than or equal to 25 µm, as per the information provided by the manufacturer. The specific gravity of the material was 2.06, and its bulk density was 500 kg/m³.

Figure 3.1: Rice Husk Ash (RHA).

Constituents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**K_2O**	**Na_2O**	**LOI**
RHA	0.53	93.07	0.31	0.26	0.55	-	2.06	0.08	1.97

Table 3.1: Chemical Composition Of RHA.

The particle size distribution tested using the standard sieve sets from 4.75mm to 0.045 mm.

Sr. No.	**IS sieve**	***% Passing of sample***
1	0.045	99
2	0.075	100
3	0.090	100
4	0.150	100

5	0.300	100
6	0.425	100
7	0.600	100
8	1.18	100
9	2.36	100
10	4.75	100

Table 3.2: Particle Size Of Rice Husk Ash (RHA)

3.1.2 Cement

Ordinary Portland Cement (53 grade), manufactured by Ultratech Company and conforming to IS 12269-1987, was used for the investigation.

3.1.3 Aggregates

The aggregate properties that are most important with regard to strength concrete are: particle shape, particle size distribution, mechanical properties of the aggregate particles, and possible chemical reactions between the aggregate and the paste which may affect the bond. The aggregate grading must be very tightly controlled.

3.1.3.1 Coarse Aggregate

For concrete, the coarse aggregate particles themselves must be strong. From both strength and rheological considerations, the coarse aggregate particles should have roughly equal dimensions; either crushed rock or natural gravels.

3.1.3.2. Fine Aggregate

The fine aggregate should consist of smooth rounded particles, to reduce the water demand. A fineness modulus of 3.0 or greater is recommended, both to decrease the water requirements and to improve the workability of these paste-rich mixes. Of course, the sand too must be free of silt or clay particles.

Figure 3.2: Fine Aggregates.

Figure 3.3: Coarse Aggregate.

The properties and particle size distribution for different types of aggregate used in this experimental work is given below.

Sr.no	Property	Average value of different types of aggregates		
		20 mm dn	10 mm dn	Sand
1	Fineness modulus	7.08	6.2	2.9
2	Specific gravity	2.78	2.7	2.64
3	Bulk density(kg/m^3)	1470	1500	1880
4	Water absorption(%)	2.07	2.18	2.44
5	Organic matter	Nil	Nil	Nil

Table 3.3: Properties of the Aggregate

Sr. no.	Is sieve no.	% passing of sample			
		20 mm dn	10 mm dn	Sand (FA)	Comined aggregate
1	Pan	0	0	0	0
2	0.075	0	0	0.15	0.05
3	0.15	0	0	0.85	0.28
4	0.30	0	0	16.65	2.21
5	0.6	0	0	64.25	12.08
6	1.18	0	0.81	76.55	21.45
7	2.36	0	2.24	85.95	28.06
8	4.75	2.52	15.64	93.2	43.12
9	10	18.4	92.16	100	63.52
10	20	86.04	100	100	95.68
11	40	100	100	100	100
12	80	100	100	100	100

Table 3.4: Particle Size Distribution of Aggregate

3.1.4 Plasticizers

To improve the workability of the fresh Rice Husk Ash concrete as rice husk ash has very large surface area so its workability is greatly affected. So to improve workability of concrete containing rice husk ash we add plasticizer such as, alignosulphonate based super plasticizer.

4.Experiment Study

This chapter provides details of the experimental study conducted at the Bhumi Laboratory. Essentially, Rice Husk Ash (RHA) was used to replace a specific weight of cement in the production of Ordinary Concrete. As rice husk ash is a pozzolanic material, it cannot be replaced entirely by the weight in kilogram of cement in the production of ordinary concrete. Currently, due to the rapid rate of infrastructural development, the prices of cement, as well as its consumption, have increased significantly in India, resulting in higher costs. India is also the world's second-largest producer of rice. Hence, the incorporation of rice husk ash act as a supplementary cementing material in the manufacturing of ordinary concrete will utilize the waste material rice husk ash, as well as reduce the consumption of cement, which poses environmental problems during its manufacturing.

4.1 The main objectives of the preliminary laboratory work

• To familiarize oneself with the making of Rice Husk Ash (RHA) concrete by replacing rice husk ash with 10%, 15%, 20%, and 25% weight that of cement in the production of ordinary concrete.

• To observe the effect of RHA used as a pozzolanic material on the fresh and hardened properties of ordinary concrete and compare it with ordinary Portland cement concrete.

• To develop the process of mixing, casting, and curing regime.

4.2 Mix Proportions of Rice husk Ash (RHA) Concrete

The compressive strength and workability of rice husk ash concrete are influenced by the percentage of rice husk ash replacement by weight of cement, as well as the water-cement ratio and plasticizer content in the mix.
Experimental results by various researchers have shown the following:
• As the water-cement ratio of the concrete mix increases, the strength decreases, but the workability increases.
• As rice husk ash is a hygroscopic material, it requires more water to maintain the same workability levels as that of ordinary Portland cement concrete, but this can be compensated by increasing the plasticizer content slightly, which, however, increases the overall costs.

4.3 Mixing, Casting and Curing of Rice Husk Ash (RHA) Concrete:

4.3.1 Mixing

• It was found that the fresh rice husk ash concrete was of the same color as OPC and was cohesive. The amount of water in the mixture played a crucial role in the behavior of fresh concrete. The following procedure was adopted for mixing rice husk ash concrete.

• Mix all dry materials for about three minutes. Add water containing a plasticizer at the end of the dry mixing, and continue the wet mixing for an additional four minutes.

• The workability and serviceability of the fresh concrete was measured using a conventional slump test.

Figure 4.1: Mixing Of Rice Husk Ash (RHA) Concrete By Hand Mixing

4.3.2 Casting

- Each cube specimen was cast in three layers by compacting manually as well as by using a vibrating table.
- The casting of Rice Husk Ash concrete specimens is similar to the ordinary cement concrete specimens.
- Each layer received 25 strokes of compaction by a standard compaction rod for concrete, followed by further compaction on the vibrating table.

Figure 4.2: Casted Beams And Cubes

4.3.3 Curing

Specimens were cured in water before the test days at normal room temperature. The tests were performed at the end of 7 and 28 days. The test specimens shall be stored on site at a location free from vibration, under damp matting, sacks, or other similar materials for 24 hours and 30 minutes from the time the water is added to the other ingredients. The temperature of the storage location shall be between in the range of 20 °C to 30 °C. After 24 hours, they shall be marked for later identification, removed from the moulds, and, unless required for testing within 24 hours to be kept in clean water at a temperature of 24 °C to 30 °C.

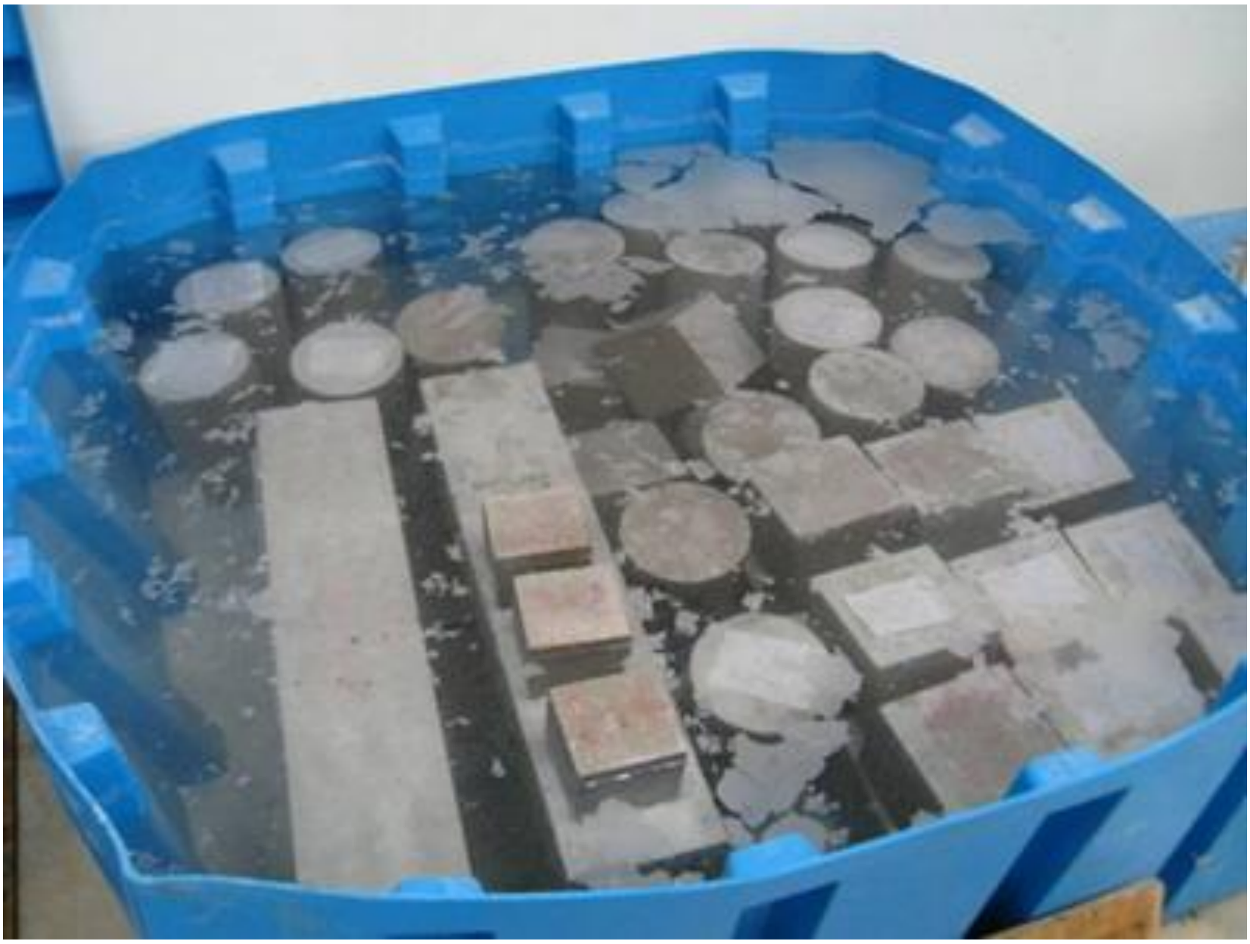

Figure 4.3: Curing Of Sample In Water

4.4 Quantity Estimation and Planning of Testing Work

4.4.1 Specimen Details of the work

Description	**Compressive strength test**	**Flexure test**
Specimen	**Cube**	**Beam**
Specimen size(mm)	150x150x150	100x100x500
No. of specimen	3	3
Days of testing	7,28	7,28
Total no. of specimens for one series.	6	6
Volume of each specimen (m^3)	0.003375	0.005
Volume for all specimens (m^3) for one series	0.02025	0.03
Total specimens for all	30	30

series		
Total volume for all series (m^3)	0.10125	0.15

Table 4.1: Specimen Details Of The Work

Total weight of concrete = 2215.4 kg
Total volume of concrete = 0.92 m^3

4.4.2 Mix proportion of RHA blended concretes

Cement	Kg/m^3	400	360	340	320	300
RHA	(%)	0	10	15	20	25
RHA	Kg/m^3	0	40	60	80	100
CA 10 dn	Kg/m^3	448	448	448	448	448
CA 20 dn	Kg/m^3	672	672	672	672	672
Fine aggregate	Kg/m^3	662	662	662	662	662
W/(C+RHA)	-	0.52	0.52	0.52	0.52	0.52
Water	Kg/m^3	208	208	208	208	208
Plasticizers	Kg/m^3	2.9	3.18	3.26	3.65	5.32

Table 4.2: Mix Design (Per m^3) of Concrete

4.5. Details of test conducted at BHUMI LAB

4.5.1. Compressive strength test

A test result is the average of at least three standard cured strength specimens made from the same concrete sample and tested at the same age. In most cases, the strength requirements for concrete are at an age of 28 days. The concrete cubes, after 7, 28, and 56 days, were tested for their compressive strength in the following manner.

• After cleaning the bearing surface of the compression testing machine, the axis of the specimen was carefully aligned with the center of thrust of the plate. No packing was used between the faces of the test specimen and the plate of the testing machine.

• The load was applied without shock and increased continuously at a rate of approximately 140 Kg/cm2/min until the resistance of the specimen to the increasing load broke down and no greater load could be sustained.

• The compressive stress was calculated in N/mm2 from the maximum load sustained by the cube before failure.

• The average compressive stress for different mixes was calculated as follows.
Compressive Strength:-

$$F_c = \frac{P}{A}$$

Where, 'P'= Load at Failure in N and
' A 'A'= Surface area of bearing cube in mm^2

Figure 4.4: Universal Testing Machine

4.5.2. Flexural strength test

As we know, concrete is relatively strong in compression and weak in tension. In reinforced concrete members, little emphasis is put on the tensile strength of the concrete, as steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses can develop in concrete due to drying shrinkage, rusting of steel, temperature gradients, and many other reasons. Therefore, knowledge of the tensile strength of concrete is essential. A beam test is dependable for measuring concrete's flexural strength properties. Beam specimens of dimensions l00x100x500 mm were tested after seven and twenty days of water curing for flexural strength in the following manner:

• The bearing surfaces of the supporting rollers are wiped clean, and any loose sand /other material is taken out from the surfaces of the specimen where they are to contact the roller.

• The specimen was placed in the machine in such a way that the load is applied to the topmost surface as cast in the mould along the central line (Midpoint Loading Method).

• The load is introduced without shock and increased regularly at a rate such that the extreme fiber stress rises at a rate of 180 kg/mm.

• The load was increased until the specimen failed, and the maximum load applied to the specimen during the test was recorded.

• The average compressive stress for different mixes was calculated as follows:

Flexural Strength:

$$F_f = \frac{PL}{bd^2}$$

where,
P = Max. load at failure in N;
L = Length of the beam specimen in mm;
b = width of the beam specimen in mm;
d = depth of the beam specimen in mm;

Figure 4.5: Flexure Strength Machine

5.Results and Discussion

In this section, we will analyze and discuss the results obtained during the testing of cubes, including the Compressive and Flexural tests.

Mix designation	RHA(%)	Quantities (Kg/m3)		Plasticizers (Kg/m3)	Slump (mm)
		Cement	RHA		
M25(control)	0	400	0	2.71	109
R10	10	360	40	3.12	102
R15	15	340	60	3.21	94
R20	20	320	80	3.49	76
R25	25	300	100	5.64	48

Table 5.1: Mix Proportion Of RHA Blended Concrete

- The workability is good and plasticizer content of M25 and R10, R15 is within normal range.
- R20 has a medium workability range.
- R25 is less workable, and the plasticizer content is also high.

Days	M25	R10	R15	R20	R25
7 days	23.11	22.3	21.98	20.26	16.74
28 days	32.00	29	30.67	29.71	22.15

Table 5.2: Compressive Strength (MPa)

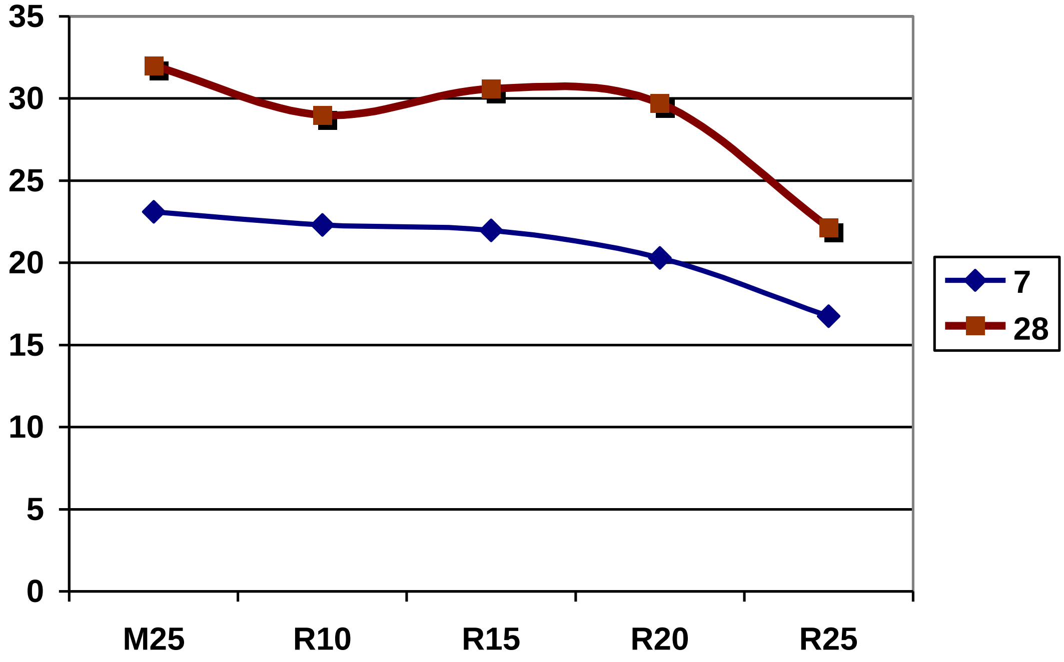

Figure 5.1: 7 & 28 Days Compressive Strength Of RHAC and OPC

• The 28-day strength of Rice Husk Ash (RHA) concrete up to 20% replacement is equivalent to ordinary Portland cement concrete.

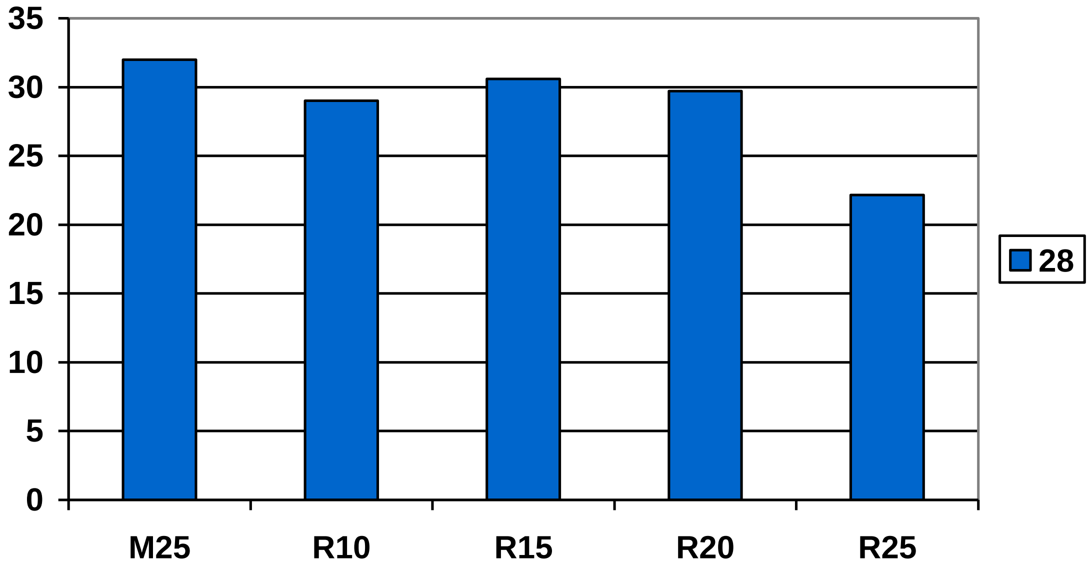

Figure 5.2: 28-Day Compressive Strength of RHAC & OPC

• Compressive strength for the 28 days for the cube is the highest compressive strength of M25, followed by R15. From the 28-day results, we can conclude that the strength of rice husk ash concrete increases at a faster rate with the passage of time compared to ordinary Portland cement concrete.

• Also, from the results, we can observe that up to 15% replacement of rice husk ash, the strength is the highest, while beyond that, it starts decreasing gradually.

Days	M25	R10	R15	R20	R25
7 days	4.23	4.21	4.19	4.00	3.81
28 days	6.93	6.78	6.85	6.72	5.18

Table 5.3: Flexure Strength (MPa)

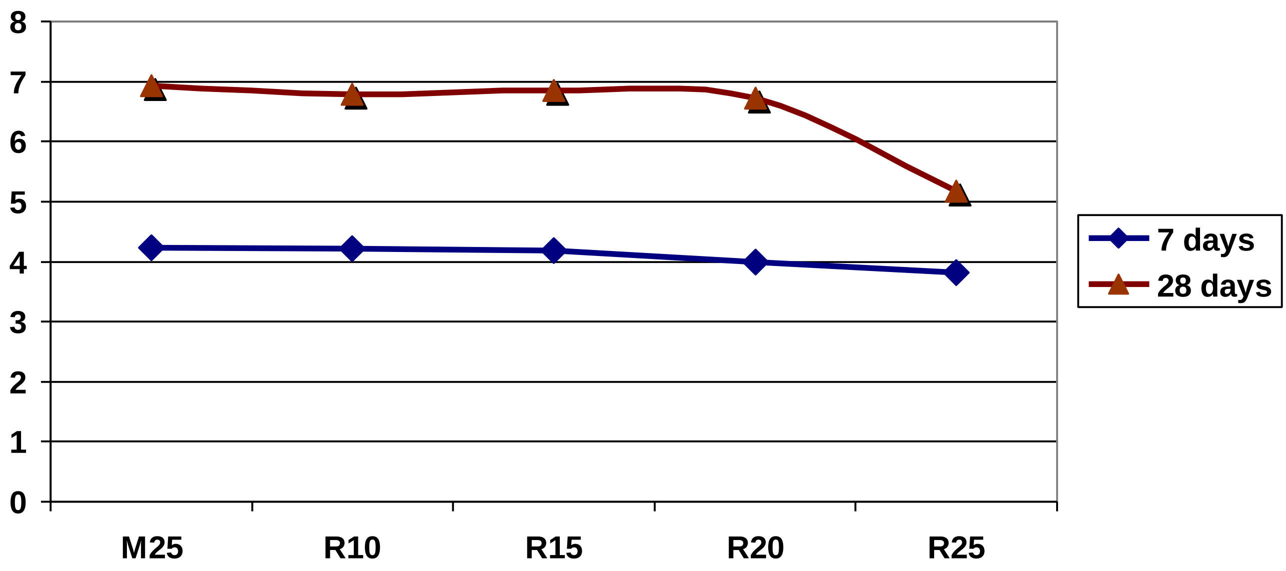

Figure 5.3: Graph of Flexure Strength of Industrial waste SCC and SCC

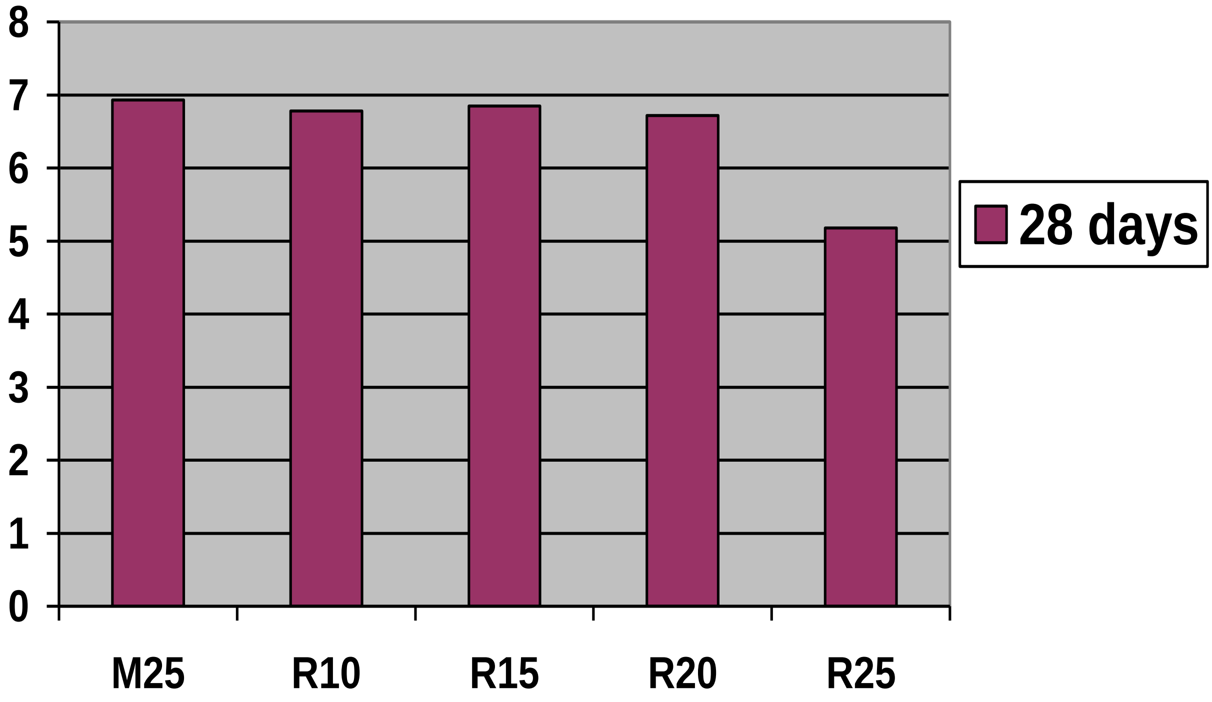

Figure 5.4: 28-Day Flexure Strength of Industrial Waste SCC & SCC

- Flexural strength for the 28 days is maximum for M25, followed by R15 and R10. Minimum flexural strength of R25.

6.Conclusion

1.As the percentage of Rice Husk Ash (RHA) concrete increases, the slump decreases because rice husk ash is a hygroscopic material. However, this can be compensated for by slightly increasing the plasticizer content.

2.To maintain workability, the plasticizer requirement of 25 percent replaced Rice Husk Ash (RHA) concrete is very high and hence, because of slump loss considerations, it is not advisable to replace 25% rice husk ash by weight of cement in the production of ordinary concrete.

3.The 7 day strength of Rice Husk Ash (RHA) concrete is less than ordinary Portland cement concrete and it decreases as the rice husk ash percentage increases, possibly because the pozzolanic reaction has not started and the strength is only due to the filler effect of rice husk ash particles and C-S-H gel formation of cement particles.

4.The 28-day strength of Rice Husk Ash (RHA) concrete up to 20% replacement is equivalent to ordinary Portland cement concrete.

5.Also, from the results, we can observe that up to 15% replacement of rice husk ash, the strength is the highest while beyond that it starts decreasing gradually.

6.Hence we can conclude that 15% is optimum replacement of rice husk ash by weight of cement in the production of concrete from strength as well as workability considerations. However, for medium workability conditions ordinary concrete replaced by up to 20% Rice Husk Ash (RHA) can also be used.

7.The economic advantages of incorporating Rice Husk Ash in concrete are that it is easily available in India, as it is the second largest producer of rice in the world.

8.By using this Rice husk ash in concrete as partial replacement the emission of greenhouse gases can be reduced in large extent. As a result there is greater possibility to gain more number of carbon credits.

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Indian standards:

Table 8: Required IS codes

IS 10262:1982	Recommended guidelines for concrete mix design
IS 516:1959	Test method for the strength of concrete
IS 383:1970	Specifications for coarse and FA from natural Sources for concrete
IS 2386:1963	Code for finding different properties of aggregates
IS 9103:1999	Code for specification of superplasticiser
IS 9013-1978	Code for determining the compressive strength of concrete in accelerated-cured concrete test specimens.
IS 12269:1987	Specification for 53 grade ordinary Portland cement.

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