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Rice Husk Ash Concrete: Study with Experimental and Theoretical result of Compressive Strength and Other Characteristics

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree.

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DEDICATION

We would like to dedicate this thesis to our beloved parents and our honorable thesis supervisor Prof. Dr. Md. Anayet Ullah Patwari.

DECLARATION

We hereby declare that, except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is our work and contains nothing which is the outcome of work done in collaboration with others, except as specified in texts and Acknowledgements. This dissertation contains fewer than 12,000 words including appendices, bibliography, footnotes, tables, equations, and has fewer than 100 figures.

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Finally, we seek an excuse for any errors that might be in this report despite our best efforts.

ABSTRACT

This book presents a study on the development of the physical properties of Portland cement by using rice husk ash (RHA) as a supplementary material instead of cement, where RHA from the local paddy milling industry in Bangladesh was used. The study was directed after a specific curing period of 7 days on models with two different replacement percentages of RHA, 5% and 10%. The experimental results of these models were compared with the model containing 0% rice husk ash. Total three cylinders were constructed following the dimension of 100mm radius and 200mm length for each cylinder. In the UTM machine, the experiment was induced to find tensile strength, elongation, Young's modulus, and failure point. The burning process of rice husk was conducted following the village burning process. It is concluded that residual RHA has a positive impact on compressive strength at an early age, but more relevant was the long-term action of RHA concretes formed by regulated incineration. Comparing the simulated and experimental results, the yield strength and the crack patterns came out almost similar to the ideal one for both the models containing 5% and 10% RHA. Results of yield strengths and comparisons between the crack patterns indicate the significance of using the residual RHA as a replacement of some percentage of cement in the concrete.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Rice husks are the hard-protective coverings of rice grains that are separated from the grains during the milling process. Rice husk is an abundantly available waste material in all rice-producing countries, and it contains about 30%-50% of organic carbon. In the course of a typical milling process, the husks are removed from the raw grain to reveal whole brown rice which upon further milling to remove the bran layer will yield white rice. Current rice production in the world is estimated to be 700 million tons. Rice husk constitutes about 20% of the weight of rice and its composition is as follows: cellulose (50%), lignin (25%-30%), silica (15%-20%), and moisture (10%-15%). In the Rice Husk Ash, it is possible to found approximately 20% silica in the amorphous form [1]. In addition, it consists of 60-65% volatile matter, 10-15% fixed carbon, and 17-23% ash[2]. It contains approximately 40% cellulose, 30% lignin group, and 20% silica 112 Eco-efficient Masonry Bricks and Blocks[3] Rice husk can absorb water ranging from 5% to 16% of unit weights, and the unit weight of rice husk is 83-125 kg/m3. The ash of rice husk contains approximately 90% silica, which is a highly porous structure and is lightweight, with a high specific surface area. The bulk density of rice husk is low and lies in the range of 90-150 kg/m^3. Sources of rice husk ash (RHA) will be in the rice-growing regions of the world, for example, China, India, and the far-East countries. RHA is the product of the incineration of rice husk. Most of the evaporable components of rice husk are slowly lost during burning and the primary residues are the silicates. The characteristics of the ash are dependent on

(1) composition of the rice husks,

(2) burning temperature, and

(3) burning time

For every 100 kg of husks burned in a boiler, about 25 kg of RHA is produced. Rice husk is used as a fuel for parboiling paddy in rice mills in some regions, while it is also field-burned as a local fuel in others. However, the combustion of rice husks in such cases is far from complete and the partial burning also contributes to air pollution. Rice husks have a calorific value of about half that of coal and assuming that the husks have about 8% -10% moisture content and no bran, the calorific value is calculated to be 15 MJ/kg. Under controlled burning conditions, the volatile organic matter in the rice husk consisting of cellulose and lignin is removed and the residual ash is predominantly amorphous silica with a (microporous) cellular structure (Fig.1). The basic surface area of RHA, as measured by the Brunauer-Emmett-Teller (BET) nitrogen adsorption process, can range from 20 to as high as 270 $\frac{m^2}{g}$, while that of silica fume, for example, is in the range of 18-23 $\frac{m^2}{g}$ [4].

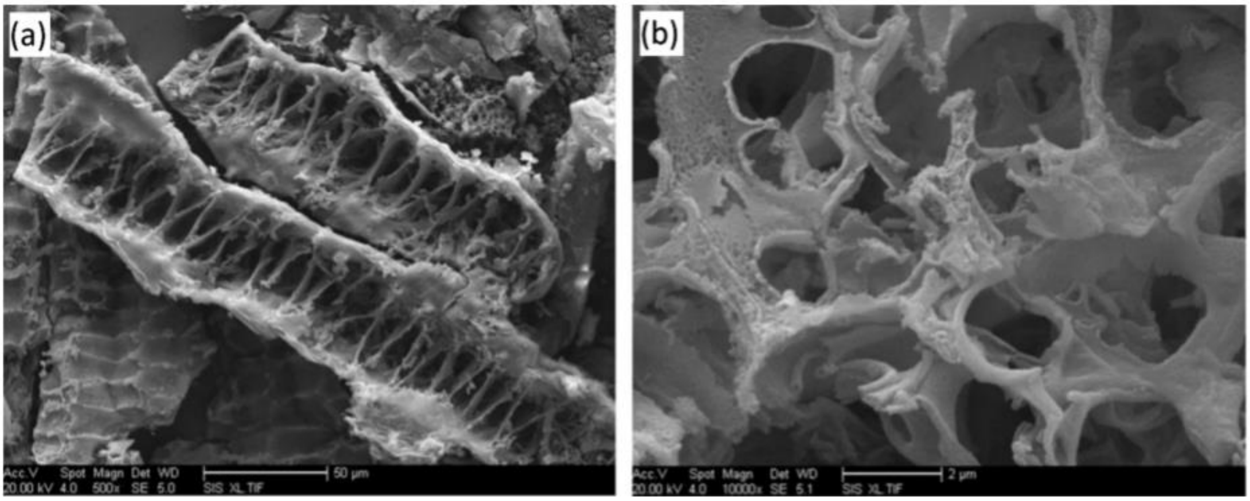

Figure 1:Scanning electron micrograph of RHA. (A) 500 magnification and (B) 1000 magnification [5]

The chemical composition of RHA is heavily influenced by combustion conditions, and silica must be held in an amorphous state by controlling the burning temperature. The ash generated by uncontrolled combustion (as in open-field burning or industrial furnaces at temperatures above 700°C-800°C) will contain significant amounts of nonreactive silica minerals cristobalite and tridymite. Such ashes would need to be ground to very fine particle size to develop pozzolanic activity, which is likely to make their use financially unviable. Amorphous silica is the main constituent of ash in controlled combustion (burning temperatures in the range of 500°C-700°C for about 1 hour), and its reactivity is due to the presence of this type of silica and its very wide surface area resulting from the microporous structure of ash particles. Although reactivity of a pozzolanic material improves upon increasing its fineness, [6] reckon that grinding RHA to a high degree of fineness is not advisable since this material derives its pozzolanic activity from the internal surface area of its microporous particles which is already very high.

1.2 Properties of Rice Husk Ash

RHA, fly ash, silica fume, and other related admixtures can have different chemical and physical properties. However, they have little impact on their properties unless they are followed by major mineralogical adjustments, which are in turn contingent on the processing or formation conditions. They go on to say that a mineral admixture's mineralogical and granulometric properties decide how it affects engineering properties of concrete like workability, strength, and durability. The following sections go into the physical and chemical characteristics of RHA.

1.2.1 Physical properties

RHA is a fine substance with particle sizes varying from 6 to 10 m, with the average particle size being less than 45m. As Fig. 1 shows, RHA particles are strongly cellular and have a microporous character with a high internal surface area, with RHA particles (with a mean size of up to 45 m) having a specific surface area three times that of silica fume particles (with a mean size of 0.1-1 m). Since RHA's pozzolanic properties are derived from its large internal surface area, grinding this ash to a fine powder would be useless. According to[7] Sugita et al. (1997), The specific pore volume of coarse RHA can reach 0.16 cm3 /g, with pore sizes ranging from 240 nm to 12.3 nm and an average radius of 12.3 nm. RHA has a high porosity, which means it retains a lot of water, which can affect the fresh properties of mortar or concrete containing RHA. While fine grinding RHA does not increase its reactivity, it does have the potential to change the pore structure, reducing water absorption. In-ground RHA pore sizes vary from 2 to 5 nm, with an average radius of 4 nm. Now physical properties have been showing below in Table 1:

Properties	**Value**
Mean particle size (μm)	3.80 – 7.4
Specific gravity	2.06 – 2.10

Fineness (passing 45 µm sieve) (%)	99
Specific surface ($\frac{m^2}{g}$)	36.47

Table 1: Physical properties of RHA [8], [9], [9]–[11]

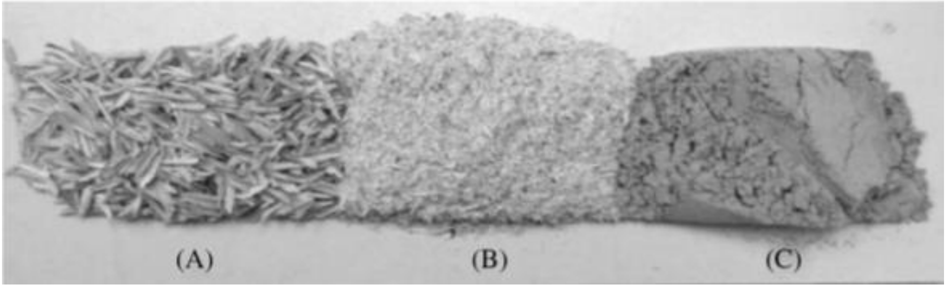

Figure 2: Samples of (A) rice husk, (B) burnt rice husk as ash, (C) RHA after grinding[12]

The effect of grinding (carried out using a Los Angeles mill) time on the physical properties of RHA is summarized in Table 2[12]. This table shows that raising the grinding time from 90 to 270 minutes resulted in a 70% reduction in average particle size, rendering the RHA particles comparable in size to the cement grains. Fig. 2 presents samples of rice husk and its ash with part (c) of this figure showing the ash in its ground state[12].

Material	RHA F0	RHA F1	RHA F2	RHA F3
Grinding time (minutes)	90	180	270	360
Average particle size (µm)	63.8	31.3	18.3	11.5
BET nitrogen adsorption ($\frac{m^2}{g}$)	25.3	27.4	29.1	30.4

Table 2: Variation of particle size with grinding time[12]

1.2.2 Particle Size Distribution

This table shows that raising the grinding time from 90 to 270 minutes resulted in a 70% reduction in average particle size, rendering the RHA particles comparable in size to the cement grains. Improperly burnt RHA can have specific surface area values of about 177 $\frac{m^2}{g}$, and when such samples are subject to controlled burning at temperatures of 700°C for 6 hours, the specific surface area can decrease to values as low as 54 $\frac{m^2}{g}$. The decrease in specific surface area is proportional to the heating temperature and time, and sustained heating at high temperatures induces an agglomeration effect, resulting in lower porosity. The specific surface area of the burnt samples increased to 81 $\frac{m^2}{g}$ when they were wet ground for an additional 80 minutes.

1.3 Chemical composition

After burning at a temperature in the range of 600℃-700℃ for 2 hours, RHA will consist of 90% - 95% SiO_2, 1% -3% K_2O, and about 5% unburnt carbon. Provided it is burnt properly, the quality of ash from different sources will not vary significantly. The most significant effect of the conversion of rice husk into RHA is on the amount of silica (5-fold increase) and the loss of ignition (LOI) (an almost 10-fold decrease). In the below table 3 and table 4, the properties of the rice husk ash from different selected authors are being shown.

Particulars	**Proportion**
Silicon Dioxide	86.94%
Aluminum Oxide	0.2%
Iron Oxide	0.1%
Calcium Oxide	0.3 – 2.25%
Magnesium Oxide	0.2 – 0.6%
Sodium Oxide	0.1 -0.8%
Potassium Oxide	2.15 – 2.30%

Table 3: Standard Properties of Chemical Composition of Rice Husk Ash

Particulars	**Proportion** [8]	**Proportion**[13]	**Proportion**[9]
Silicon Dioxide	87.2	87.3	86.98
Aluminum Oxide	0.15	0.15	0.84

Iron Oxide	0.16	0.16	0.16
Calcium Oxide	0.55	0.55	1.40
Magnesium Oxide	0.35	0.35	0.57
Sodium Oxide	1.12	1.12	0.11
Potassium Oxide	3.68	3.68	2.46

Table 4: Properties of Chemical Composition of Rice Husk Ash by selected authors

1.4 Application of Rice Husk Ash

Rice husk is used for different applications depending upon their physical and chemical properties like ash content, silica content, etc. In power plants, rice husk is directly used as a good fuel. It is also used as a raw material for making some compounds like silica and silicon compounds. Rice husk has various applications in different industries and domestic fields.

a) **As an industrial fuel:** Rice husk is used as a fuel for processing paddy and generating process steam. Combustion and gasification generate heat energy. Rice husk is used as a fuel in low-capacity boilers in small-scale process industries. 1 ton of rice husk is needed to produce 1 MWH (million-watt-hour) of electricity. It's also used as a source of renewable energy in the home [14].

b) **Preparation of activated carbon:** Rice husk is used as a raw material for the manufacture of activated carbon because it contains a high amount of cellulose and lignin. Because of their complex microporous structure, activated carbon is an important adsorbent [15].

c) **Rice husk as a fertilizer and substrate**: Rice husk composted slowly due to its high lignin content, so earthworms were used to speed up the process. Rice husk can be turned into fertilizer in four months using the vermicomposting technique. Boiled rice husk is used as a substrate or medium for gardening, including hydroculture in some cases [16].

d) **As Pet food fiber:** Rice hulls are the rice's outermost covering and are available in organic and natural varieties. Rice hulls are a low-cost by-product of human food production that can be used as a source of fiber and filler in low-cost pet foods [17].

e) **Substrate for silica and silicon compound:** Since rice husk contains 20% silica, it is an excellent raw material for producing silicon compounds such as silicon nitride, zeolite, silica, and pure silicon [18].

f) **Used for making bricks**: Bricks are made from rice husks. The higher the percentage of rice husk in the brick, the more porous the brick will be and the stronger the thermal insulation will be [19].

g) **Other uses:** Rice husk is used to make xylitol, furfural, ethanol, acetic acid, and other products. In the metal and computer industries, it is used as a cleaning and polishing agent. It is also used as building material [20] and also used as industrial raw material example-as an insulating board material, filler in plastics, filling material, for making panel board, etc.[21].

1.5 Outline of the work

In this book, the details of the study and the result have been discussed briefly. Discussion of rice husk ash, its other uses, our methodology, previous works of our model, analysis of results, and suggestions all are included in this book. This book has been divided into five (5) chapters according to the topic.

In the first chapter, an introduction to this project is given. An overview of the project and the book have been discussed. The description of rice husk ash properties, application of rice husk ash have been discussed at the end.

In the second chapter, previous works related to this study have been reviewed. Previous works on the production of rice husk ash, the use of rice husk ash in concrete, the fineness effect of RHA on the concrete strength, the compressive strength of RHA blended in concrete, the tensile strength of RHA concrete, and pozzolanic activity of RHA have been reviewed.

In the third chapter, the methodology of the experiment is described. Materials used in the experiment, how the mixing properties of the square-shaped block and cylindrical shaped block have been selected, working procedure for square block and cylindrical block with the description of the test are discussed. Also, rice husk burning with its processing and lastly the experimental setup of the experiment is discussed.

In the fourth chapter, results from our experiment are presented. The results have been analyzed and shown in graphical form. The crack pattern has been discussed for cylindrical blocks.

In the fifth chapter, the conclusion of our book is given by discussing the overview of our work and the results

Relevant figures and tables are presented throughout the book and their lists are indexed. References of the research papers which were necessary for our experiment are added at the end of the book.

CHAPTER 2

LITERATURE REVIEW

In this section, the fundamentals of the concrete system will be discussed along with the necessary parameters needed for analysis. Besides, modifications for the improvement of the concrete system will be discussed. Besides, some light will be shed upon existing research related to the title topic “Cement replacement with Rice Husk Ash” and research scopes.

2.1 Production of RHA

RHA can be produced by burning rice husk in an open field or under special temperature-controlled incineration conditions. The high carbon content of RHA created by open burning has harmed the properties of concrete and resulted in a highly crystalline shape in structures. Various incineration processes have been used by researchers [22][23][24][25]. The quality of RHA is controlled by the incineration process, which produces amorphous, which is required for structural concrete [26]. From the previous study [27]–[31], it was found that the highest amorphous silica could be obtained by burning the rice husk at the temperature ranges of 500°C–700°C and the specific surface area up to 150 $\frac{m^2}{g}$ will be maximum at that temperature.

2.2 Uses of RHA in concrete

Fapohunda et. al[26] discovered that unless sufficient admixtures are used, the workability of concrete reduces as the percentage of cement substituted by RHA increases. Zhang MH et al. [13] suggested using RHA concrete with a low water-cement ratio and admixtures and demonstrated that RHA has a high silica content, which helps to increase the longevity of concrete when combined in the proper proportions with cement. RHA concrete spreads less than normal OPC concrete when exposed to a magnesium sulfate solution (control concrete). When exposed to magnesium sulfate solution, RHA concrete had a 2% lower strength loss than OPC concrete. Chindaprasirt et. al[3] stated that RHA in concrete improved chemical resistance, according to the report. Zarrei et al.[32] said that the use of RHA in combination with cement was found to be effective in reducing chloride ion penetration and water absorption. . Nicole PH et al.[33] stated that the resistance to chloride penetration increases as the RHA substitution level rises. Christopher et al.[26] said that in coastal zones, the use of RHA in concrete decreases the risk of concrete corrosion due to chloride penetration.

Monika Chanu et al.[34] stated that RHA concrete has greater long-term reliability than OPC concrete when 10–30% of the cement is substituted with RHA. Mahmud et al. [35] stated that according to the report, concrete with 15% RHA and 85% OPC as overall binding content reached optimum strength. In the study of Zhang et al. [36], 10% cement replaced by RHA exhibits upper strength than control concrete at all ages. Ganesan et al. [37] observed that the compressive strength of OPC concrete was stronger than that of concrete containing up to 30% RHA with cement. Ravindar et al. [38] experimented and found that self-compacting concrete's compressive strength, splitting tensile strength, and ultimate tensile all improve by up to 15% as RHA content is increased. Alex et al. [39] found that For 10, 15, and 20% substitution of cement by RHA, the percentage increase in tensile strength is 57.2, 56.02, and 55.04, respectively. They discovered that all samples' divided tensile strength and compressive strength improve at the same time. According to their findings, mechanical strength improved as RHA size decreased, and 20 percent RHA substitution is ideal for 15- and 60-minute ground samples. Low-carbon RHA replacement cement blocks have significantly higher compressive, flexural, and cracking tensile strengths than high-carbon RHA replacement cement blocks. However, simple concrete was found to be stronger than RHA substitutes in both cases by Selvaraja et al. [40]. Furthermore, the use of RHA has the potential to reduce the expense of supplementary cementitious content by up to 40%.[26].

2.3 Fineness Effect of RHA on the Concrete Strength

Rice husk ash cement's reactivity, like that of other hydraulic blocks of cement, is highly dependent on the particular surface area and/or particle size. The hydration process begins at the surface of the cement particle; the rate of hydration is determined by the fineness of the cement, and fineness is a critical factor for rapid strength growth [41]; similarly, the fineness of RHA is a valuable property for the strength of blended concrete. AN Givi et al.[42] found that at a standard of 10% RHA substitution, ultra-fine RHA mixed concrete provides greater strength than control concrete and RHA blended concrete (with an average particle size of 95 m). DD Bui et al.[43] explained that for RHA content of 10% at 90 days, the ultra-fine RHA mixed concrete showed the greatest increase in compressive power, equivalent to RHA (average particle size of 95 m) -blended concrete. At 90 days, the compressive power of 20% RHA concrete is roughly equal to that of control concrete. The high pozzolanic reactivity of ultra-fine RHA is linked to the positive results of ultra-fine RHA-blended concrete obtained as a result of the rapid consumption of Ca (OH) generated during Portland cement hydration at early ages. As a result, the hydration of cement is accelerated, and further reaction products are formed in greater quantities. Aside from that, there's the particle pack to consider. De Sensale et al.[44] said that because of the filler effect of the smaller particles in the mixture, the long-term compressive resistance of concretes with RHA is higher. In the study of P Chindaprasirt et al. [45], nonetheless, as the fineness of RHA increases, the properties of lightweight aggregate derived from RHA improve.

2.4 Compressive Strength of RHA Blended in Concrete

Experiments in previous experiments have shown that using RHA as a partial substitute for cement increases the compressive strength of concrete. The amounts of cement that were replaced ranged from 5% to 30% by weight. However, various studies showed that the desired amount of cement substitution by RHA to reach optimum strength differed. H. Thanh Le et al. (2014)[46] reported that The incorporation of RHA has improved compressive intensity independent of age. For maximal compressive power, a substitution percentage of 10% was found to be optimal. The high pozzolans of RHA, arising from the large SSA and high silica content, are thought to be responsible for its positive effect on compressive power. RHA reacts vigorously with water and calcium hydroxide produced during cement hydration to create additional C–S–H. The additional C–S–H compound is the primary strength-contributing compound in concrete, and it also fills in capillary pores to strengthen the microstructure of the paste matrix and transition region, resulting in increased compressive strength. However, RHA is expected to increase compressive strength due to internal water curing and a lower effective w/b ratio of concrete. The experimental study carried by A. Muthadhi et al. (2013)[47] showed that The overall compressive pressure is 20 percent RHA for all the mixtures under investigation. RHA increases the production of compressive strength in two ways, aside from its pozzolanic activity; accelerates the hydration process in the wet phase by supplying more process nucleation sites, while its pore-filling effect improves the packing properties of solid particles in the concrete matrix in later ages. Ganesan et al. (2007)[37] concluded that concrete containing 20% RHA demonstrated maximum compressive power. The key factors for excellent pozzolanic behavior and improved compressive strength are amorphous silica and the fine RHA particle size. Rodriguez de Sensale (2006) [48] reported that the RHA concrete had a greater compressive strength at 91 days compared to RHA-free concrete. The improvement in the compressive power of the RHA concretes was primarily due to the filler effect (physical) and the pozzolanic effect (chemical/physical). H. Chao-Lung et al. (2011)[49] also reported an increase in compressive strength for 10% replacement of cement by RHA.

2.5 Tensile Strength of RHA Concrete

Tensile strength of concrete is essential in determining the load at which the concrete structure can crack; its expertise is useful in the construction of pavement slabs and airfield runways. [50]. Research work was performed by Habeeb and Fayyadh [51] to investigate the effects of concrete incorporating 20% RHA as partial replacement of cement at three different particle sizes. They observed that the tensile strength of the concrete increased systematically by raising the substitution of the RHA. The utilization of RHA also shows significant improvement in flexural strength by Gemma et al. [44] and split tensile strength by Sarkar et al. [52]. The results of splitting tensile strength and less air permeability are observed by De Sensal [44], this can be affected by the residual RHA and the filler effect of the smaller particles in the mixture. However, the coarser RHA particle mixture shows a smaller increment in tensile and flexural strength as reported by Habeeb and Fayyadh [51]. The greater flexural strength and the higher compressive strength were observed by Zhang *et al*. [53] in the RHA blended concrete for the finer RHA mixture due to the increased pozzolanic reaction and the packing ability of the RHA fine particles. Splitting tensile strength of RHA blended concretes was investigated by Ganesan *et al*. [37]; and explained from the findings, the tensile strength of RHA blended concrete steadily raises the RHA replacement rate by up to 20%.

2.6 Pozzolanic Activity of RHA

According to The American Society of Testing and Materials (ASTM), pozzolan is a siliceous or alumino-siliceous substance that has little or no cementitious property on its own, but when finely divided and in the presence of moisture, it can chemically react with alkali and alkaline earth hydroxides to form compounds with cementitious properties at ordinary temperatures. [54]. According to the Ruben et al. [55] the rate of pozzolanic reaction and hardening of pozzolan-lime mortars can be increased by reintroducing various techniques, such as grinding pozzolans, compacting blends, and adding chemicals. Zhang et al.[53] explained that the pozzolanic behavior that can be produced due to the amorphous phase material is the most significant contribution of RHA, according to the researcher. The key hydration and reaction ingredients for RHA paste are calcium hydroxide Ca (OH) and calcium silicate hydrates C-S-H. As RHA is used in concrete, it decreases porosity and the volume of Ca (OH)2 in the interfacial region, as well as the thickness of the interfacial zone between the aggregate and the cement paste, as opposed to OPC paste. V.P Della et al.[56] said that the processing of rice husk ash will contain between 85 and 95 percent by weight of amorphous silica. Yu *et al*. [57] studied the reaction between RHA and Ca(OH)2 solution and proposed that in the presence of water, a fine C-S-H gel forms. This result is in agreement with the findings of Feng *et al*. [58]. However, Lin *et al*. [59] reported that some pozzolanic materials include amorphous silica, which reacts with lime more readily than crystalline silica. RHA is a highly reactive pozzolanic substance as a result of this property, and it is suitable for use as a substitute in lime-pozzolan mixes and Portland cement. According to Dakroury *et al*. [60], the reactivity of RHA in the presence of lime is determined by two factors: I the non-crystalline silica content and (ii) the precise surface of the RHA. Or used as a cement substitute material, RHA with fine particles can speed up the early hydration of tricalcium silicate (C3S). The RHA's large specific surface area is the primary cause of this phenomenon. [58]. They also reported that the pozzolanic activity of RHA, which is created by hydrochloric acid pretreatment of rice husk, is higher than that of RHA that has not been processed (ordinary RHA). Although pozzolans' small particles are less reactive than Portland cements, when spread in cement pastes, they produce a significant number of nucleation cites for the precipitation of hydration materials. Malhotra [61] concluded that the strength production of RHA concrete is similar to fly ash/slag concrete but with a higher pozzolanic activity it makes the pozzolanic reactions start at early ages rather than later as is the case with other replacement cementing products. From a research work, Mehta [62] reported that the finer particles of RHA speed up the reactions and form smaller CH crystals. Berry *et al*. [63] revealed that high volume of RHA not completely reacted fill up the voids and enhance density of the paste.

CHAPTER 3

METHODOLOGY

In this chapter, both the experimental and theoretical procedure has been conducted to verify the effectiveness of the performance of the Rice Husk Ash blended with Cement.

3.1 Experimental Details

In this portion, the experimental details of this work will be discussed briefly for both the cylindrical block and square block.

3.1.1 Materials Used

Ordinary Portland cement (OPC): Conforming to IS 8112-1989 was used for the investigation is given in Table 5.

Particulars	Proportion
Silicon Dioxide	22.00%
Aluminum Oxide	5.60%
Iron Oxide	4.00%
Calcium Oxide	63.90%
Magnesium Oxide	1.70%
Sulfur Oxide	2.30%
Others	0.20%

Table 5: Composition of OPC used for the investigation [64]

Sand*:* Fine Sand has been used for this experiment. According to ASTM, this type of sand particles should pass through the No. 16 sieves. This is usually used in plastering works.

Rice Husk Ash*:* A total of 15kg of Rice Husk has been burnt for two days maintaining almost 50°C - 60°C temperature which is a conventional process.

Water: Normal tap water has been used in this experiment in the normal condition of the environment.

3.1.2 Mixing properties of Square Shaped block

Cement, Rice Husk Ash, Sand, and Water have been mixed following ASTM criteria for the experiment. The percentages in table 6-8 for the elements has been followed for the whole experiment.

Each of the blocks is named following a common pattern.

e.g. **B-S-RHA5** where **B** stands for Block, **RHA** stands for Rice Husk Ash, **S** stands for Square, and **5** stands for the percentage of ash in that specific block.

Following is the table mentioning the amounts of different ingredients in the blocks:

Ingredients	**B-S-RHA5**	**B-S-RHA10**	**B-S-RHA20**
Cement	78.11 gm	74 gm	65.78 gm
RHA	4.11 gm	8.22 gm	16.44 gm
Sand	226.11 gm	226.11 gm	226.11 gm
Water	37.78	37.78	37.78

Table 6: Amount of Ingredients in kilograms for B-S-RHA5, B-S-RHA10, and B-S-RHA20.

3.1.3 Mixing properties of Cylindrical Shaped block

Cement, Rice Husk Ash, Sand, and Water have been mixed following ASTM criteria for the experiment. The amounts of different elements mentioned in table 6 have been used to make the mixture for the experiment where each of the blocks is 5.5 kg in weight.

Each of the blocks is named following a common pattern.

In the naming convention of the blocks, for example, **B-C-RHA5** where **B** stands for Block, **RHA** stands for Rice Husk Ash, **C** stands for Cylindrical, and **5** stands for the percentage of ash in that specific cylindrical block.

Following is the table mentioning the amounts of different ingredients in the blocks:

Ingredients	B-C-RHA 0	B-C-RHA 5	B-C-RHA 10
Cement	1.31 kg	1.2445 kg	1.179 kg

RHA	0 kg	0.0655 kg	0.131 kg
Sand	3.59 kg	3.59 kg	3.59 kg
Water	0.6 L	0.6 L	0.6 L

Table 7: Amount of Ingredients in kilograms for B-C-RHA0, B-C-RHA5, and B-C-RHA10.

3.2 Working Procedure for Square Block

In the experiment, details can be explained in two shades. One is to forming the square-shaped block for the compression test and the following is the compression test. In the below both have been described fully.

3.2.1 Formation of the Block for testing

3.2.1.1 Rice Husk Burning:

A total of 15 kg of Rice Husk has been collected from the local market which is already processed locally. Then a total of 15 kg of Rice Husk has been stored and burnt with Kerosene at first and then burn away for almost 48 hours maintaining around 50℃ to 60℃ temperature. After that, the Rice Husk ash was collected and found with many extra leftover particles. In figure 3, it is visible that the ash particles are mixed up with different leftovers.

3.2.1.2 Fine Rice Husk Ash Processing

Rice Husk Ash was filtered using a standard sieve. After the filtering process, only the fine rice husk ash was found from the burned element which can be seen in fig. 3.

Figure 3: Rice Husk Ash before and after filtering

3.2.1.3 Measuring the elements

According to table 6, for each percentage, the required amount of cement, rice husk ash, sand, and water was measured perfectly in a mechanical weight machine. In figure 4, the WLC 20/A2 Precision Balance and the water-containing funnel can be seen.

Figure 4: WLC 20/A2 Precision Balance and Water Containing Funnel

In figure 5, measuring the weight of cement, rice husk ash, sand and water can be seen.

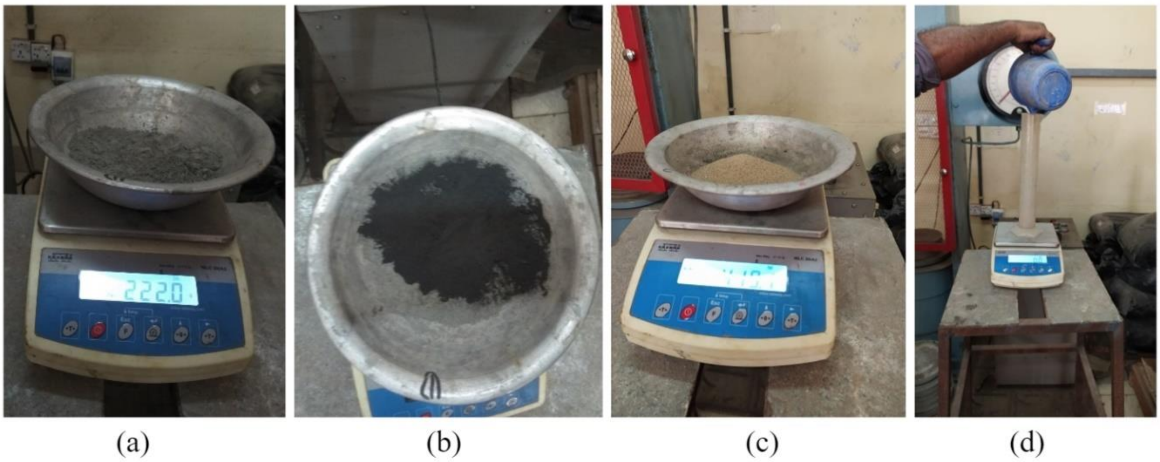

Figure 5: Measuring the weight of (a) Cement, (b) Rice Husk Ash, (c) Sand, and (d) water for perfect proportion

3.2.1.4 Mixing the elements

In the Automatic Mixture Machine, Rice Husk Ash, cement, sand, and water have been mixed perfectly and homogeneously for every percentage of rice husk ash. Three sets of mixing were containing the amount of mixture for three blocks for each percentage.

Figure 6: C0086 Automatic Laboratory Mixer

3.2.1.5 Setting the mold

After the automatic mixing, the molds were cleaned and grease was applied inside of each of the molds. The mixture can be seen in figure 8 and the molds before filling the mixture can be seen in figure 7.

Figure 8: Mold for setting the blocks

Figure 7: Mixture of the elements

Then the mixtures have been put in the molds slowly and by continuous hammering and pushing gently. The molds have been tightened up with the screws. In figure 9, mold for B-S-RHA10 can be seen after setting up

Figure 9: Mold for B-S-RHA10

3.2.1.6 Setting for 7 days curing

Then these three molds have been left at a dry and shaded place covering with a wet towel for 24 hours. After 24 h, the specimens were removed from the mold and subjected to water curing for 7 days.

3.2.1.7 After the curing

After the curing, the specimens have been placed in a shaded place for drying. In figure 10, all the blocks can be seen mentioning their percentage.

Figure 10: Specimens after the curing

3.2.2 Description of the Test

3.2.2.1 Compression strength finding using Compression testing machine

Compressive strength test was carried out in concrete cubes of size 2*2*2 cubic-inches. Specimens with ordinary Portland cement concrete replaced by rice husk ash at 5%, 10%, 20% replacement levels were cast. During molding, the cubes were manually vibrated.

Figure 11: During Compression test for B-S-RHA5 in the Compression-Flexural Testing Machine

After 24 h, the specimens were removed from the mold and subjected to water curing for 7 days. After a specified period of curing, the specimens were tested for compressive strength using AIMIL compression testing machine of 2000 kN capacity at a rate of loading of 140 kN/min. The tests were carried out on triplicate specimens and the average compressive strength values were recorded.

Figure 12: B-S-RHA20 after the compression test

3.3 Working Procedure for Cylindrical Block

In the experiment, the first task done was forming the cylindrical blocks and the next phase was conducting the compression test. The elements used for the cylinders are cement, rice husk ash, and sand which have been showing in figure 13.

(a) (b) (c)

Figure 13:Elements used for making the cylindrical block (a) Cement (b) Sand (c) Rice Husk Ash

The sequence of processes followed from burning the rice husk to the after-curing state is mentioned in the following sequence diagram:

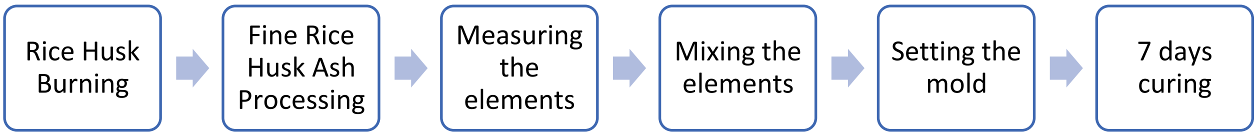

Figure 14: Work steps from burning the rice husk to the end of curing

3.3.1 Rice Husk Burning

A total of 15kg of Rice Husk has been collected from the local market which is already processed locally. Then all the Rice Husk has been stored and burnt with Kerosene at first and then burnt away for almost 72 hours maintaining around 50℃-60℃ temperature. After that, the Rice husk ash was collected and found with many extra leftover particles. In figure 16(b), it is visible that the ash particles are mixed up with different leftovers.

3.3.2 Fine Rice Husk Ash Processing

Rice Husk Ash was filtered using a standard sieve of 1.18mm and then 600 microns. After the filtering process, only the fine rice husk ash was found from the burned element which can be seen in figure 16(a).

(a) (b)

Figure 15: Sieve used for filtration process (a) 1.18 mm (b) 600 microns

(a) (b)

Figure 16: (a) Burned RHA after the filtering (b) Leftovers after the filtration

3.3.3 Measuring the elements

For each percentage, the required amount of cement, rice husk ash, sand, and water were measured perfectly in a precision balance/scale machine. In figure 17, the WLC 20/A2 Precision Balance and the water-containing funnel can be seen.

(a) (b)

Figure 17: (a) WLC 20/A2 Precision Balance and (b)Water Containing Funnel

In figure 18, measuring the weight of cement, rice husk ash, sand and water can be seen.

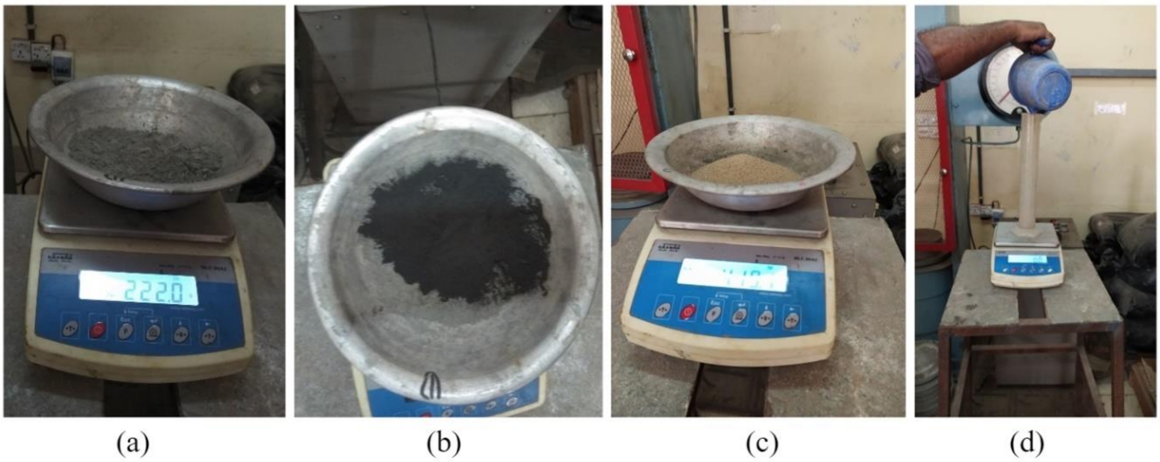

Figure 18: Measuring the weight of (a) Cement, (b) Rice Husk Ash, (c) Sand, and (d) water for perfect proportion

3.3.4 Mixing the elements

In the Automatic Mixture Machine, Rice Husk Ash, cement, sand, and water have been mixed perfectly and homogeneously for every percentage of rice husk ash. Three sets of the mixture were made containing the amount for three blocks for different percentages.

Figure 19: C0086 Automatic Laboratory Mixer

After the mixing, the hand mixing process also followed for better mixing. The sand and cement were mixed intimately with a spade, turning the mixture over and over again until it is of even color throughout and free from streaks. The whole mass has been mixed at least three times by shoveling and turning over by twist from the center to side, then back to the center, and again to the sides. A hollow is made in the middle of the mixed pile. Three-quarters of the total quantity of water required should be added while the materials are turned in towards the center with spades. The remaining water is added by a water-can fitted with a rose head, slowly turning the whole mixture over and over again until a uniform color and consistency is obtained throughout the pile. 5% extra cement has been added than the specified for machine mixing when hand mix cement concrete is produced.

Figure 20: Mixture of the elements after the hand mixing using hand-shovels

3.3.5 Setting the mold

After the automatic mixing, the molds were cleaned and grease was applied inside each of the molds. The function of applying grease inside the mold was to minimize the chance of the block-wall's sticking to the body of the mold. The mixture can be seen in figure 20 and the mold before filled up by the mixture can be seen in figure 21.

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Figure 21: Mold for setting cylindrical block

Then the mixtures have been put in the molds slowly and by continuous hammering and pushing gently to let the air out of the mixture. The molds have been tightened up with the screws. In figure 23, molds after setting up for the different blocks are shown.

Figure 22: Hammer for pushing the mixture inside the mold

3.3.6 Setting for 7 days curing

Then these three molds have been left at a dry and shaded place covering with a wet towel for 24 hours.

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Figure 23: Setting the blocks for 24 hrs

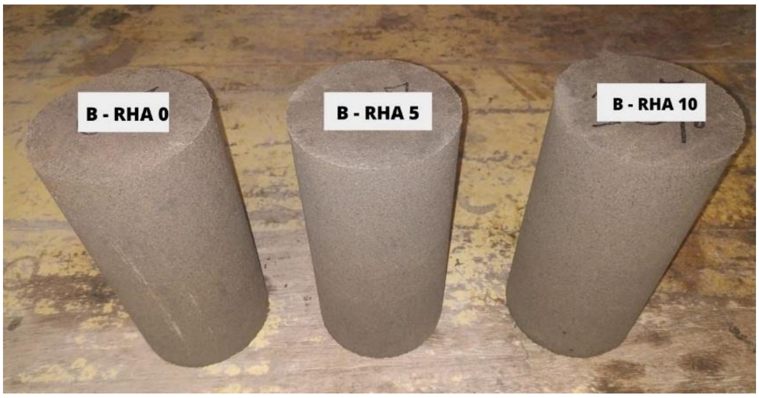


Figure 24: Cylindrical Blocks after 24 hrs. setting

After 24 hours, the specimens were removed from the mold and subjected to water curing for 7 days. Curing was done to the blocks for providing adequate moisture, temperature, and time to allow them to achieve the desired properties for their experimental use.

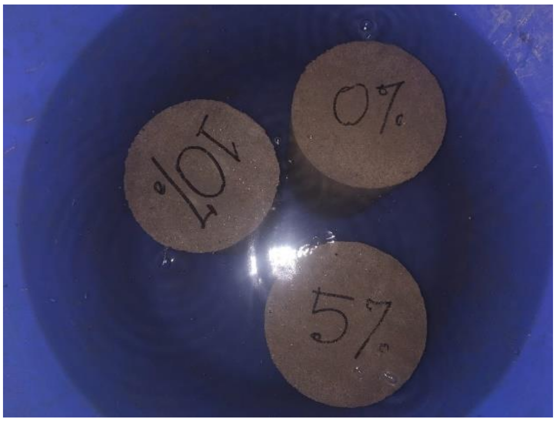


Figure 25: During the Curing Process

3.3.7 After the curing

After the curing, the specimens have been placed in a shaded place for drying. In figure 24, all the blocks can be seen mentioning their percentage.

3.4 Experimental Setup:

3.4.1 Servo hydraulic UTM:

The compressive test was conducted using Servo hydraulic Universal Testing Machine (UTM) and Load vs Axial strain curve was achieved for all three models from this. All the mechanical properties required for the experiment and the strain-strain curve were sorted out from that initially achieved curve.

Figure 26: Universal Testing Machine (UTM)

3.4.1.1 Features of UTM:

- The compression and bending test space is situated between the under the beam and the workbench on most oil cylinder down machines.
- Style features a four-column, two-screw arrangement with exceptionally high stability.
- Internal mesh high-pressure gear pump with low noise, constant oil pressure, and mechanical limit safety.

- The closed-loop servo control system is made up of the electric controller, proportional valve, load sensor, displacement sensor, extensometer, and computer.

3.4.1.2 Specifications

Item	Description
Max. load	300KN
Load range	6KN-300KN
Load accuracy	±1%
Elongation resolution	0.01mm
Piston stroke	250mm
Max. piston stroke speed	50mm/min
Elongation accuracy	±1%
Max. Tensile space	300mm (excluding piston stroke)
Max. Compression space	250mm (excluding piston stroke)
Display mode	PC
Clamping mode	Hydraulic
Operation mode	Manual
Flat sample thickness	0-15 mm
Clamping width	70mm
Round sample diameter	Φ10-φ32 mm
Compression plate size	170*170mm
Load frame dimensions	900*750*2200mm
Oil source dimensions	1200 x 550 x 1100mm

Table 8: Specifications of the Universal Testing Machine

3.4.2 Strain Gauge:

The axial strain was measured using Strain-gauge which can also be used to measure some mechanical quantities like strain. The term "strain" basically consists of tensile and compressive strain. The contraction achieved along the length of the cylinder when external force was applied to the cylindrical objects was used to pick up the desired quantity. Stress is defined as the internal resisting forces of the blocks, and strain is defined as the occurrence of displacement and deformation, which was caused by applying the external force by the UTM machine.

Figure 27: Strain Gauge

3.4.3. C0086 Automatic Laboratory Mixer

Of a robust construction, specially designed for the effective mixing of cement and mortar pastes. Including three cycles with automatic mixing sequences.

Figure 28: C0086 Automatic Laboratory Mixer

Vat capacity: 5 liters.

Equipped with two speeds: 140 ± 5 or 275 ± 5 rpm for rotation and 62 ± 5 or 125 ± 5 rpm for planetary movement.

Providing the option to select automatic mixing or one of the two automatic programs.

A sound signal notifies speed shifts, pauses, and mixing times when a software is picked. An automatic dispenser is included for filling the hopper with sand within the necessary 30 times. In compliance with Directive EC 89/392, it comes complete with a vat, stainless steel paddle, sand dispenser, and a safety door that automatically stops the test if it is opened.

Power supply: 380 V. three-phase 50 Hz.

Dimensions: 340 x 460 x 700 mm.

Weight: 45 kg.

3.4.4 WLC 20/A2 Precision Balance

In the laboratory and industry, precision balances allow for fast and accurate mass determination. The devices have an internal battery that allows them to work in areas where there is no access to electricity.

Figure 29: WLC 20/A2 Precision Balance

The balance features a stainless-steel weighing pan, and a backlit LCD guaranteeing clear weighing result presentation.

Maximum capacity [Max]: 20kg
Readability [d]: 0.1g

2 RS232, USB type A, and USB type B communication interfaces The interfaces enable peripheral devices, such as a printer, computer, USB flash drive, and an additional display, to work together. The WLC balances include an ALIBI memory and a real-time clock. They can be fitted with 4 IN / 4 OUT as an option.

3.4.5 Compression-Flexural Testing Machine Digital Semi-Automatic Control System

Figure 30: Compression-Flexural Testing Machine

Features:

- 4 x 20 characters alphanumeric display
- 65 Ì‡000 points high resolution (0.1 KN)
- Large storage capacity for test data on a USB memory stick
- Ethernet port to download data to PC using the SW/TRM software (Optional)
- Symbols for load, stress, and applied load rate are shown simultaneously for easy adjustment
- LAN connection to PC for data transmission in real-time
- Memory management solutions include displaying tests saved on a USB memory stick, downloading data to an internal printer or PC, deleting individual tests, and resetting the entire memory
- A multi-coefficient calibration procedure with automated data storage eliminates the need for manual intervention
- Language and unit’s selection (kN, ton, lbf)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result and discussion for square blocks

Table 10 shows the compressive strength of rice husk ash replaced concretes for 7 days of curing. From the table, it is found that the highest strength can be found for 5% of Rice Husk Ash replaced cement. Also, in figure 31 it can be seen that for crack initialization, it has been taken maximum time for 5% Rice Husk Ash and minimum for 20% Rice Husk Ash.

BLOCK	LENGTH mm	HEIGHT mm	WIDTH mm	WEIGHT (gm)	Load-avg (KN)	Pressure (MPa)
B-S-RHA5	50	50	50	230.9	14	6.61
B-S-RHA10	50	50	50	226.2	12.05	4.81
B-S-RHA20	50	50	50	213.85	7.05	2.815

Table 9: Dimensions and Loads applied on different blocks

B-S-RHA5		B-S-RHA10		B-S-RHA20	
Time (s)	Load (kN)	Time (s)	Load (kN)	Time (s)	Load (kN)
0	1.5	0	0	0	1.4
15	1.6	5	0	10	1.6
26	1.7	11	11.6	16	1.8
42	1.8	12	12.05	20	2.2
45	2			24	7.2
49	12				
50	13				
51	13.5				
52	14				

Table 10: Table for Load vs Time graph

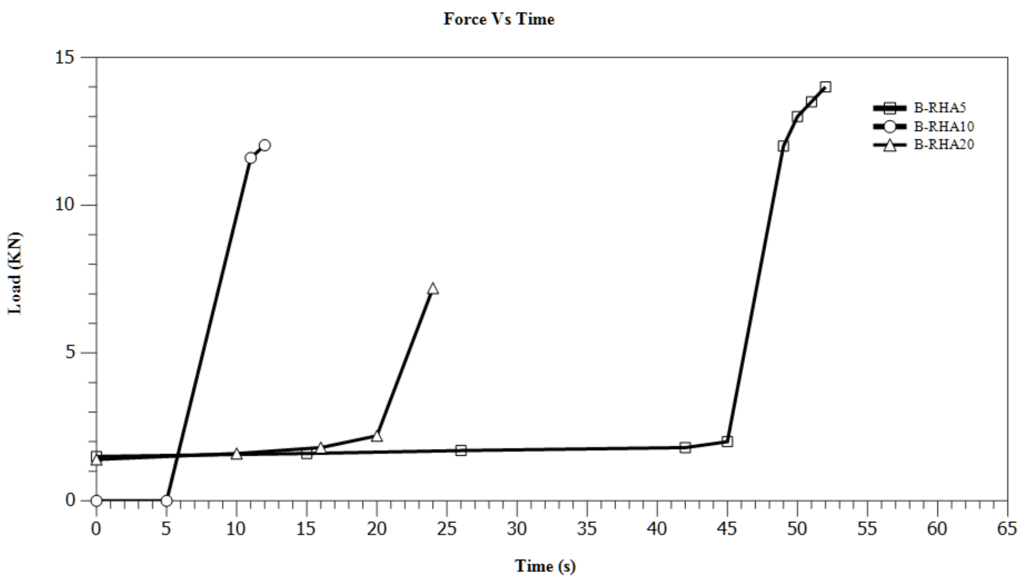


Figure 31: Load vs Time Graph for the square blocks

4.2 Result and discussion for cylindrical blocks

After processing the test by UTM machine, load vs deflection of the position for each of the cylinders have been collected. From these data, stress vs strain curves has been found out. The following figures (32-34) show a stress-strain curve for 0%, 5%, and 20% replacement of RHA respectively.

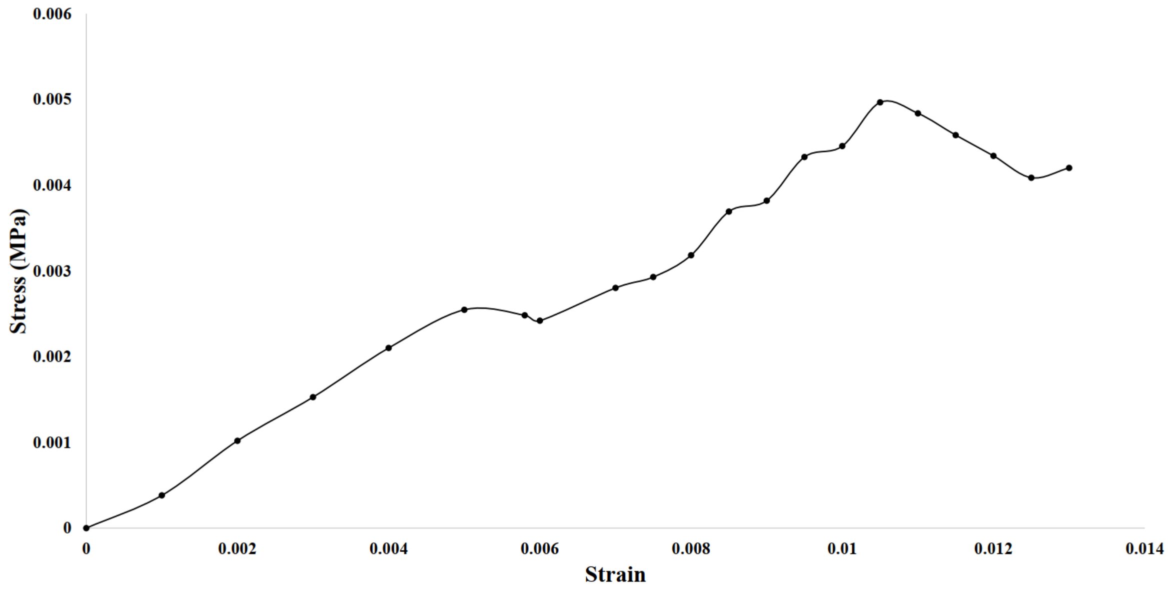


Figure 32: Stress vs strain curve for B-C-RHA0

Figure 32 represents, yield strength is 0.002419 MPa and the ultimate strength is 0.004965 MPa and fracture happens at 0.004201 MPa. This curve belongs to 0% rice husk ash mixing with cement.

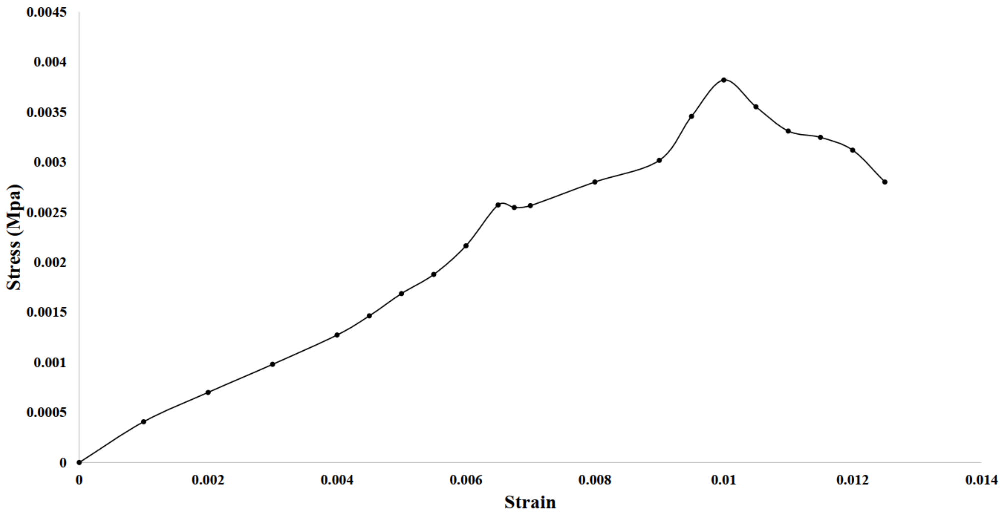


Figure 33: Stress vs strain curve for B-C-RHA5

From figure 33, it can be seen that the yield strength is 0.0025464 MPa and ultimate strength is 0.003819 MPa, and fracture happens at 0.0028102 MPa. Here, yield strength for B-C-RHA5 is quite similar to B-C-RHA0 (slight increment of 5%). Ultimate strength for B-C-RHA5 gets decreased to 23% comparing with B-C-RHA0.

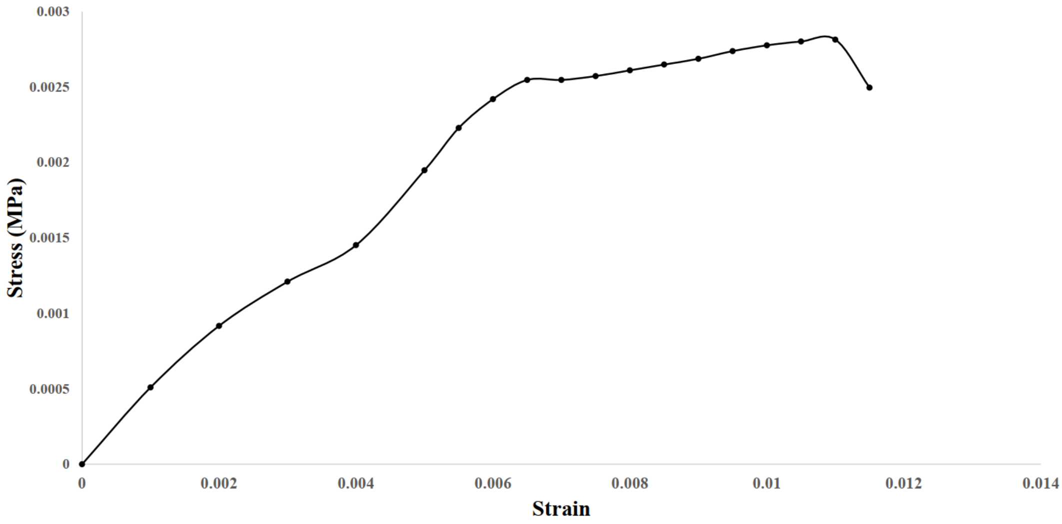


Figure 34: Stress vs strain curve for B-C-RHA10

From figure 34, it can be seen that the yield strength is 0.0025 MPa and ultimate strength is 0.0029 MPa, and fracture happens at 0.0023102 MPa. Here, yield strength for B-C-RHA10 is quite similar to B-C-RHA0 (slight increment of 3%). Ultimate strength for B-C-RHA10 gets decreased to 41% comparing to B-C-RHA0.

4.2.1 Crack Pattern for Cylindrical Blocks:

A CAD model has been designed and Structural Analysis has been done using data derived from the experiments, from which a similar kind of crack pattern has been generated compared to the experiment. Figure No 35(a) represents the mesh used in the simulation where figure 35(b) represents the model that has been used in the experiment. In the analysis total of 715369 nodes and 226178 elements have been used. Ansys has been used as simulation software.

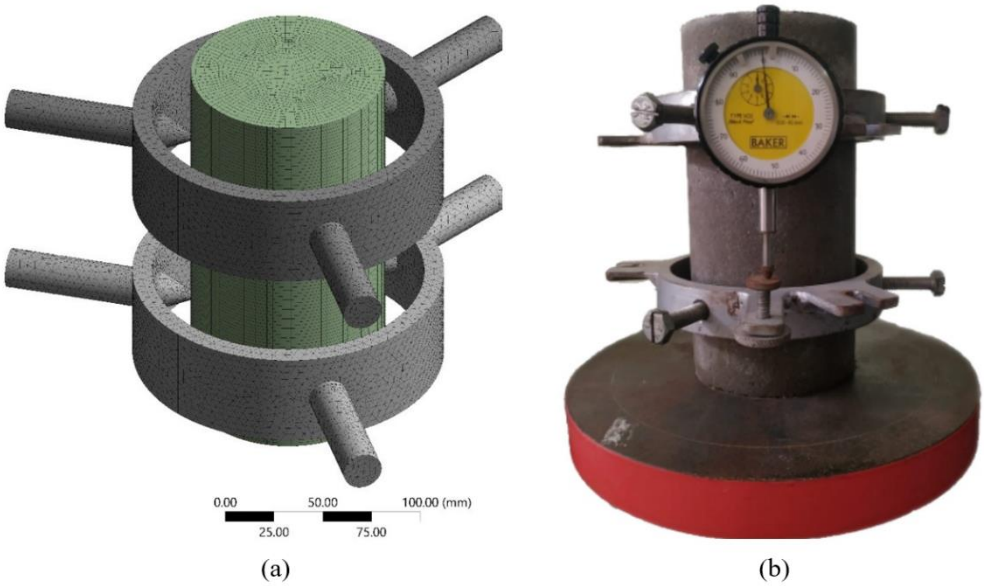


Figure 35: (a) Prototype model for simulation in Ansys (b) Real-life model for experiment

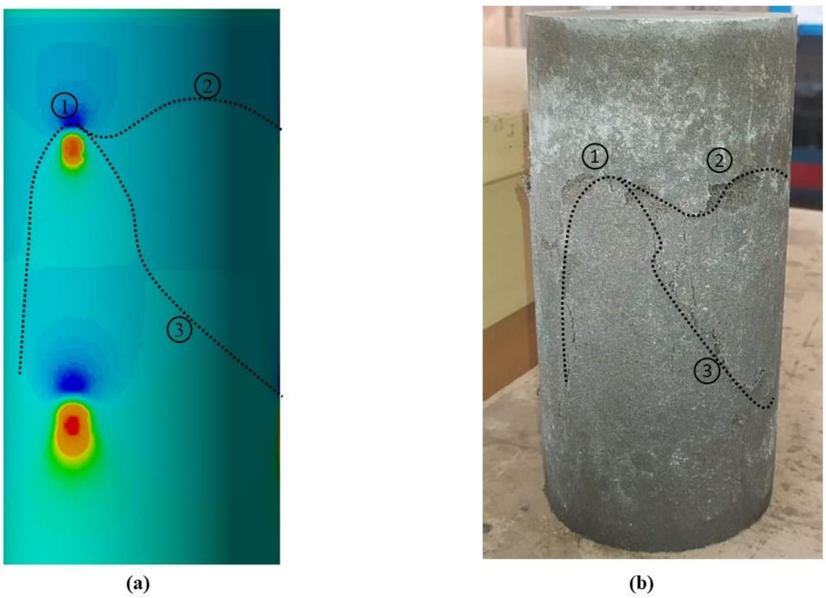


Figure 36: Crack pattern for B-C-RHA0 (a) Simulated (b) Experimental

Fig. 36 represents shows similarities in crack pattern between simulation result and experimental result. Here, the black dotted line represents the crack pattern for both simulated and experimental models where points 1, 2 & 3 in simulated results represent similar points in experimental results.

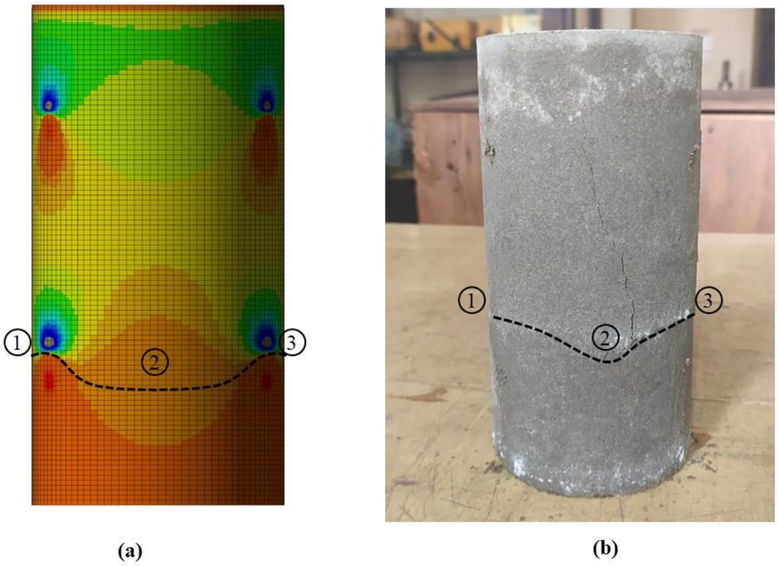
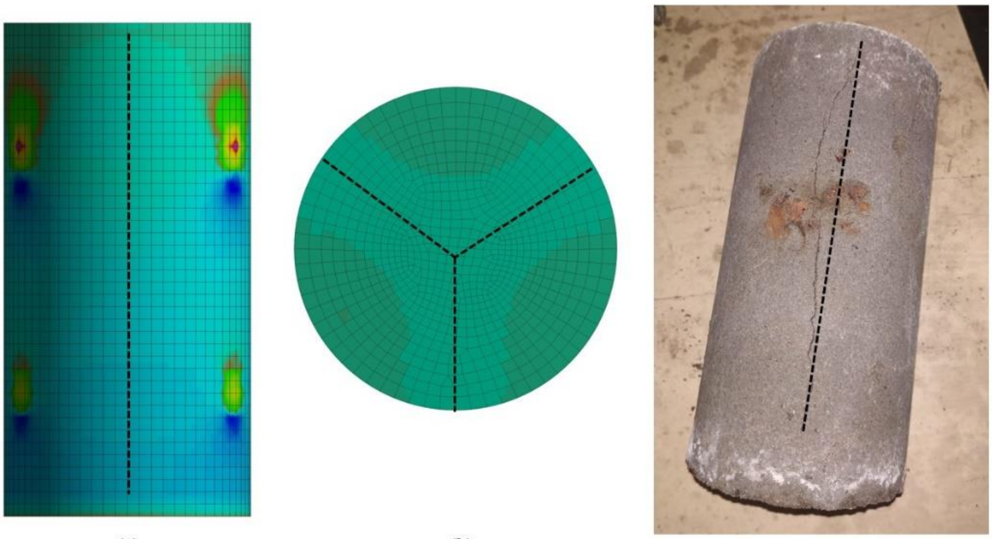


Figure 37: Crack pattern for B-C-RHA5 (a) Simulated (b) Experimental

Figure 37 represents similarities in crack pattern between simulation results and experimental results for B-C-RHA5. Here, the black dotted line defines the crack pattern for both simulated and experimental models. But the stress concentration is much distributed in the simulated result that’s why in this book, point 2 has been taken at the resultant line.



(a) (b) (c)

Figure 38: Crack pattern for B-C-RHA10 (a) Simulated: Front

(b) Simulated; Top (c) Experimental

Figure 38 shows similarities in crack pattern between simulation results and experimental results for B-C-RHA10. Here, the crack pattern is very difficult to visualize from the front simulated view but from the top view, the stress concentration is divided into three sections from where a longitudinal crack shall be generated which is similar to the experimental result.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

In this study, Rice Husk Ash has been used as the replacement for Cement. Square-sized blocks have been used for experiment purposes. The size of each block is 2 inches by 2 inches. A compressive strength test has been conducted to find out the compressive strength of each block. A total of nine square-shaped same-sized blocks has been used for the experiment.

For this investigation, 5% Rice Husk Ash, 10% Rice Husk Ash and 20% Rice Husk Ash have been used instead of the same amount of cement from the mixture. The mixture has been prepared with Cement, Rice Husk Ash, Sand, and Water following standard mixing criteria.

Then the experiment has been done by the compression flexural testing machine to test the compression for each of the square blocks. Considering pozzolanic activity, from the load vs. time graph and tabular form it is visible that for the 5% RHA mixture the result is more efficient.

After that, cylindrical-shaped blocks have been used for further experimental purposes. The size of each block has been selected as 100mm diameter and 200mm height. Compressive strength test and strain gauge test have been conducted to find out the compressive strength and the following one for the strain of each block. Total three cylindrical-shaped same-sized blocks have been used for the experiment.

For this part, 0% Rice Husk Ash, 5% Rice Husk Ash and 10% Rice Husk Ash have been used instead of the same amount of cement from the mixture. The mixture has been prepared with Cement, Rice Husk Ash, Sand, and Water following standard mixing criteria. In the UTM machine, the experiment was comprehended and the Stress vs strain curve was generated to make a comparison of 5% & 10% RHA-mixed blocks with the result of the mixture of 0% RHA. Yield strength was almost similar for all the blocks with a maximum error of 5%. Considering ultimate strength for both the blocks, it got decreased in a considerable amount comparing to the ideal 0% RHA-mixed block. From the comparison between the simulated results and experimental results, the crack patterns got almost similar to the ideal result.

In concrete, between 5% and 10% replacement of RHA with the cement without any coarse aggregate, the yield strength of the concrete with 5% RHA increases to 5% whereas, in the case of 10% RHA replacement, it increased up to 3%. Thus, in this study, the 5% RHA replacement is more efficient as a pozzolanic material.

It is concluded that residual RHA has a positive influence on the compressive strength of concretes, thus RHA can be used as a replacement of a specific proportion of cement in concrete.

5.2 Recommendation

Rice husk ash can create pozzolanic activity in the mixing of the cement. This ability paves the way to use waste materials like RHA in the cement industry. Different mixing ratio of RHA and cement was compared to justify the claim and hereby the findings are better for 5% RHA replacement. This built the foundation of future experimental work regarding the use of rice husk ash in the cement industry. The curing days can be increased up to 90 days with an improved curing procedure to find out the possibility of using rice husk ash at commercial projects. This technology of cement replacement can be a great move regarding the sustainable solution associated with the challenges of air pollution due to cement production.

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