PERFORMANCE OF ACID LEACHED RICE HUSK ASH AS CEMENT REPLACEMENT MATERIAL

TENG KAR ING

UNIVERSITI TUNKU ABDUL RAHMAN

PERFORMANCE OF ACID LEACHED RICE HUSK ASH AS CEMENT REPLACEMENT MATERIAL

TENG KAR ING

A project report submitted in partial fulfilment of the

requirements for the award of the degree of Bachelor of Science (Hons)

Construction Management

Faculty of Engineering and Green Technology

Universiti Tunku Abdul Rahman

SEPTEMBER 2024

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : 

Name : Teng Kar Ing

ID No. : 20AGB03185

Date : 23 September 2024

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"PERFORMANCE OF ACID LEACHED RICE HUSK ASH AS CEMENT REPLACEMENT"** was prepared by **TENG KAR ING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons) Construction Management at Universiti Tunku Abdul Rahman.

Approved by,

Signature :

Supervisor : Dr. KWAN WAI HOE

Date : 23 September 2024

Specially dedicated to

my beloved father, mother and supervisor

ACKNOWLEDGEMENT

I would like to express my deepest and sincerest gratitude to all those who have provided me with support, guidance and encouragement to successfully complete my final year project.

First of all, I would like to express my deepest gratitude to my supervisor, Dr. Kwan Wai Hoe, who provided knowledge and patience to guide me through the final year project. In addition, he was always available for consultation and provided me with suggestions to solve the challenges and problems I faced. His help enhanced the overall quality and depth of my work.

I would also like to express my sincere gratitude to [University/Institution Name] and [Department Name] for providing me with the resources, facilities and academic environment to carry out this project effectively and smoothly. The infrastructure and tools are crucial to the outcome of this work.

Furthermore, I would like to thank my dear family, whose continuous support has been the pillar of strength throughout my academic career. They provided emotional and motivational support when I faced problems and encouraged me to complete my final year project.

Finally, I would like to express my deepest gratitude to those who have contributed directly or indirectly to my final year project.

PERFORMANCE OF ACID LEACHED RICE HUSK ASH AS CEMENT REPLACEMENT MATERIAL

ABSTRACT

This study investigated the impact of acid on rice husk ash and the performance of acid leached rice husk ash (RHA) as a replacement of cement. The main objective of this study was to test the reactivity of rice husk ash (RHA) leached with different types of acids and the mechanical properties of mortar when mixed with rice husk ash (RHA) that leached by acids. Hydrochloric acid (HCL), sulfuric acid (H2SO4), and nitric acid (NHO3) were used as leaching agent, with two leaching times such as 30 hours and 36 hours. The RHA that leached by different acids and times were tested by x-ray diffraction test (XRD) and particle size analysis test (PSA). Mortars with different RHA contents such as 0%, 5%, and 10% were also prepared and tested for compressive strength and water absorption.

The results of the study showed that the RHA that leached by acid can reduce the amount of crystalline silica and the smallest particle size was obtained in RHA that leached by hydrochloric acid for 36 hours. It was found that RHA with the smallest particle size can improve the compressive strength of mortar, where mortar containing 5% RHA has the highest compressive strength compared to mortar containing 10% RHA. It was also found that mortar containing 10% RHA leads to increased water absorption with reduced strength. It was also found that the addition of RHA in mortar mixtures leads to decreased workability. When the proportion of RHA in mortar increase, workability decrease.

Based on the results, it is recommended to use acid leaching of RH to reduce crystalline silica and suggest hydrochloric acid to leach RH to obtain the smallest particles, because amorphous silica and small particles can enhance pozzolanic reaction. It was also found that leaching RHA for 36 hours is more effective than 30 hours. The proportion of RHA leached with hydrochloric acid to replace cement in mortar should be 5% as it can maximize the compressive strength while reducing water absorption. Further research is needed to investigate the effect of other acid types and the long-term durability of mortar mixtures with RHA as cement replacement materials in different environments. In addition, the use of other additives or adjustment of the water-cement ratio should be investigated to optimize the workability of mortar mixture that mixed with RHA.

Keywords : Acid, Rice husk ash, Cement replacement, Mortar, X-ray diffraction, Particle size, Durability, Workability, Compressive strength

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

°	Degree
°C	Degree Celsius
Mpa	Megapascal
um	Micrometer
Mm	Millimeter
%	Percentage
A12O3	Aluminum Oxide
Ca(OH)2	Calcium Hydroxide
CaO	Calcium Oxide
C-S-H	Calcium Silicate Hydrate
CO2	Carbon Dioxide
Cl^-	Chloride ions
HCL	Hydrochloric Acid
H^+	Hydrogen Ions
Fe2O3	Iron Oxide
MgO	Magnesium Oxide
NHO3	Nitric Acid
OPC	Ordinary Portland Cement

K_2O	Potassium Oxide
RH	Rice Husk
RHA	Rice Husk Ash
Si	Silicon
SiO_2	Silicon Dioxide
H_2SO_4	Sulfuric Acid
H_2O	Water

CHAPTER 1

INTRODUCTION

1.1 Background

According to the Wilkie, & Dyer, 2023, mortar materials are divided into many types, including bedding mortar, stucco, interior wall plaster and exterior wall plaster, etc. It has been a key building material and an important material in many cultures around the world. In additional to this, mortar and concrete are the most common items in construction. The difference between them is that mortar is a paste formed by mixing fine aggregate, cement and water, while concrete is a mixture of water, coarse aggregate and cement, which is harder. But mortar can also be hardened, it just needs to be solidified through the hydration reaction process. Even after hardening, it can maintain its strength and stability even under water.

According to Shetty, S. et al. 2023, accidents often occur in the construction industry, such as mechanical accidents, falling from high-rise buildings, objects hitting the head of worker, etc. In addition, smoke and dust emitted by machinery and materials can also lead to the possibility of death and are often referred to as environmental and occupational pollution. For the example, cement workers or labors who are exposed to the smoke condition and dust condition that produced by cement for every day or long-term, the cement workers or labors will get the chronic obstructive pulmonary disease that caused by cement on site. Today's builders or contractors usually use Portland cement, which contains many types of metal oxides or metallic impurities, including calcium oxide

(C02), silicon oxide (CiO2), aluminum oxide (Al2o3), iron oxide (Fe203), magnesium oxide (MgO), sand and etc. Therefore, if long-term or everyday exposure to Portland cement, it will increase the prevalence of respiratory problems and airway obstruction. According to the survey, cement workers or labors who are directly or straightly exposed to dust and smoke for a long time are more likely to suffer from shortness of breath, respiratory epithelial cell inflammation, asthma and cough, compared with cement workers who take preventive measures. (Rahmani, & A.H. 2018).

When cement is produced, large amounts of carbon dioxide are emitted, which also contributes to air pollution and global warming. As cement factories continuously produce cement, the process releases harmful pollutants into the atmosphere and into the environment. In addition to polluting the air and increasing the greenhouse effect, these toxin-containing smog and gases can cause humans to face eye irritation problems, asthma problems, cough problems, and chronic bronchitis. In addition, when the air is polluted, acid rain will also fall, which will be harmful to the health of humans who are exposed to acid rain. This study also examines how to reduce dependence on cement and recommends the use of cement substitutes. (Emetere, & Dania, 2019)

In order to solve the problem of the impact of cement, it is necessary to find suitable substitutes for cement. Previous studies have found that rice husk is also used as a substitute and to replace cement. Rice husk (RH) is an agricultural waste obtained during the process of rice milling, and its weight accounts for approximately 22 percentage (%) of the weight of rice. There are about 25 percentage (%) of the rice husk weight is processed again to be converted into rice husk ash (RHA). Since rice husk ash contains amorphous silica, it can be generated as pozzolan to make concrete and mortar by replacing it with cement or other components of concrete in specific proportions. Through the previous study, rice husk ash had mentioned that it can be used as material in proportion for replacement of ordinary Portland cement to obtain concrete or mortar with good strength and properties as compared to ordinary concrete. (Gautam, Batra, & Singh, 2019)

According to the Kwan and Wong, 2020, many people are aware of the environmental impact and harm caused by high production of cement, such as ordinary Portland cement (OPC), so more and more people would like to use rice husk ash (RHA) as a replacement or substitute for cement. Although rice husk ash (RHA) contains or consists high silica (SiO_2), it also contains other alkaline impurities that are not friendly and cause degradation to concrete or mortar before leaching by acid. The alkaline impurities have including potassium oxide (K_2O) and sodium oxide (Na_2O). The presence of crystalline silica in the non-reactive phase does not participate in chemical reactions with the cementitious material and therefore does not contribute to the strength development or durability improvement of the concrete or mortar. Apart from this, the purpose of acid leaching or acid treatment is also to increase and promote the extraction of silica (SiO_2) from rice husk ash (RHA) and improve engineering and durability properties of concrete or mortar. (Steven & et ,2021) This study also included testing the impact of acid to the rice husk ash (RHA) and the performance of acid leached rice husk ash (RHA) in concrete.

1.2 Problem Statement

Rice is the most important food in the world for humans, providing sufficient carbohydrate for humans. But at the same time, it also creates a lot of agricultural waste. According to the survey, the country with the largest agricultural production is China, with an estimated rice production of 210 million tons in 2019. The source of rice husks comes from rice, so based on the amount of rice in 2019, there are about 37.8 million (tons) of rice husks (RH) can be obtained in rice fields. Besides, Rice is composed of 72 percentage (%) of rice, 5 percentage (%) to 8 percentage (%) of bran, and 20 percentage (%) to 22 percentage (%) of rice husk. It means that 1 million (tons) of rice will produce about 0.20 million (tons) of rice husk, and each million (tons) of rice husk (RH) can produce or output about 0.18 to 0.20 million (tons) of rice husk ash (RHA). In addition, rice husk (RH) consists about 75 percentage (%) to 90 percentage (%) of organic matter, including 40 percentage (%) of cellulose, 30 percentage (%) of lignin, etc., and 17 percentage (%) of the remaining minerals such as silica, salts, etc. (Steven & et ,2021). Before discovering the purpose and usefulness of rice husks (RH), people would destroy these rice husks (RH) that could not be reused. For example, people were burning rice husks (RH) and burying them to destroy staggering amounts of rice husks (RH). In the end, improper disposal methods such as burning or burying rice husks (RH) in rural areas will cause soil pollution and air pollution, which means that rice husks (RH) will also have a great impact on the environment. (Njoku, Nwaokafor, & Okeke, 2021).

Agro-industrial wastes could be considered as emerging biomass fuel resources, with rice husks (RH) becoming one of the important and largest resources in the world. Usually, the rice husk (RH) can used to generate electricity or heat, but will produce or output harmful gases when using certain equipment, but to a lesser extent. Based on the investigation, rice husk ash (RHA) was found to be a potential biomass fuel product, derived from rice husks (RH) and producing high-purity amorphous silica under specific combustion conditions. After the combustion, the content of silica in the rice husk ash (RHA) is up to 80%. Therefore, rice husk ash (RHA) that contain high silica content can be used in value-added products of cement and concrete, such as improving the engineering characteristic, mechanical properties and durability of cement or concrete. In addition, mortar or concrete that made or manufactured by rice husk ash (RHA) is cheaper and more environmentally friendly than ordinary mortar that uses limestone, electricity and coal resources. (Liu & et, 2020)

According to the Bakhshi, Mortaheb, & Amini, 2021, when acid is dissolved in water, it will dissociate into hydrogen ions (H^+) and anions. The hydrogen ions in acid make the solution acidic. When metal impurities encounter an acidic solution, they will react with hydrogen ions, causing the metal impurities to dissolve in the acidic solution and disperse. Once dispersed, the metal can be separated from the original material through techniques such as filtration or decantation. Therefore, acid can effectively remove metal impurities from solid materials.

According to Kwan and Wong, 2020, combustion duration and combustion temperature have a certain impact on the activity of rice husk ash (RHA). When rice husk is burned for 2 hours at a temperature of 500°C to 1400°C, the whole rice husk ash (RHA) has the highest activity, but the metallic impurities and organic matter in the rice husk (RH) that affect the properties of the mortar must be burned, such as hemi-cellulose, cellulose and lignin. In addition, it is unclear what other factors influence the performance of mortar that made by rice husk ash (RHA), and there may be other methods or factors that can be used to improve the properties or performance of mortar in the future. In addition, rice husk ash (RHA) contains high amounts of alkaline impurities, such as potassium oxide (K2O) and sodium oxide (Na2O). These alkaline impurities will destroy the properties of mortar and form "activators of crystalline silica " during the high temperature combustion and long-term combustion process. (Saceda, De Leon, and Wittayakun,, 2011). In order to remove these alkaline impurities, the rice husk needs to be acid treated before burning to obtain rice husk ash (RHA) with higher activity. Without acid treatment, the organic matter contained in rice husks will be decomposed to produce carbon when burned. Carbon dioxide is formed when carbon comes into contact with oxygen. If the temperature exceeds the dissociation temperature of potassium oxide (K2O), non-oxidized carbon will be formed, resulting in the formation of a molten glass portion on the surface of the rice husk ash. (Kamath, & Proctor, 1998) This means that the molten layer acts as a barrier, preventing the surface of the rice husk from coming into contact with oxygen and carbon dioxide, ultimately promoting the crystallization of silica. (Vayghan, Khaloo, & Rajabipour,2013) In addition, organic matter and metal impurities in rice husks can also cause less reactive in pozzolanic reactions, making RHA appear brown or reddish brown. According to surveys, the color of high-purity silica is white. (Chakraverty, & Banerjee). After acid treatment and combustion, the content of amorphous silica in rice husk ash (RHA) can up to 90 percentage (%). The acids that are often used in acid leaching include sulfuric acid (H2SO4), hydrochloric acid (HCL) and nitric acid (HNO3), but sulfuric acid (H2SO4 and nitric acid (HNO3) are scarce and less reported from the previous research. This study explores the performance of acid leached to the rice husk ash (RHA) as replacement of cement. To examine and determine the durability and mechanical properties of mortar when the performance of acid leached to the rice husk ash (RHA).

1.3 Aim and Objective

The purpose of this study was to determine the impact of acid on rice husk ash or mortar and the performance of acid leached rice husk ash (RHA) as a replacement of cement. To achieve this goal, this study has developed the following objectives to help it achieve its objectives, as follows:

i) To examine type of the acid on reactivity of rice husk ash (RHA).

ii)To determine the mechanical properties of mortar when performance of acid leached rice husk ash (RHA).

1.4 Scope of Study

The purpose of this study is to better understand the application of acid treatment in rice husk ash (RHA) forming mortar, focusing on how to enhance the strength and other engineering properties of the mortar. As a large amount of rice is produced around the world, the amount of rice husk (RH) is also increasing. So, this study also talking about how to reuse this useless rice husk, called agricultural waste in effective. It was discovered that rice shells can be burned to form rice husk ash (RHA), which has the potential to be used as a pozzolanic material, which can partially replace cement in mortar or concrete, and can also enhance the performance of mortar or concrete. However, rice husk ash (RHA) that has not been treated with acid contains alkaline impurities and will have a great impact on mortar and concrete. For example, potassium oxide and sodium oxide can degrade the performance of mortar and concrete. Therefore, the mortar samples of rice husk ash (RHA) with different concentrations of acid were studied. In order to evaluate about the acid affects the quality of mortar when rice husk ash (RHA) is used as a partial replacement for cement, the study will use experimental techniques to support the study. This study will lay the foundation for more research and development of rice husk ash (RHA) as a replacement or sustainable material in the construction sector. Understanding the engineering quality and durability of RHA mortar treated with acid was one of the research goals. To achieve these goals, the following objectives will be the main support of the research:

• Review of the literature about the performance of acid leached rice husk ash (RHA) as a replacement of cement to form mortars and its effect on material properties. This review will provide the reader with a comprehensive overview of recent advances in this research field and identify areas where further research is still needed.

• Design and preparation of mortar samples formed with different amounts and types of acid used in rice husk ash (RHA). The samples of mortar will be prepared by replacing different proportion cement with rice husk ash (RHA). The different types of acid also used to leach rice husk (RH) in this study, and observe the impact of different acid depend on reactivity of rice husk ash and the mechanical properties of the mortar.

• Examine and determine the mechanical properties of mortar samples such as compressive strength. Standard of laboratory testing procedures will be conducted and used to evaluate the performance of acid that effect the strength of the mortar that mixed with rice husk ash (RHA).

• Evaluate the tensile properties of mortar samples such as water absorption. These properties will be examined to evaluate the acid affects the durability of the mortar. Evaluate the workability of mortar sample such as flow table test, to evaluate the rice husk ash (RHA) affects the workability of the mortar.

1.5 Limitation of Study

This study has several limitations that need to be considered and this problem may prevent the continuation of this study. First, there may be differences in the quality of raw materials. For example, the quality of rice husk ash will vary due to factors such as rice type, production method, and processing conditions. If only rice husk ash was used as material in this study, the findings may not be generalizable to other sources. Second, the quality of acid may also vary, such as acid production methods and processing conditions and other factors. Third, this study will be conducted under controlled laboratory conditions rather than an external environment, which may cause the data to differ from actual field conditions. Therefore, the results of this study may not be directly applicable to construction sites because of different environments. The fourth problem faced is the limited sample size, because this study will use a smaller sample size for testing, it may not be representative of the wider material or construction project population. Fifth, changes in environmental conditions affect the mortar in this study. The performance of the mortar will be affected by temperature, humidity, contact with chemicals or other environmental factors, and cannot accurately reflect the material under real conditions. The sixth issue faced was the limited time in this study, which may have prevented the researchers from conducting long-term durability tests of the mortar or investigating the effect of acid over time on properties of mortar, such as strength.

1.6 Significant of Study

The application of rice husk ash (RHA) in mortars and the application of acid treatment in rice husk ash (RHA) are the new area of research and this research will contribute to enriching the existing knowledge in the field of construction. This finding will provide meaningful and valuable insights into the use of acid-treated rice husk ash as a sustainable material can be applied in the construction industry. This study will determine the optimal type of acid to be applied to rice husk (RH) or mortar without degrading the mechanical and durability properties of the mortar. The research will further investigate the reactivity of rice husk ash (RHA) that leached by different acid such as formation of crystalline silica and particle size. The results of this study can be of practical application as well as helpful in the construction industry.

1.7 Chapter Outline

This research paper is divided into five chapters, which are Chapter 1, Chapter 2, Chapter 3, Chapter 4 and Chapter 5.

Chapter 1: Introduction

This chapter describes about acid, cement, rice husk and rice husk ash in this study. This chapter also describes the purpose, aims, significance and scope of the study and the problems statement such as formation of crystalline silica in the rice husk ash (RHA) will degrade the properties of mortar.

Chapter 2: Literature Review

This chapter will collect and describe the tests and surveys that early researchers conducted to gather the information and knowledge needed for the success of this study. It will be combined with recent and previous research about acid and rice husk ash, the previous data from earlier researchers are very helpful to this research and study.

Chapter 3: Research Methology

This chapter will explain and discuss the materials and tests that will be used in this study to achieve the goals of this study and help readers or researchers better understand the experimental methods.

Chapter 4: Result and Discussion

This chapter will explain and analyze the test results and the test results will be written in Chapter 4 Results and Discussion.

Chapter 5: Conclusion and Recommendation

This chapter is to avoid the future researchers from making the same mistakes and to achieve better results through this study. The recommendations and results of this study will also be presented in detail in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review in Chapter 2 will introduce the relationship between rice husk ash (RHA) and acid and some early research on rice husk ash in mortar. This section will review other researchers studying rice husk ash concrete or mortar and review the materials required for its production, with acid as the focus. The success and objectives of this subsequent study depend on following.

Early researchers have focused on the research of rice husk, and obtained results and patents in these studies. This study is about the performance of acid and the impact of acid. It has also been proven that rice shells can eliminate alkaline impurities, such as potassium oxide and sodium oxide, through the process of strong acid solution. (Kwan, & Wong, 2020). These basic impurities can lead to the formation of crystalline silica, ultimately leading to reduced reactivity of rice husk ash (RHA) in pozzolanic reactions. In addition, acid leaching can also help remove metal impurities contained in rice husk (RH), including such as aluminum oxide (Al_2O_3), iron (III) oxide (Fe_2O_3), calcium oxide (CaO), and magnesium oxide (MgO). If these metal impurities that have not been treated by acid leading will form ash after burning, it will cause the amorphous silica in the rice husk ash (RHA) to not be the purest. The acids that are often used in acid leaching include sulfuric acid (H_2SO_4), hydrochloric acid (HCL) and nitric acid (HNO_3), and weak acid solutions such as citric acid ($C_6H_8O_7$) are not used. An important step in the acid leaching process is boiling. After preliminary leaching and boiling of the rice husk (RH), high-purity silica and more silica can be obtained from the rice husk. Although these acids will not cause damage or degradation to the amorphous silica in rice husk, they are threatening and dangerous to humans and the environment. In addition, sulfuric acid (H2SO4) will form water-insoluble metal sulfates during the acid pretreatment of rice husk (RH). (Faizul and Kein, 2019)

2.2 Hydrochloric Acid (HCL)

Hydrochloric acid is a very strong and typically non-oxidizing acid, so it can be completely dissociated into H+ and Cl-. Although hydrochloric acid (HCl) is a non-oxidizing acid compared to strong oxidizing acids such as nitric acid (HNO_3) and sulfuric acid (H_2SO_4), HCl can dissolve many metals through an acid-base reaction rather than oxidation. (Schmiermund, T., 2022). In this process, the metal reacts with the hydrochloric acid to form metal chlorides and hydrogen gas. In a hydrochloric acid system, basically large metal materials will undergo severe activation corrosion when they come into contact with hydrochloric acid. In addition, the corrosion rate will be significantly accelerated as the concentration and temperature of hydrochloric acid increase. There are also a large number of highly active chloride ions in the hydrochloric acid medium. Therefore, hydrochloric acid can easily destroy the passivation film on the surface of metal materials and cause comprehensive corrosion of the materials. Even stainless-steel metal will suffer from pitting corrosion, stress corrosion cracking and other phenomena when it comes into contact with hydrochloric acid. (Fan, R. et al., 2021)

Metal+2HCl→Metal Chloride+H2

Mg+2HCl→MgCl2+H2

Magnesium reacts with hydrochloric acid to form magnesium chloride and hydrogen gas; it means that the magnesium chloride is the metal salt.

2.2.1 Concentration of Hydrochloric Acid

Table 2.1 The comparison of element in between of un-leached with acid and leached with hydrochloric acid from previous research

Element	*Un-leached acid*	*0.01m*	*0.1m*	*0.5m*	*1.0m*	*2.0m*	*3.0m*
Silica (SiO2)	95.772	98.84	99.30	99.582	99.49	99.90	99.87
Potassium oxide (K2O)	0.618	0	0	0.018	0	0.03	0.03
Aluminum oxide (Al2O3)	0.046	0	0	0.168	0	0	0
Iron (3) oxide (Fe2O3)	0.050	0	0	0.025	0	0.03	0.06
Calcium Oxide (CaO)	0.667	0	0	0.043	0	0.03	0.03
Magnesium Oxide (MgO)	0.397	0	0	0.016	0	0	0
Other	2.45	0.256	0.344	0.148	0.377	0.01	0.01

.Un-leached acid, 0.5 hydrochloric acid -(Bakar, Yahya, & Gan, 2016)

0.01, 0.1 and 1.0M hydrochloric acid- (Seng, W.Y., 2019)

2.0 and 3.0M Hydrochloric acid- (Abdul Salim, Z.A. et al. 2023)

Above are the results of concentration of hydrochloric acid (HCL) had done by previous, there are 7 condition that used to test the amount of silica (SiO2) and other metallic impurities or alkaline impurities. For example, un-leached acid, 0.01m, 0.1m, 0.5m, 1.0m, 2.0m and 3.0m of hydrochloric acid. Hydrochloric acid is the common acid that usually used to leach rice husk ash (RHA) according to early research, but it is dangerous to human and environment. According to early research, the hydrochloric acid always used to eliminate metallic impurities, such as aluminum oxide (Al_2O_3), iron (III) oxide (Fe_2O_3), calcium oxide (CaO), and magnesium oxide (MgO). The alkaline impurity or harmful impurity also can be eliminated from rice husk ash (RHA), such as potassium oxide (K_2O). These tests were used to get high purity of silica (SiO_2) and enhanced the pozzolanic characteristic from rice husk ash (RHA). According to Bakar, Yahya, & Gan, 2016, 95.772 percentage (%) and 99.582 percentage (%) of silica (SiO_2) was produced from un-leached rice husk ash (ARH) with hydrochloric acid and 0.5m hydrochloric acid (HCL) leached rice husk ash (RHA), both burned at 600 degrees (°C) for 2 hours. These tests were proven that the amount of silica (SiO_2) from rice hush ash (RHA) that had through acid treatment is more than rice husk ash (RHA) without acid treatment. According to Seng, W.Y., 2019, 0.01m, 0.1m, 1.0m, 2.0m, 3.0m of hydrochloric acid leached to rice husk ash (RHA) and burned in 800 degrees (°C) for 2 hours, resulted in 98.84 percentage (%), 99.30 percentage (%) and 99.49 percentage (%) of silica (SiO_2) was produced from rice husk ash (RHA). These result data found that the amount of silica (SiO_2) is increasing, when the amount of hydrochloric acid (HCL) that leached to rice husk (RH) is increasing. According to Abdul Salim, Z.A. et al. 2023, 99.90 percentage (%) and 99.87 percentage (%) of silica (SiO_2) was produced form rice husk ash (RHA) that was leached 2.0m and 3.0m hydrochloric acid (HCL), both burned in 700 degrees (°C) for 4 hours. The result of data from this research proved that the amount of hydrochloric acid (HCL) more than 1.0m, the temperature of burning more than 600 (°C) and the time for burning more than 2 hours can get more purity of silica (SiO_2) from rice husk ash (RHA). In the conclusion, the hydrochloric acid (HCL) can be a leaching agent, because it can almost to remove metallic or alkaline impurities, and almost to get the purities of silica (SiO_2) form rice husk ash (RHA).

2.3 Sulfuric acid (H_2SO_4)

According to Sulistiyono, E. et al., 2021, sulfuric acid was applied to extract pure silica from quartz sand in Sukabumi, Indonesia. It was found that high-purity silica could be obtained by removing impurities such as aluminum and iron from the quartz sand through sulfuric acid leaching. And in this study, it was found that sulfuric acid was very effective in removing aluminum and iron impurities, with the highest removal rates of up to 42% and 85%. This can improve the quality of low-grade silica and become a raw material for the glass industry.

Metal+H_2SO_4→Metal Sulfate+H_2

$2Al+3H_2SO_4 \rightarrow Al_2(SO_4)_3+3H_2$

Aluminium reacts with sulfuric acid to form Aluminium sulfate and hydrogen gas; it means that the aluminium sulfate is the metal salt.

2.3.1 Concentration of Sulfuric acid

Table 2.2 The comparison of element in between of un-leached with acid and leached with sulfuric acid from previous research.

Element	*Un-leached acid*	*0.1m*	*0.5m*
Silica (SiO_2)	92.20	94.72	99.083
Potassium oxide (K_2O)	0.20	0.08	0.016
Aluminum oxide (Al_2O_3)	0.11	0.38	0.605
Iron (3) oxide (Fe_2O_3)	0.06	0.24	0.017
Calcium Oxide (CaO)	0.16	0.26	0.050
Magnesium Oxide (MgO)	0.10	0.14	0.035
other	7.17	4.18	0.195

0.5 sulfuric acid -(Bakar, Yahya, & Gan, 2016)

Un-leached acid, 0.1 sulfuric acid (Azza, lH. et al. 2022)

Above are the results of concentration of sulfuric acid (H_2SO_4) had done by previous, there are 3 condition that used to test the amount of silica (SiO_2) and other metallic impurities or alkaline impurities. For example, un-leached acid, 0.1m, 0.5m, of sulfuric acid. Sulfuric acid (H_2SO_4) will form water-insoluble metal sulfates during the acid pretreatment of rice husk. According to Azza, lH. et al. 2022, 92.90 percentage (%) and 94.72 percentage (%) of silica (SiO_2) was produced from un-leached rice husk ash (ARH) with sulfuric acid and 0.1m sulfuric acid (H_2SO_4) leached rice husk ash (RHA), both burned at 550 degrees (°C) for 3 hours. These tests were proven that the amount of silica (SiO_2) from rice hush ash (RHA) that had through acid treatment is more than rice husk ash (RHA) without acid treatment. According to Bakar, Yahya, & Gan, 2016, 0.5 of sulfuric acid leached to rice husk ash (RHA) and burned in 600 degrees (°C) for 2 hours, resulted in 99.083 percentage (%) of silica (SiO_2) was produced from rice husk ash (RHA). This result had proven that 0.5m of sulfuric acid is enough to achieve 99 percentage (%) of silica (SiO_2) from rice husk ash (RHA). Since most of the acids used in previous studies are hydrochloric acid, there is relatively little information about sulfuric acid.

2.4 Nitric acid (NH03)

According to the Deng, J., Feng, X. and Qiu, X., 2009, the use of nitric acid and ultrasonic time can remove heavy metals in sludge. The results show that the removal rates of Cu, Zn, and Pb will increase with the increase of nitric acid concentration and ultrasonic time, and the removal rates can reach 9.5%, 82.2%, and 87.3%, respectively. In addition, it was found that the contribution of ultrasound and nitric acid to the extraction process of heavy metals was 18-22% and 78-82%, respectively. This means that in terms of removing heavy metals, the effect of nitric acid is far greater than that ultrasound.

$Metal + NH03 \rightarrow Metal\ Nitrate + H_2$

$Zn + 4HNO_3 \rightarrow Zn(NO_3)_2 + 2H_2O + 2NO_2$

Zinc reacts with sulfuric acid to form zinc nitrate and hydrogen gas; it means that the zinc nitrate is the metal salt.

2.4.1 Concentration of Nitric acid

Table 2.3 The comparison of element in between of un-leached with acid and leached with nitric acid - (Ghorbani, Sanati, & Maleki,2015)

Element	*Un-leached acid*	*1.0N*
Silica (SiO2)	85.15	94.79
Potassium oxide (K2O)	4.95	0.11
Aluminum oxide (Al2O3)	0.29	0.06
Iron (3) oxide (Fe2O3)	0.19	0.02
Calcium Oxide (CaO)	1.31	0.49
Magnesium Oxide (MgO)	0.92	0.11
Other	7.19	4.42

Above are the results of concentration of nitric acid (HNO3) had done by previous, there are 2 condition that used to test the amount of silica (SiO2) and other metallic impurities or alkaline impurities. According to Ghorbani, Sanati, & Maleki,2015, 85.15 percentage (%) and 94.79 percentage (%) of silica (SiO2) was produced from un-leached rice husk ash (ARH) with nitric acid and 1.0n sulfuric acid (HNO3) leached rice husk ash (RHA), both burned at 600 degrees (°C) for 6 hours. These tests were proven that the amount of silica (SiO2) from rice hush ash (RHA) that had through nitric acid treatment is more than rice husk ash (RHA) without acid treatment. Since most of the acids used in previous studies are hydrochloric acid, there is relatively little information about nitric acid.

2.5 Comparison between hydrochloric acid, sulfuric acid and nitric acid

Table 2.4 Comparison between hydrogen acid, sulfuric acid and nitric acid in 1N-(Ghorbani, Sanati, & Maleki,2015)

Element	*Hydrochloric acid (1N)*	*Sulfuric acid (1N)*	*Nitric acid (1N)*
Silica (SiO2)	95.55	92.89	94.79
Potassium oxide (K2O)	0.05	0.02	0.11
Aluminum oxide (Al2O3)	0.13	0.08	0.06
Iron(3) oxide (Fe2O3)	0.03	0.02	0.02
Calcium Oxide (CaO)	0.56	1.14	0.49
Magnesium Oxide (MgO)	0.09	0.13	0.11
Other	3.49	5.82	4.42

Table 2.5 Comparison between hydrogen acid, sulfuric acid and nitric acid in 1M-(Fernando, Pineda & Rosales, 2018)

Element	*Hydrochloric acid (1M)*	*Sulfuric acid (1M)*	*Nitric acid (1M)*
Silica (SiO2)	98.48	98.22	98.44
Potassium oxide (K2O)	0.60	0.71	0.63
Aluminum oxide (Al2O3)	0.10	0.14	0.11
Iron(3) oxide (Fe2O3)	0.08	0.10	0.09

Calcium Oxide (CaO)	0.25	0.27	0.36
Magnesium Oxide (MgO)	0.10	0.21	0.22
Other	0.39	0.35	0.15

Above tables Above are the results of concentration of hydrochloric acid (HCL), sulfuric acid (H2SO4) and nitric acid (HNO3) had done by previous, these two tables are from different resources. According to Ghorbani, Sanati, & Maleki,2015 and Fernando, Pineda & Rosales, 2018, The concentration of these three acids is the same, 1.0m or 1.0n, but the temperature of combustion process and the time in these two types of resources is different. According to the table 2.4 and 2.5 on above, the amount of silica (SiO2) from the rice husk ash that through treatment of sulfuric acid (H2SO4) is more than treatment of nitric acid (HNO3), but lesser than hydrochloric acid (HCL). It means that the silica from rice husk ash (RHA) that had through treatment of hydrochloric acid (HCL) is the highest purities.

This also means that hydrochloric acid is stronger than sulfuric acid and nitric acid, because hydrochloric acid dissolves in water and completely ionizes into hydrogen ions (H^+) and chloride ions (Cl^-). So compared to sulfuric acid and nitric acid, almost all molecules of hydrochloric acid are split into ions and the concentration of hydrogen ions is higher. The reaction of hydrochloric acid will also be more violent when it comes into contact with many metals. This is because the chloride formed by the reaction is usually more soluble than sulfate, so it will dissolve the metal ions faster. (Van Der Hagen, and Järnberg, 2009)

2.6 X-Ray Diffraction Test

Table 2.6 Crystalline and amorphous of silica in RHA from previous research

Sample	2θ	References
Sample leached without acid	20.9°, 26.7°, 45.7° and 50.6	Azat, S. *et al.*, 2019
Sample leached by HCL	22◦	Nzereogu, P.U. *et al.*,2023

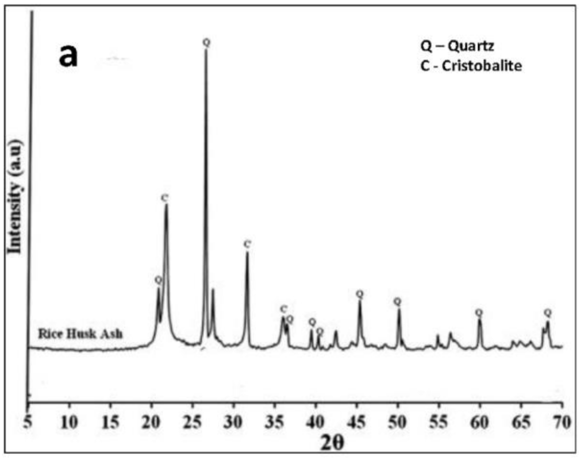


Figure 2.1 Sample leached without acid.

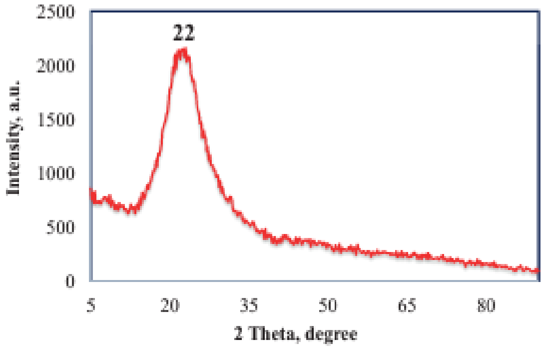


Figure 2.2 Sample leached by acid.

High temperature can effectively remove organic matter and obtain a large amount of silica. However, when the temperature reaches a certain temperature, the silica will form crystalline silica, which is caused by metal impurities. Therefore, acid treatment is not only to reduce metal impurities, but also to obtain a large amount of amorphous silica instead of crystalline silica. According to Azat, S. *et al.*, 2019, the characteristic crystal structure appears in rice husk ash and the formation of crystal are caused by burning rice husks in the temperature range of 700–950 °C and the rice husk without acid pretreatment.

The XRD pattern of crystal shows in figure 2.1, the result shows that it has a sharp and strong diffraction peaks. The notable features are the peaks appearing at scattering angles (2θ) such as 20.9°, 26.7°, 45.7° and 50.6°, which reflects the ordered crystalline nature of quartz present in rice husks. In figure 2.2, The XRD pattern shows a broad peak at 2θ equal to 22°, which is identified as an amorphous structure. In addition, there is no sharp peak of ordered crystal peaks in the acid-treated rice ash, which proves that the sample is amorphous. (Nzereogu, P.U. *et al.*,2023)

2.7 Particle Size Analysis Test

Table 2.7 Particle size analysis of RHA from previous research. (Leong, Tuck Lun, 2015).

sample	**D(50)**
RHA through temperature 600	67.09 um
RHA through temperature 700	85.85 um

According to Hamid, 2013, the particle size of RHA has a certain effect on the reactivity of pozzolan, and it is found that the smaller the particles, the higher the reactivity of pozzolan can be improved. The pozzolan properties can help improve the compressive strength and durability of mortar formed by replacing lime with RHA. Therefore, the particle size distribution of the sample can be determined by particle size analysis. The main reason is that fine RHA particles can act as micro fillers and refine the pore structure. According to the table 2.7, the results show that the particle size of the both samples had reached 67.09 um and 85.85 um.

2.8 Flow table test

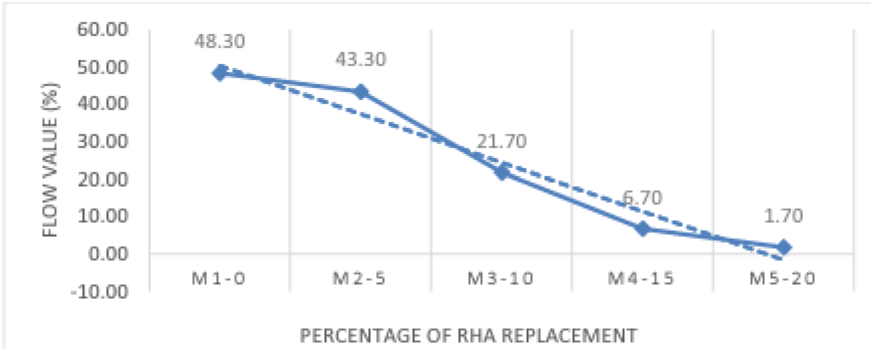


Figure 2.3 The Workability of mixture vs the percentage of RHA replacement.

According to Padhi, 2018, there is a great relationship between the workability of the mixture and the percentage of RHA replacement. Since the use of RHA to replace cement in concrete will significantly reduce the workability of the mortar. The reason comes from the particles of RHA, the round and fine particles can replace fine aggregates and lead to better performance. In addition, when the replacement of cement by RHA increases, the fineness modulus of fine aggregates containing RHA will decrease, resulting in a decrease in slump value.

According to Figure 2.3 (Zakaria, N. *et al.*, 2023), when the percentage of RHA replacing cement increases, the workability index will also decrease. This also proves that the low density of RHA will reduce the workability of mortar or concrete. In addition, rice husk ash has a high specific surface area, so it has a very strong water absorption. Therefore, previous researchers also believed that when the amount of RHA continues to increase, the workability will decrease. The main reason is the water absorption capacity of RHA. (Tayeh, B A. *et al.*, 2021)

2.9 Water Absorption Test

Table 2.8 Water absorption of mortar from previous research.

Sample	Water absorption %	References
Sample without RHA	4.63%	Salas, A. *et al.* ,2009.
Sample without RHA	4.12%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA	4.26%	Salas, A. *et al.* ,2009.
Sample 5% replacement of RHA	3.95%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA	3.7%	Endale, S.A. *et al.*,2022
Sample 15% replacement of RHA	3.46%	Endale, S.A. *et al.*,2022
Sample 20% replacement of RHA	3.23%	Endale, S.A. *et al.*,2022
Sample 25% replacement of RHA	3.05%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA leached by acid	3.61%	Salas, A. *et al.* ,2009.

According to Salas, A. *et al.* ,2009., surface water absorption is one of the factors that affect reinforced concrete structures, such as reducing its durability and other properties. The lower the permeability and pore continuity of concrete, the stronger the resistance of concrete or slurry. In addition, the presence of pozzolanic reactivity can greatly reduce the average pore size, making concrete or slurry have better impermeability. According to the survey, mortar containing 10% RHA showed lower water absorption because the addition of RHA makes the mortar less water absorption. The reason is that RHA is smaller in size and can be used to fill the pores between mortars. When amorphous silica partially contacts with cement hydration products such as calcium hydroxide, it reacts and eventually forms a secondary C-S-H gel. In addition, it was found that acid treated RHA would degrade the water absorption of mortar. For the results in table 2.8, the water absorption rate of RHA without acid treatment and RHA with acid treatment are 4.26% and 3.61%. It means that apply acid treatment can reduce about 0.65%.

According to the Endale, S.A. *et al.*,2022, it was found that the addition of RHA to the cement matrix did result in a significant decrease in water absorption. This could be attributed to the pore refinement caused by the addition of RHA, which resulted in a decrease in water absorption when the packing density increased. According to table 2.8, the results show that the water absorption rate of cement replaced by 5% to 25% rice husk ash is reduced from 4.21% to 3.05%.

2.10 Compressive strength test

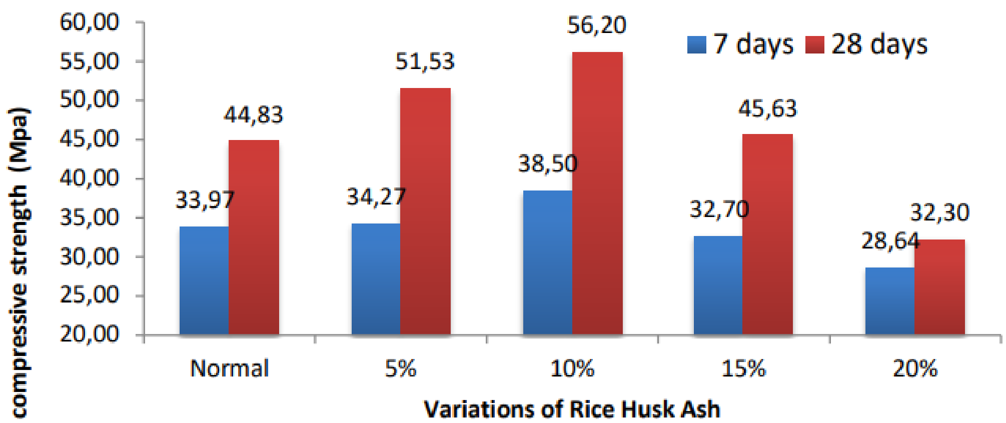


Figure 2.4 Graph comparing the mean compressive strength of concrete at 7 days and 28 days, with variations of rice husk ash of 0%, 5%, 10%, 15%, 20% as the cement substitute. (Nursyamsi, N, 2021)

According to Figure 2.4 it is found that the sample with 10% RHA replacing cement has the highest compressive strength and the sample with 20% RHA replacing cement has the lowest compressive strength. The results show that the maximum compressive strength that the sample can withstand after 7 days of curing is the sample with 10% RHA replacing cement, which is 38.50 MPa. The minimum compressive strength is the sample with 20% RHA replacing cement, which is 28.64%. In addition, the compressive strength continues to increase until 28 days, reaching a maximum of 56.20 MPa and a minimum of 32.30 MPa. (Nursyamsi, N, 2021)

According to Bakar, 2016, RH can remove organic matter and obtain a large amount of silica, but metal impurities that consist in the RHA will prevent RHA from obtaining purer silica. Therefore, RH through acid treatment can help improve pozzolanic reactivity, which can reduce crystalline silica and increase amorphous silica. In addition, purer silica can also be easily obtained. It is also demonstrated that RHA with pozzolanic properties can improve the properties of mortar such as compressive strength. (Antiohos, S.K., 2014)

Table 2.9 Compressive Strength of Mortar with 0% RHA, 10% RHA without leached by acid and 10% RHA leached by acid. (Vayghan, 2013)

sample	Replacement (%)	Compressive strength
		28 days
RHA	0%	45.81 Mpa
RHA without leached by acid	5%	51.40 Mpa
RHA without leached by acid	10%	55.17 Mpa
RHA leached by acid	5%	43.10 Mpa
RHA leached by acid	10%	59.68 Mpa

According to table 2.9, it is proved that the acid treated RHA can make the sample have higher compressive strength. The highest index is 59.68 Mpa, which is the sample with 10% RHA replacing cement. This table also proves that RHA has a certain impact on the performance of mortar. In addition, the compression resistance of mortar also increases with the percentage of RHA replacement. (Vayghan, 2013)

CHAPTER 3

MYTHOLOGY RESEARCH

3.1 Introduction

This chapter is a methodological chapter explaining the study, explaining how the study was conducted and implemented to achieve the aims and objectives of the study. This study will use statistical analysis and laboratory research as research methods. Several tests will also be conducted in this study, pozzolanic activity index testing (PAI), x-ray fluorescence spectroscopy testing (XRF), x-ray diffraction testing (XRD), particle size analysis (PSA), scanning electron microscopy (SEM), density, workability, compressive strength test, flexural strength test and water absorption test. This test will evaluate the performance of mortar using acid leached rice husk ash when rice husk ash replaces cement. This chapter discusses the materials required and the types of testing performed.

3.2 material

Rice husk mortar will be used for the purpose and testing of this study. In order to manufacture rice husk mortar with high performance, this study will utilize 7 different types of materials such as Portland Composite Cement (PCC), Rich Husk Ash (RHA), hydrochloric acid (HCL), sulfuric acid (H_2SO_4), nitric acid (HNO_3), fine aggregate and water.

3.2.1 Portland Composite Cement (PCC)

Figure 3.1 Portland composite cement (PCC)

Portland composite cement is a cement composed of Portland cement clinker and other auxiliary cementitious materials. Other auxiliary cementitious materials include granulated blast furnace slag, fly ash, limestone fines or silica fume, which can help enhance the durability, workability and sustainability of cement. The fly ash is a by-product of coal combustion in power plants, improves workability, reduces heat generation, and enhances the long-term strength and durability of the mortar. Granular blast furnace slag (GBFS) is a by-product of the ironmaking process. In addition to helping to improve processability and reduce heat generation like fly ash, it is also highly resistant to sulfate and chloride attack. Silica fume is a by-product produced from silicon and ferrosilicon alloys, and it helps sizing improve strength, durability and resistance to corrosion and chemical attack. The final limestone powder is formed from ground limestone particles which, like granular blast furnace slag (GBFS), contributes to workability, durability and improved sulfate resistance.

3.2.2 Rice Husk Ash

Figure 3.2 Rice husk

Rice husk (RH) is derived from rice grains. It is the outer protective layer and hard outer layer of rice grains. It can be called rice husk or rice husk. Brown rice or white rice requires a milling process to separate the rice husk from the edible rice grains before they can be eaten as food. Rice husk is composed of cellulose, hemicellulose, lignin, silica, and small amounts of ash and other minerals. Rice husk is also very lightweight but has a fibrous structure. In addition, rice husk is also known as agricultural waste. Before humans discovered its uses, it was usually disposed of by incineration or landfill. This is not only unfriendly to the environment, but also causes serious air pollution. It later attracted attention for its potential as a valuable resource in various applications, such as fuel, animal feed, soil amendment, building material and insulation.

rice husk ash (RHA) is derived from rice husk, there are about 25 percentage (%) of the rice husk weight is processed to be converted into rice husk ash (RHA). The rice husk ash (RHA) that contain high silica content can be used in value-added products of cement and concrete, such as improving the engineering characteristic, mechanical properties and durability of cement or concrete. In addition, mortar or concrete that made or manufactured by rice husk ash (RHA) is cheaper and more environmentally friendly than ordinary mortar that uses limestone, electricity and coal resources.

3.2.3 Acid

Hydrochloric acid (HCL), sulfuric acid (H_2SO_4) and nitric acid (HNO_3) are used as acid solution or acid treatment leached to rice husk (RH), because rice husk contains high amounts of alkaline impurities, such as potassium oxide (K_2O) and sodium oxide (Na_2O). These alkaline impurities will destroy the properties of mortar and form "activators of crystalline silica " during the combustion process. In order to remove these alkaline impurities, the rice husk needs to be acid treated before burning to obtain rice husk ash (RHA) with higher activity. It means that these three types of acid can help is to increase the extraction of silica (SiO_2) from rice husk ash (RHA) and increase the purity if silica (SiO_2).

3.2.4 Fine Aggregate

Fine aggregate is a material often seen and used in the construction industry. It can also be called sand. It is a granular material composed of finely crushed particles. The fine aggregate is smaller than the coarse aggregate but larger than the silt particles. The particle size is generally 0.075mm to 4.75mm. Fine aggregate also plays a vital role in concrete mixes as it fills the voids between coarse aggregate particles, provides volumetric stability and improves workability. Fine aggregate also helps improve the strength and durability of concrete. Fine aggregates with rounded particles tend to improve workability, while angular particles enhance the bonding between the particles and the cement slurry.

Fine aggregate is usually used in making mortar rather than coarse aggregate. Mortar is a cement material and can also be called an adhesive. Fine aggregate is often used to fill the voids between larger particles of cement in a mortar mixture and helps to improve the overall volumetric stability of the mortar. In addition, sand contributes to the workability of the mortar, making it easier to spread, compact and form. Because the fine particles of sand can be used to lubricate the mixture, it will be easier to apply and work with in masonry work. The mortar therefore increases the strength and durability of the finished masonry. This is because it provides sufficient adhesion, thus enhancing the bonding strength and overall structural integrity of the mortar. In addition, fine aggregate can also provide internal support for the mortar matrix by reducing water ash and help control mortar shrinkage. This method reduces cracks and improves the long-term performance of the masonry. In summary, fine orthopedics can provide mechanical and workability to mortar.

3.2.5 Water

Water is often used to initiate the hydration process of cement, binding the ingredients together and forming a solid matrix. So, the reaction of the cement particles with water to form a hydrated calcium silicate (C-S-H) gel will determine the strength and durability of the mortar. Additionally, water is added to the mortar to achieve the desired consistency and workability. For example, it provides good adhesion and consolidation of mortar between masonry units. In addition, water is the medium for mixing the dry ingredients of the mortar, helping the cementitious material to be evenly distributed throughout the mixture and into a paste. In terms of chemistry, water can also activate chemical reactions, allowing the chemical components to effectively improve the performance of the mortar. Water is also very important in the curing aspect, helping to maintain sufficient moisture content in the mortar to promote hydration and strength development, such as improving the performance and durability of the mortar.

3.3 Preparation of Rice Husk Ash Through Acid Treatment and Combustion

Figure 3.3 Process of acid teratment

Figure 3.4 Electric furnace

In preparing rice husk, 0.1 molar hydrochloric acid (HCl), 0.1 molar sulfuric acid (H2SO4) and 0.1 molar nitric acid (HNO3) will be used. First, prepare rice husks and weigh the required weight, which is 3 kg of rice husks. Then, wash it several times to remove other substances. Drain the washed rice husk to avoid excess moisture. Next, add 12L of distilled water to the rice husk and divide into 3 parts. During the process, 0.1 m of HCl was added to the rice husk slowly and gradually while keeping stirring in order to mix thoroughly, leaching time is 30 hours and 36 hours. After acid treatment, rinse the mixture with water several times until the pH reaches neutral. The cleaned rice husk is dried at 100°C for two hours until the moisture content reaches 10%, and then it is put into a electric furnace and burned for two hours at a temperature of 800°C. The burned rice husks eventually turn to ash. Repeat the above steps twice with sulfuric acid and nitric acid.

3.4 mix proportion of rice husk ash

The dosage of rice husk ash (RHA) to replace the cement mixture are,0%,5% and 10%%. In addition, in order to form a mortar mixture, the ratio of cement to sand is 1:2 and the ratio of cement to water is 1:0.5.

3.5 mixing process of mortar

Start by weighing out the proportions of materials required, including cement, sand and water. Then, mix together the finished proportions of ingredients, add water and mix thoroughly until it's consistent and smooth. After mixing, add the RHA to the mixture and continue mixing until the RHA is evenly distributed in the mortar. Finally, the mortar mixture is poured into the mold and allowed to harden.

3.6 process of casting, molding and demolding


Figure 3.5 Mortar cube (50mm x 50mm x50mm)

Different types of tests and different sizes of RHA mortar samples were used in this study. Firstly, the pouring procedure follows BS EN 12390-2. The compressive strength test and water absorption test were carried out by pouring 50mm and 50mm mortar cubes. Before the casting process, the mold must be cleaned and coated with a layer of grease. The purpose of cleaning is to prevent other debris from being mixed in, and the purpose of grease is to facilitate demolding. After the mortar is placed in the mold, it is vibrated in order to reduce or avoid any honeycombing issues. After casting and stripping, the samples were kept at 25°C for 24 hours.

3.7 Process of Curing

Figure 3.6 Water tank for curing

During the curing process, sufficient water and heat need to be provided. Therefore, the water temperature needs to be maintained between 25 and 29 degrees Celsius for curing, and the curing period is divided into 3 days, 7 days, and 28 days.

3.8 Experiment Test

This study will conduct, x-ray diffraction testing (XRD), particle size analysis (PSA), water absorption test, flow table test and compressive strength tests in order to test and determine the mechanical properties and uses of the mortar.

3.8.3 X-Ray Diffraction Testing (XRD)

This study will conduct X-ray diffraction testing (XRD) on rice husk ash (RHA). First prepare different acid-leached rice husk ash, making sure it is fine powder and has a high surface area. Then, rice husk ash loaded onto a sample holder or stage within the XRD instrument, and spread and compacted onto the holder to ensure a uniform diffraction pattern. The XRD instrument emits X-rays onto the surface of the rice husk ash, and the crystal structure in the rice ash interacts with the X-rays, producing diffraction according to Bragg's law. When the crystal structure in rice husk ash interacts with X-rays, a diffraction pattern is produced. The final diffraction pattern will show the peak composition corresponding to the angle of diffraction of the crystal planes in the rice husk ash. The diffraction data collected by an XRD instrument is in the form of a two-dimensional image or a series of intensity and angle maps, forming a diffraction pattern. Diffraction data can be analyzed by software to identify the crystal structure in rice husk ash. If the crystallinity of the rice husk ash is higher, it will typically result in more pronounced diffraction peaks in the XRD pattern. The study will collect, record and compare crystals in rice husk ash with different acid leaches.

3.8.4 Particle Size Analysis (PSA)

Figure 3.7 particle size analyzer

The study will measure and analyze the particle size distribution in RHA using a particle size analyzer. The test will evaluate the particle size (D0.1, D0.5, D0.9) and specific surface area of RHA. The data will be analyzed and compared to see which acid is most effective in leaching RHA to obtain smaller particles and larger specific area.

3.8.9 Flow Table Test

Figure 3.8 Flow table test

The study will conduct flow table test accordance with ASTM C230 / C230M- 21, to evaluate the workability or consistency of the mortar, similar to a slump test. The difference is that the flow table test does not measure the slump of concrete, which means vertical settlement, whereas the flow table test measures the horizontal flow of concrete spread on a flat circular surface. First, prepare the mortar sample, place it on the flow table unit, and level the table. The flow table device is composed of a circular steel table with a diameter of about 700 mm, and then a rigid circular metal mold with an inner diameter of about 200 mm and a height of about 50 mm is placed in the middle of the platform. The mortar sample is introduced into the mold and spread and compacted within the mold. After compaction, lift the mold smoothly and vertically to allow the mortar to flow laterally and spread outward. Use a ruler to measure the diameter of the mortar spread on the bench in two perpendicular directions. Repeat different mortar samples and make comparisons. Higher flow values indicate higher workability, which means the mortar is more fluid and easier to spread and compact. Conversely, lower flow values indicate lower workability, which means the concrete is harder.

$$Flow\ Table = (D1 - d)/\ d \times 100$$

Where,

D1 = Diameter of the flow, mm

d = Original Diameter (100 mm)

3.8.6 Water Absorption Test

After a 28-day curing period, the samples were tested for water absorption accordance with ASTM C1403- 22a. The water absorption test was used to measure the water absorption of the mortar that mixed with RHA. This test was performed in accordance with ASTM C1403-22a, using 50 mm × 50 mm × 50 mm cubes to perform the test and the mortars will be cured for 28 days. After curing, the mortars were dried in an oven at 100°C for 24 hours and the dry weight was recorded. After record the dry weight of mortars, the mortars will be immersed in water for 30 minutes to allow the samples to absorb water. Lastly, record the weight of the samples after 30 minutes. The test was repeated for the other samples and the water absorption test was performed again.

$$Water\ absorption\ (\%) = (W_w - W_d)\ /W_d \times 100\ \%$$

Where,

Wd = Weight of dry sample, g

Ww = Weight of wet sample, g

3.8.7 Compressive Strength Test

Figure 3.9 Compressive test machine

In this study, in order to test the durability and compressive strength performance of the mortar, the compressive strength test and durability test will be conducted with a mortar cube size of 50 mm × 50 mm × 50 mm. Mortar cubes were tested at 3, 7 and 28 days in compliance with ASTM C109/C109M-21 standards. The final results are run through a compressor to evaluate the sample's maximum load capacity and compressive strength, the value of result in Mpa.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents and analyses the results of laboratory tests. This study evaluates the reactivity of RHA when leached by three types of acids through x-ray diffraction test (XRD) and particle size analysis test (PSA). The types of acids include hydrochloric acid, sulfuric acid and nitric acid. This study also tests the performance of mortars by replacing 0%, 5% and 10% of the cement with rice husk ash through water absorption test, flow table test and compressive strength test. It is evaluated whether the acid leaching of rice ash has any effect on the performance of mortars and do the comparison. The performance factors to be evaluated such as workability, water absorption and compressive strength.

The RHA samples that tested in XRD test and PSA test has 7 samples, such as RHA without acid treatment, RHA leached by HCL in 30h, RHA leached by HCL in 36h, RHA leached by H2SO4 in 30h, RHA leached by H2SO4 in 36h, RHA leached by NHO3 in 30h and RHA leached by NHO3 in 36h. The mortar samples that tested in flow table test, water absorption test and compressive strength test has 9 samples, such as mortar without contain RHA, mortar contain 5% RHA without acid treatment, mortar contain 10% RHA without acid treatment, mortar contain 5% RHA leached by HCL in 36h, mortar contain 10% RHA leached by HCL in 36h, mortar contain 5% RHA leached by H2SO4 in 36h, mortar contain 10% RHA leached by H2SO4 in 36h, mortar contain 5% RHA leached by NHO3 in 36h and mortar contain 10% RHA leached by NHO3 in 36h.

4.2 XRD Test

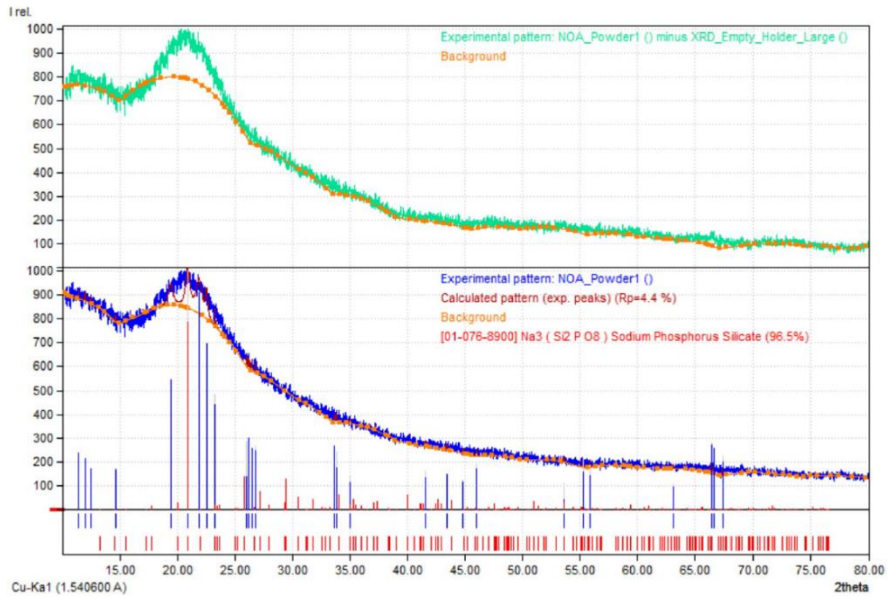


Figure 4.1 XRD pattern of RHA without acid treatment (Appendix 1)

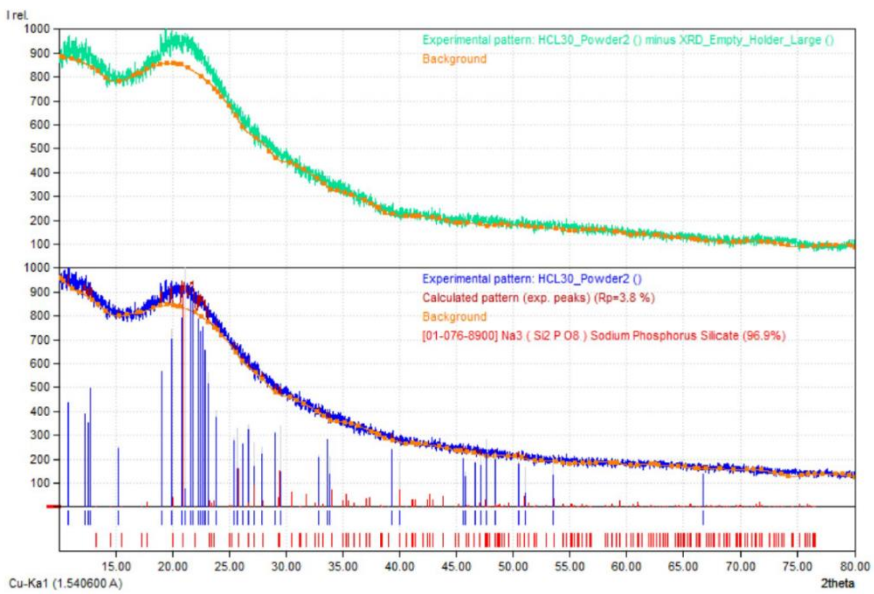


Figure 4.2. XRD pattern of RHA through acid treatment (Appendix 2)

According to the figure 4.1, this is the XRD result of RHA without acid treatment. The result shows that the broad peak in the XRD pattern appears between $2\theta=15°$ and $2\theta=25°$, but there is a slightly sharp feature in the broad peak. This means that RHA without acid treatment has amorphous silica and a small amount of crystalline silica. In addition, a weaker peak was found at 66.42° 2θ, which also proved that this peak indicated the presence of a smaller amount of crystalline silica in this phase. According to the figure 4.2, there is less crystalline silica present in the RHA that has been acid treated compared with RHA without acid treatment. The result also shows that the broad peak in the XRD pattern appears between 2θ=15° and 2θ=25°. The different between RHA that has been acid treated and RHA without acid treatment in the XRD pattern is the RHA without acid treatment has a narrower peak. It means that the RHA that has been acid treated has more amorphous silica and less crystalline silica compared with RHA without acid treatment.

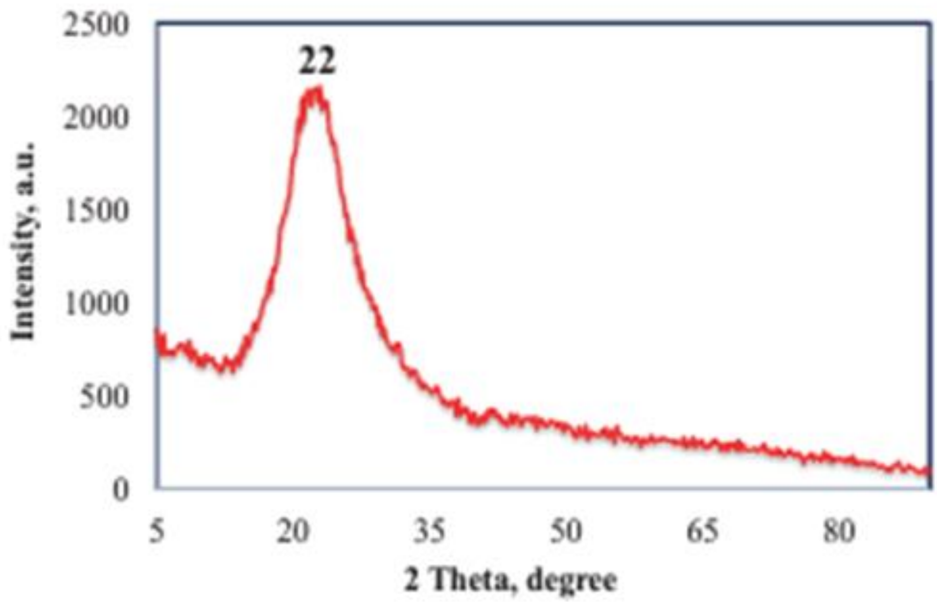


Figure 2.2 Sample leached by acid (Nzereogu, P.U. *et al.*,2023)

According to figure 2.2, the XRD pattern shows a broad peak at 2θ equal to 22°, which is identified as an amorphous structure. Besides, the XRD pattern shows a broad peak at 2θ equal to 20.9° and 21.1° in the figure 4.1 and 4.2. It means that the broad peak around 20.9° and 21.1° are characteristic of amorphous silica.

Table 4.1 Content of crystalline silica and amorphous silica in the RHA

sample	Crystalline %	Amorphous %
RHA-NO	6.02	93.98
RHA-H30	4.62	95.38
RHA-H36	5.71	94.29
RHA-S30	4.23	95.77
RHA_S36	4.66	95.34
RHA-N30	4.56	95.44
RHA-N36	4.96	95.04

RHA-NO - RHA without acid treatment (Appendix 1)

RHA-H30 - RHA leached by HCL in 30h (Appendix 2)

RHA-H36 - RHA leached by HCL in 36h (Appendix 3)

RHA-S30 - RHA leached by H2SO4 in 30h (Appendix 4)

RHA_S36 - RHA leached by H2SO4 in 36h (Appendix 5)

RHA-N30 - RHA leached by NHO3 in 30h (Appendix 6)

RHA-N36 - RHA leached by NHO3 in 36h (Appendix 7)

According to the table 4.1, the results the sample that no leached by acid (RHA-NO) contains 6.02% of crystalline silica and 93.98% of amorphous silica. Comparing with other RHA that have undergone different acid treatments, it found that acid treatment does help reduce crystalline silica and increase amorphous silica. According to the results in table 4.1, the lowest crystalline silica is about 4.23% and the highest amorphous silica is about 95.77 % (RHA-30). It means that the highest percentage of crystalline silica can reduce about 1.79% In this test, three acids were used to leach RH, i.e., hydrochloric acid, sulfuric acid and nitric acid, and two times were used to leach RHA, i.e., 30 hours and 36 hours. According to the survey, the longer the leaching time, the less crystalline silica should be present. However, the results showed that the RHA leached after 36 hours (RHA-H36, RHA-S36, RHA-N36) had more crystalline silica than the RHA leached after 30 hours (RHA-H30, RHA-S30, RHA-N30) . Since RH is poured into water before adding acid, some RH will not be evenly leached, which will eventually cause data problems. The problem lies in the leaching step, the acid should not be added after RHA is added to water. Water and acid should be mixed first to get dilute acid before leaching RHA, so that RHA can be evenly leached. Although there were some errors, but this test can be proved that acid can remove metal impurities in RHA to obtain higher amorphous silica and reduce the formation of crystalline silica in RHA.

4.3 PAI Test

Table 4.2 The result of particle size analysis test

sample	d(0.1), (um)	d(0.5), (um)	d(0.9), (um)	specific surface area (m2/g)	surface weighted mean d(3.2), (um)	vol. weighted mean d(4,3), (um)
RHA-NO	**14.457**	**74.452**	**378.491**	**0.189**	**31.822**	**156.392**
RHA-H30	**12.812**	**63.076**	**238.508**	**0.212**	**28.299**	**119.380**
RHA-H36	**11.299**	**55.472**	**208.308**	**0.237**	**25.352**	**103.900**
RHA-S30	**13.557**	**63.652**	**233.866**	**0.205**	**29.240**	**113.498**
RHA_S36	**11.344**	**56.383**	**212.578**	**0.234**	**25.618**	**99.632**
RHA-N30	**13.643**	**66.041**	**261.179**	**0.202**	**29.697**	**116.456**
RHA-N36	**11.859**	**59.789**	**247.633**	**0.225**	**26.676**	**117.205**

RHA-NO – RHA without acid treatment (Appendix 8)

RHA-H30 – RHA leached by HCL in 30h (Appendix 9)

RHA-H36- RHA leached by HCL in 36h (Appendix 10)

RHA-S30 – RHA leached by H2SO4 in 30h (Appendix 11)

RHA_S36 - RHA leached by H2SO4 in 36h (Appendix 12)

RHA-N30 – RHA leached by NHO3 in 30h (Appendix 13)

RHA-N36 - RHA leached by NHO3 in 36h (Appendix 14)

The particle size analysis test is used to test the size or diameter of each individual particle in the material. According to the survey, the particles of RHA will affect the performance of mortar or concrete. The above table 4.2 shows 6 key terms in particle size analysis, such as D (0.1), D (0.5), D (0.9), specific surface area, surface weighted average, and volume average particle size. First, D10, D50, and D90 are cumulative particle size distributions, which are used to describe the range of particle sizes in the sample. These three cumulative particle size distributions can also be defined as 10%, 50%, and 90% of the particles are smaller than certain sizes. According to the results in the table 4.2, the sample with the largest particle size is RHA without acid treatment (RHA-NO), with 10% of the particles smaller than 14.457 um, 50% of the particles smaller than 74.452 um, and 90% of the particles smaller than 378.491 um. The sample with the smallest particle size is RHA-H36, with 10% of the particles smaller than 11.299 um, 50% of the particles smaller than 55.472 um, and 90% of the particles smaller than 208.308 um. The next smallest particle size is RHA-S36, and the third is RHA-N36. So, the order of particle size from small to large is RHA-H36, RHA-S36, RHA-N36, RHA-H30, RHA-S30, RHA-N30 and RHA-NO.

According to the specific surface area scores in the table 4.2, the sample with the largest specific surface area is RHA-H36, which is 0.237m2/g. The sample with the smallest specific surface area is RHA-NO, which is 0.189m2/g. The order of specific surface area from small to large is RHA-NO, RHA-N30, RHA-S30, RHA-H30, RHA-N36, RHA-S36 and RHA-H36.

Next, the surface weighted average focuses on the average particle size based on surface area. The highest value of the surface weighted average in the sample is RHA-NO, which is 31.822um. The lowest value is RHA-H36, which is 25.352um. So, the order of surface weighted average values from low to high is RHA-H36, RHA-S36, RHA-N36, RHA-H30, RHA-S30, RHA-N30 and RHA-NO. This proves that RHA-H36 has a greater weight for finer particles and also proves that the lower surface weighted average has finer particles with larger surface area. RHA-H36 can be used in mortar to achieve the greatest improvement in pozzolanic reactivity, compressive strength and packing density.

Finally, the volume weighted average diameter focuses on the average particle size based on volume. The highest value of volume weighted average in the sample is RHA-NO, which is 156.392um. And the lowest value of surface weighted average is RHA-S36, which is 99.632um. So, the order of volume weighted average values from low to high is RHA-S36, RHA-H36, RHA-N36, RHA-H30, RHA-S30, RHA-N30 and RHA-NO. This proves that RHA-NO, which has the highest volume weighted average, has coarser particles.

Table 2.7 Particle size analysis of RHA from previous research. (Leong, Tuck Lun, 2015)

sample	**D(50)**
RHA through temperature 600	67.09 um
RHA through temperature 700	85.85 um

According to table 2.7, the result of sample that no leached by acid and done by previous researcher has high value of D(50), 67.09 um and 85.85 um. Comparing to table 4.1, the sample that no leached by acid also has a high value of D(50), 74.452 um.

According to these two results, the D(50) value of sample that leached by acid can decrease about 12.74% to34.22% compared with the D(50) value of sample that no leached by acid. It means that the particle size of particle in the sample that leached by acid is finer than sample that no leached by acid, the specific area of particle in the sample that leached by acid also wider than sample that no leached by acid at the same time.

This test prove that the larger the specific surface area of the particles, the greater the enhancement of the pozzolanic reaction, which can help enhance the reaction between RHA and calcium hydroxide ($Ca(OH)_2$) in cement, forming more calcium silicate hydrate (C-S-H), which greatly improves the compressive strength of the mortar. Generally, particles with larger surface areas have finer particles, which can easily fill more voids in mortar and concrete, making the mortar or concrete denser and stronger. The high surface area makes the mortar or concrete contribute to better bonding and more efficient load transfer between particles. In addition, a higher specific surface area exposes more surface area to water, which can increase the hydration reaction and setting time. So, the RHA-H36 is the sample that suitable to cast mortar or concrete.

4.4 Flow Table Test

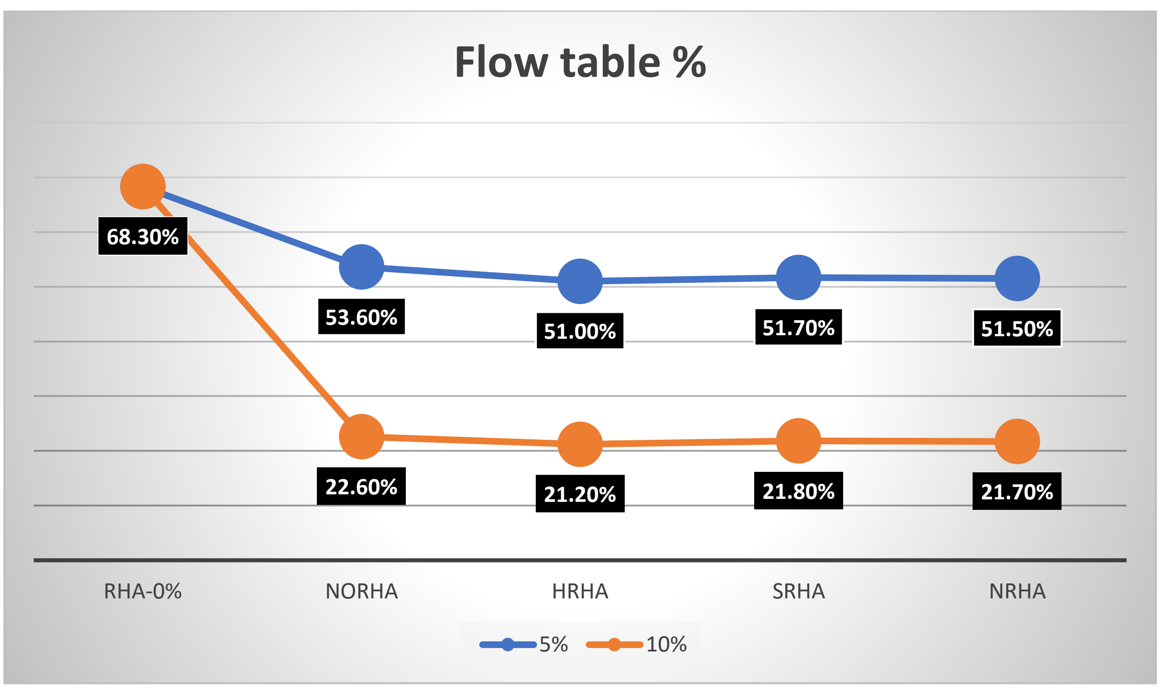


Figure 4.3 The workability of mortar mixed with RHA

RHA-0% - Mortar no contain RHA

NORHA – Mortar contain RHA without acid treatemnt

HRHA - Mortar contain RHA leached by HCL in 36h

SRHA - Mortar contain RHA leached by H2SO4 in 36h

NRHA- Mortar contain RHA leached by NHO3 in 36h

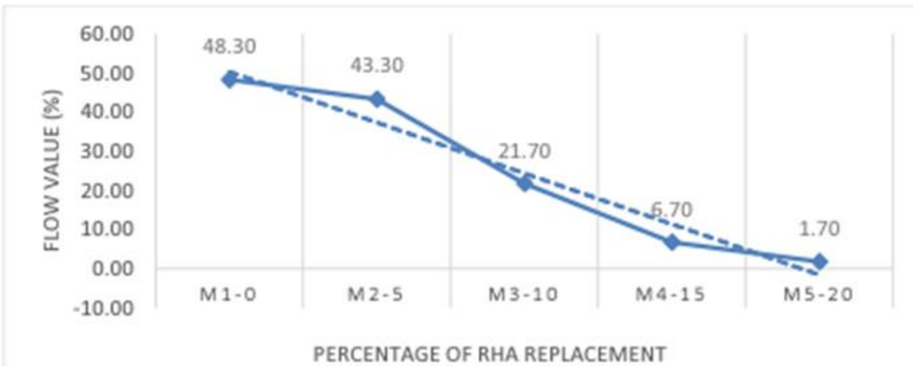


Figure 2.3 The Workability of mixture vs the percentage of RHA replacement.

Figure 4.4 Sample contains 5% RHA

Figure 4.5 Sample contains 10% RHA

The flow table test is used to measure the consistency and workability of concrete or mortar. The flow value is measured in millimeters and is expressed as an average spread of mortar. If the average spread of the sample is larger, it means that the workability is higher. At the same time, the average spread of sample is smaller, the workability is lower. According to the figure 4.3, the flow value of sample without RHA replacement (RHA-0%) is 68% and the flow value of sample that has contain RHA (NORHA-5% and 10%, HRHA-5% and 10%, SRHA-5% and 10%, NRHA-5% and 10%) is below 53.6%. It means that the rice husk ash has strong water absorption properties and low density cause the flow value decrease. At the same time, the sample that contain 10% RHA has a lower flow value compared with the sample that contain 5%.

According to previous data in figure 2.3 (Zakaria, N. *et al.*, 2023), the flow value also decreases, when the percentage of RHA contain in the sample increase. It proves that when the quantity of the RHA increase in the mortar, the flow level of the sample will be decreased. According to figure 4.4 and figure 4.5, the condition of sample that contains 10% RHA is drier than sample that contain 5% RHA. It means that the workability of sample that contains 10% RHA is lower than sample that contains 5% RHA. Rice husk ash has a high porosity due to its small particles, which means it has a lot of space to absorb more water. In addition, rice husk ash has a large surface area that requires more water to wet the particles and achieve proper dispersion in the mixture. According to the table 4.2, the RHA-H36 is the sample that leached by hydrochloric acid and time leaching is 36 hours. The result show that the RHA-H36 has finer particle and larger specific area compared with other RHA. So, the flow value of RHA that leached by hydrochloric acid (HRHA-5% and 10%) has a lowest value showed in table 4.3, which are 51% and 21.2% respectively.

4.5 Water Absorption Test

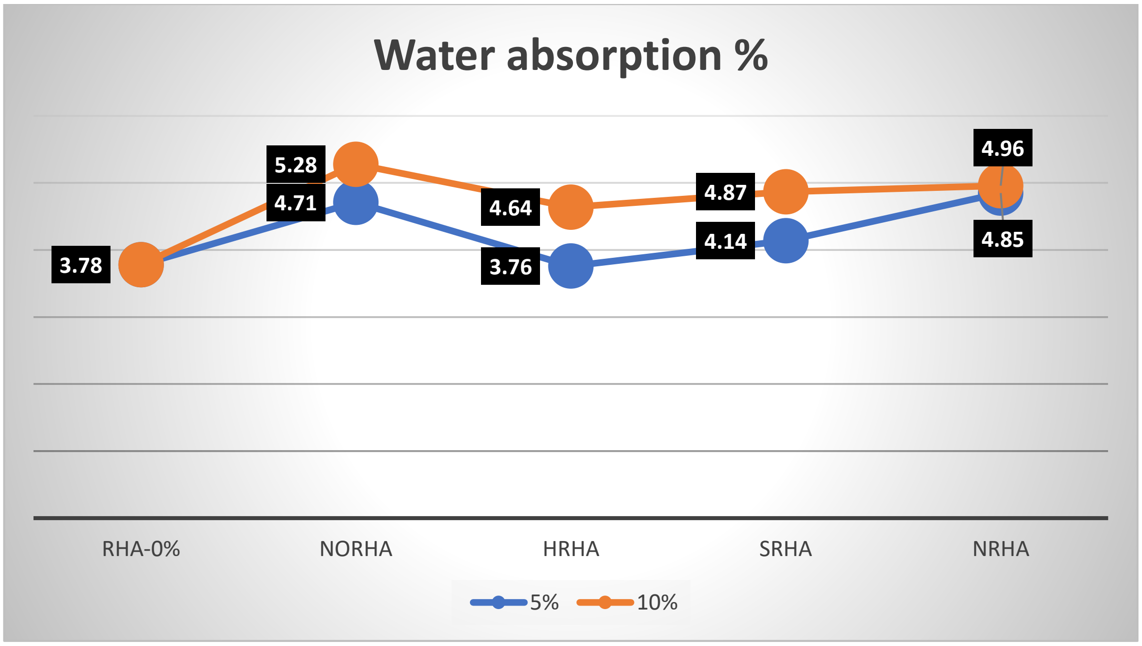


Figure 4.6 The water absorption of mortar mixed with RHA

RHA-0% - Mortar no contain RHA

NORHA – Mortar contain RHA without acid treatemnt

HRHA - Mortar contain RHA leached by HCL in 36h

SRHA - Mortar contain RHA leached by H2SO4 in 36h

NRHA- Mortar contain RHA leached by NHO3 in 36h

According to figure 4.6, the mortar mixed with 5% RHA (HRHA) that leached by hydrochloric acid has the lowest water absorption compared with others, 3.76%. The highest water absorption is the mortar mixed with 10% RHA (NORHA) that leached by nitric acid, 5.28%. So, the order of water absorption is HRHA (5%), RHA (0%), SRHA (5%), NRHA (5%), NORHA (5%), HRHA (10%), SRHA (10%), NRHA (10%) and NORHA (10%). Above data is the condition of sample after curing 28 days.

Table 2.7 Water absorption of mortar from previous research

Sample	Water absorption %	References
Sample without RHA	4.63%	Salas, A. *et al.* ,2009.
Sample without RHA	4.12%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA	4.26%	Salas, A. *et al.* ,2009.
Sample 5% replacement of RHA	3.95%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA	3.7%	Endale, S.A. *et al.*,2022
Sample 15% replacement of RHA	3.46%	Endale, S.A. *et al.*,2022
Sample 20% replacement of RHA	3.23%	Endale, S.A. *et al.*,2022
Sample 25% replacement of RHA	3.05%	Endale, S.A. *et al.*,2022
Sample 10% replacement of RHA leached by acid	3.61%	Salas, A. *et al.* ,2009.

According to the study of Salas, A. et al. 2009, RHA in mortar will produce pozzolanic reactivity and can greatly reduce the average pore size, making the mortar impermeable and reduce water absorption. The reason is that RHA is smaller in size and can be used to fill the pores between mortar. According to the table 2.7, mortar contain 10% RHA showed lower water absorption because the addition of RHA makes the water absorption of mortar lower. In addition, acid-treated RHA will reduce the water absorption of mortar. The results in Table 2.7 show that the water absorption of RHA without acid treatment and RHA with acid treatment are 4.26% and 3.61%, respectively. This means that acid treatment can reduce about 0.65%. According to Endale, S.A. et al., 2022 data, the water absorption of cement replaced with 5% to 25% rice husk ash is reduced from 3.95% to 3.05%. According to figure 4.6, the water absorption of cement replaced with 5% to 10% rice husk ash is increase about 0.11% to 0.88%. it means that the water absorption of sample that replace 10% RHA is higher than sample that replace 5% RHA and only one of the samples HRHA (5%) is lower than sample without contain RHA(RHA-0%).

4.6 Compressive Strength Test

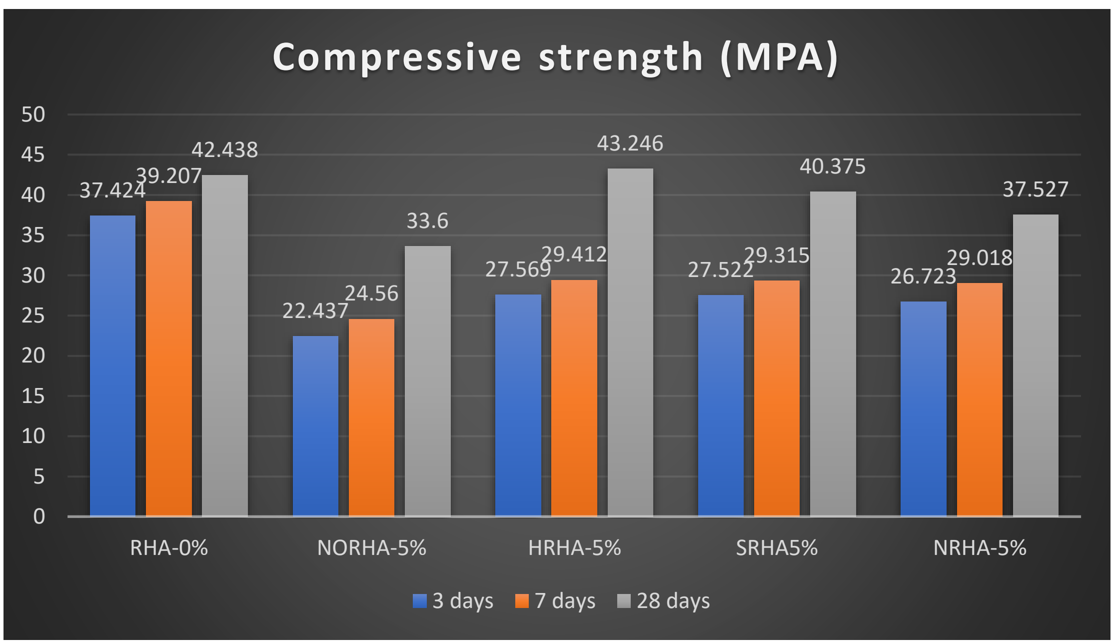


Figure 4.7 Compressive strength of mortar mixed 5% RHA

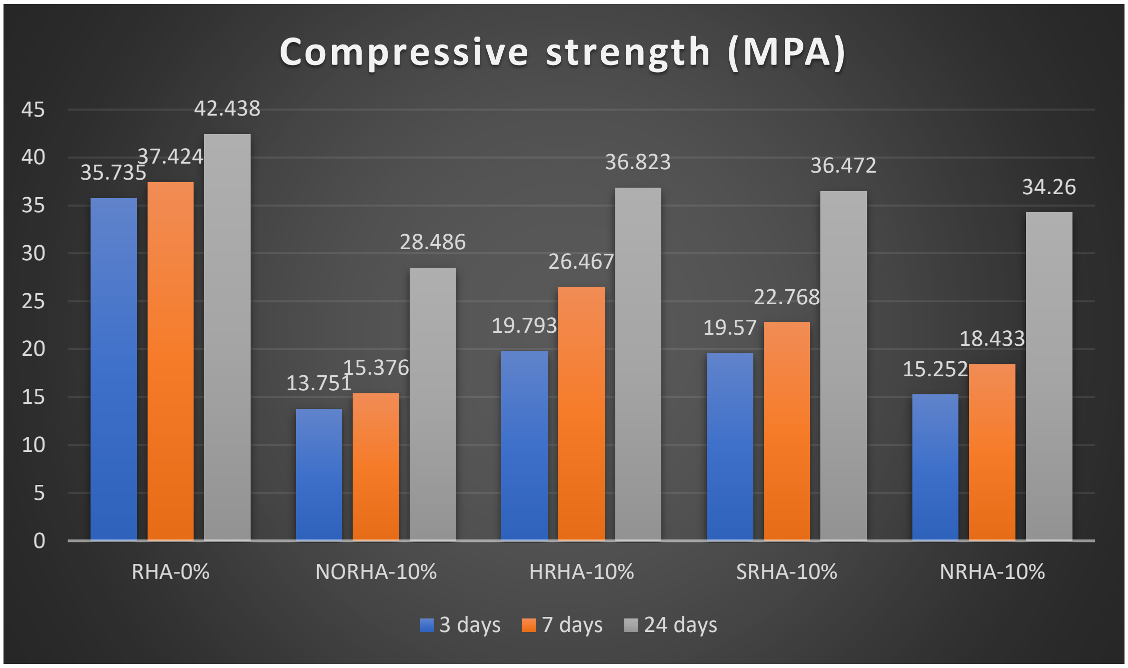


Figure 4.8 Compressive strength of mortar mixed 10% RHA

RHA-0% - Mortar no contain RHA

NORHA – Mortar contain RHA without acid treatemnt

HRHA - Mortar contain RHA leached by HCL in 36h

SRHA - Mortar contain RHA leached by H2SO4 in 36h

NRHA- Mortar contain RHA leached by NHO3 in 36h

Above figures 4.7 and 4.8 showed the compressive strength of mortar mixed with 5% and 10% RHA after curing 3 days, 7 days, and 28 days. The RHA also leached by different acid and do the comparison with them. The purpose of compressive strength is determinizing the performance of acid leached RHA as replacement cement. According to figure 4.7 and 4.8, the highest compressive strength is the sample that contain 5% of RHA that leached by hydrochloric acid (HRHA-5%), about 43.246 Mpa. According to 28 days period, almost all the samples are lower than sample without contain RHA (RHA-0%) except HRHA-5%. Comparisons between 3 days, 7 days and 28 days, the sample that contain RHA that leached by acid has a higher compressive strength compared with the sample that contain RHA without acid treatment (NORHA-5%,10%). Regardless of the results shown in Figure 4.7 or Figure 4.8, the highest value of compressive strength is sample that contain RHA leached by hydrochloric acid (HRHA-5%,10%). Second and third highest value of compressive strength are the sample that contain RHA leached by sulfuric acid (SRHA-5%,10%) and sample that contain RHA leached by nitric acid (NRHA-5%,10%), and the lowest value of compressive strength is the sample that contain RHA without acid treatment. It means that the acid can enhance the properties of mortar that contain RHA. According to results showed in figure 4.7 and 4.8, the hydrochloric acid (HCL) is a best choice and suitable to be a leaching agent to leach RHA.

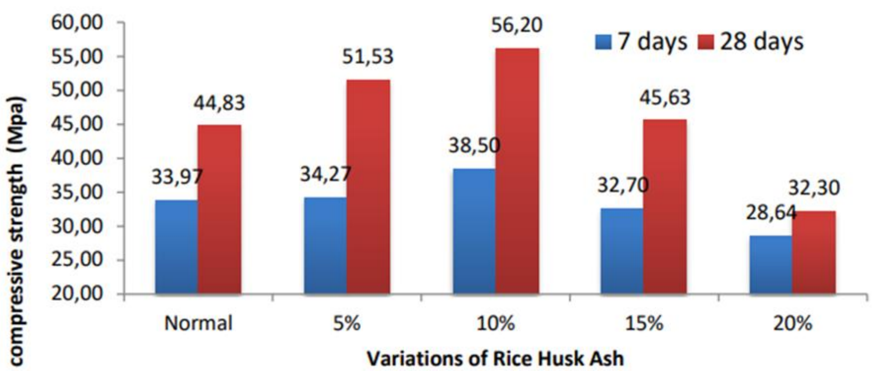


Figure 2.4 Graph comparing the mean compressive strength of concrete at 7 days and 28 days, with variations of rice husk ash of 0%, 5%, 10%, 15%, 20% as the cement substitute. (Nursyamsi, N, 2021)

According to the previous data in figure 2.4, the compressive strength was increasing when the percentage of RHA mixed with sample was increasing. The data showed that sample mixed with 10 % RHA has the highest compressive strength, and highest value is 56.20 Mpa. In additional, the compressive strength of samples that mixed with 5% and 10% RHA are higher than sample that without contain RHA. The data showed in figure 4.7 and 4.8, the factor cause almost samples have lower compressive strength compared with sample without contain RHA(RHA-0%) is low cement ratio. The reasons are the RHA contain high water absorption capacity large specific surface area, if the low amount of water contain in the cement ratio will cause the reduction in compressive strength of mortar. According to the table 4.2, RHA has a high surface area and porous, which means it can absorb a lot of water when mixing the mortar. It means that it will cause the normal water-cement ratio become lower, so the low amount of water is not be enough to meet the hydration of cement and the pozzolanic reaction of RHA in mortar. The figure 4.5 also proves that the sample that contain 10% RHA has the lowest workability, which means the condition of mortar is too dry. This kind condition of mixture very hard to cast to be a hard mortar, also hard to reach the target value of compressive strength.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The research conducted was concerned with the effect of the different types of acid on the reactivity of rice husk ash (RHA) and the mechanical properties of mortars that mixed with different proportion of RHA leached by different acids. The results of various tests were analyzed to draw conclusions regarding the effect of different acids on RHA and the suitability of RHA as an alternative material for mortars.

1. the X-ray diffraction test (XRD) diagram shows that the metal impurities in RHA will cause the silica to form crystals, and also proves that different acids can remove metal impurities and obtain more amorphous silica. The lowest and highest of crystalline silica contain in samples are about 4.23% and 6.02%. It means that the highest percentage of crystalline silica can reduce about 1.79% after acid treatment. After acid treatment, RHA can obtain up to 95.77% of amorphous silica.

2. Particle size analysis test was used and it was found that by leaching RHA with hydrochloric acid for 36 hours, smaller particles and larger specific surface area can be obtained. The smallest sizes (D0.1, D0.2 and D0.3) can reach 11.299μm, 55.472μm and 208.308μm. The order of particle size from small to large is RHA-

H36, RHA-S36, RHA-N36, RHA-H30, RHA-S30, RHA-N30 and RHA-NO. In addition, the largest specific area can reach 0.237. The order of specific surface area from small to large is RHA-NO, RHA-N30, RHA-S30, RHA-H30, RHA-N36, RHA-S36 and RHA-H36. It means that largest particle size and smallest specific surface are is the RHA without acid treatment (RHA-NO). This test proves the acid can effectively to reduce particle size of RHA and increase specific surface area. It also proves that the time to leach the RHA longer, more effectivity.

3. The flow table test shows that sample without contain RHA (RHM-0%) has the highest flow value of 68.30%, which has the best workability compared with the samples that contains RHA. Next, the medium workability mortars are HRHA (5%), SRHA (5%), NRHA (5%) and NORHA （5%）. The flow value of sample that contain 10% RHA that leached by hydrochloric acid is the lowest.RHM-20 are lowest, 21.20%. Almost samples that contain 10% RHA has lower flow value, which means low workability. This test show that the higher proportion of RHA added to the mortar, the workability of mortar is lower.

4. Water absorption test was conducted to evaluate the durability of RHA mortar. The results showed that HRHA (5%) had the lowest water absorption (3.76%). The RHA that contain high silica in mortar will produce pozzolanic reactivity and can greatly reduce the average pore size, making the mortar impermeable and reduce water absorption. As the proportion of RHA in the sample increased, the water absorption value also increased, which will affect the durability of the mortar.

5. The compressive strength of the sample leached by different acid was tested at 3, 7, and 28 days after curing. The results showed that the sample that contain 5% RHA that leached by hydrochloric acid (HRHA-5%) has the highest compressive strength at all test intervals, reaching a maximum value of 43.246 Mpa at 28 days. When the RHA content increased, the compressive strength of the mixes decreased.

So, the sample that has contain 10% RHA without acid treatment has the lowest compressive strength of 28.486 Mpa at 28 days.

Overall, the results indicate that RHA is an agriculture waste that can be a suitable replacement material in mortar mixtures. In addition, acid is helpful in improving the properties of RHA and mortar. The limitations and challenges faced are due to the decrease in workability of mortar with increasing RHA content. Higher proportion of RHA leads to lower compressive strength and also to increased water absorption. In addition, sulfuric acid and nitric acid do not perform as well as hydrochloric acid. For example, RHA leached with hydrochloric acid results in smaller particles and specific surface area.

5.2 Recommendations

The results of this study on mortars made from RHA that leached by different acids are not represent or guarantee full representation of their overall performance. This is because the performance of mortars can be affected by a variety of parameters, such as the material, the acid ph value of the RHA left after acid treatment, the curing method and other factors. Therefore, the further research is needed to obtain comprehensive information on the performance of acid and RHA mortars. Based on the results of the study, it is recommended that more types of studies be conducted in order to investigate the influence of various parameters on the performance of RHA mortars.

1. Adjustment of cement-water ratio to improve the workability of the mortar,

2. Utilization of other acids to leach RHA to obtain higher amorphous silica.

3. Utilization of high concentrations of acid to leach RHA to get better results.

4. The durability of the RHA mortar mixture should be examined under different environmental conditions.

5. Utilization other materials as cement substitutes, such as egg shells, which also have silica.

REFERENCES

Abdul Salim, Z.A. et al., 2023. Characterisation of high purity rice husk silica synthesised using solvent-thermal treatment with different concentration of acid leaching, *Jurnal Teknologi*, 85(2), pp. 101–110.

Antiohos, S.K., Papadakis, V.G. and Tsimas, S., 2014. Rice husk ash (RHA) effectiveness in cement and concrete as a function of reactive silica and fineness, *Cement and Concrete Research*, 61–62, pp. 20–27.

Azat, S. *et al.*, 2019. Extraction of high-purity silica from rice husk via hydrochloric acid leachingtreatment, *TURKISH JOURNAL OF CHEMISTRY*, 43(5), pp. 1258–1269.

Azza, lH. et al., 2022. Preparation and Characterization of Egyptian Rice Husk Ash, pp. 1–12.

Bakar, R.A., Yahya, R. and Gan, S.N.,2016. Production of High Purity Amorphous Silica from Rice Husk, *Procedia Chemistry*, 19, pp. 189–195.

Bakhshi, M., Mortaheb, H.R. and Amini, M.H., 2021. Removal of Trace Metal Impurities from Pretreated Phosphoric Acid by Foam Fractionation, *Journal of Surfactants and Detergents*, 24(3), pp. 491–499.

Chakraverty, A., Mishra, P. & Banerjee, H.D., 1988. Investigation of combustion of raw and acid-leached rice husk for production of pure amorphous white silica. *J Mater Sci*, 23, pp. 21–24.

Deng, J., Feng, X. and Qiu, X., 2009. Extraction of heavy metal from sewage sludge using ultrasound-assisted nitric acid, *Chemical Engineering Journal*, 152(1), pp. 177–182.

Emetere, M.E. and Dania, E.,2019. Short review on air pollution from cement factories, *Journal of Physics: Conference Series*, 1299(1), p. 012033.

Endale, S.A. *et al.*,2022.'Rice husk ash in concrete, *Sustainability*, 15(1), p. 137.

Faizul, C.P. and Kein, W.K., 2019. Removal of iron in rice husk via oxalic acid leaching process, IOP Conference Series: *Materials Science and Engineering*, 701(1), p. 012021.

Fan, R. *et al.*, 2021. Metal material resistant to hydrochloric acid corrosion, *Journal of Physics. Conference Series*, 1732(1), p. 012134.

Fernando, H.-R., Pineda-GomezPosidia and Rosales-Rivera, A., 2018. Synthesis and characterisation of submicron silica particles from rice husk,' *Green Materials*, 6(1), pp. 15–22.

Gautam, A., Batra, R.J. and Singh, N.K., 2019. A study on use of rice husk ash in concrete, *Engineering Heritage Journal*, pp. 01–04.

Ghorbani, F., Sanati, A.M. and Maleki, M., 2015. Production of Silica Nanoparticles from Rice Husk as Agricultural Waste by Environmental Friendly Technique, *Environmental Studies of Persian Gulf*, 2(1), pp. 56–65.

Hamid, R., Ibrahim, N. & Jamadin, A., 2013. Influence of grinding or rice husk ash to the workability and strength of concrete. International Refereed Journal of Engineering and Science (IRJES), 2(2), pp. 50-54.

Kamath, S.R. and Proctor, A., 1998. Silica Gel from Rice Hull Ash: Preparation and Characterization, *Cereal Chemistry*, 75(4), pp. 484–487.

Kwan, W.H. and Wong, Y.S., 2020. Acid leached rice husk ash (ARHA) in concrete: A Review, *Materials Science for Energy Technologies*, 3, pp. 501–507.

Leong, Tuck Lun, 2015. *Effects of Rice Husk Ash (RHS) Produced from Different Temperatures on the Performances of Concrete.* Final Year Project, UTAR

Liu, J. et al., 2020. Hydrochloric acid pretreatment of different types of rice husk ash influence on the properties of cement paste, *Materials*, 13(7), p. 1524.

Njoku, I.J., Nwaokafor, P. and Okeke, N.K.,2021. Assessment of the contamination of rice husk ash of Izzi CP, Ikwo CP and Izzi R8 rice species of South-Eastern Nigeria, *Environmental Challenges*, 5, p. 100232.

Nursyamsi, N. and Aruan, A.F., 2021. Application of rice husk ash in high strength concrete, *IOP Conference Series Materials Science and Engineering*, 1122(1), p. 012013.

Nzereogu, P.U. *et al.*,2023. Silica extraction from rice husk: Comprehensive review and applications, *Hybrid Advances*, 4, p. 100111.

Padhi R S, Patra R K, Mukharjee B B and Dey T 2018, Constr. Build. Mater. 173 289–97

Rahmani, A.H. et al., 2018. Effect of Exposure to Cement Dust among the Workers: An Evaluation of Health Related Complications, *Open Access Macedonian Journal of Medical Sciences*, 6(6), pp. 1159–1162.

Saceda, J.-J.F., De Leon, R.L. and Wittayakun, J., 2011. Properties of silica from rice husk and rice husk ash and their utilization for zeolite y synthesis, *Química Nova*, 34(8), pp. 1394–1397.

Salas, A. *et al.* ,2009. Comparison of two processes for treating rice husk ash for use in high performance concrete, *Cement and Concrete Research*, 39(9), pp. 773–778.

Schmiermund, T., 2022. Acid-Base theories, in *Springer eBooks*, pp. 205–215.

Seng, W.Y., 2019. Performance of Acid Leached Rice Husk Ash (ARHA) in Mortar, *Materials Science for Energy Technologies*, pp. 1–10.

Shetty, S. et al.,2023. Environmental pollutants and their effects on human health, *Heliyon*, 9(9), p. e19496.

Steven, S. et al., 2021. An appropriate acid leaching sequence in rice husk ash extraction to enhance the produced green silica quality for sustainable industrial silica gel purpose, *Journal of the Taiwan Institute of Chemical Engineers*, 122, pp. 51–57.

Sulistiyono, E. *et al.*, 2021. Implementation of sulfuric acid leaching for aluminum and iron removal for improvement of low-grade silica from quartz sand of Sukabumi, Indonesia, *Eastern-European Journal of Enterprise Technologies*, 3(6 (111)), pp. 32–40.

Tayeh B A, Alyousef R, Alabduljabbar H and Alaskar A 2021, J. Clean. Prod. 312 127734

Van Der Hagen, M. and Järnberg, J., 2009. 140. Sulphuric, hydrochloric, nitric and phosphoric acids. [Online] Available at: https://www.av.se/globalassets/filer/neg/sulphuric-hydrochloric-nitric-and-phosphoric-acids-2009-43.pdf > [accessed 19 Apr. 2024]

Vayghan, A.G., Khaloo, A.R. and Rajabipour, F., 2013. The effects of a hydrochloric acid pre-treatment on the physicochemical properties and pozzolanic performance of rice husk ash, *Cement and Concrete Composites*, 39, pp. 131–140.

Wilkie, S. and Dyer, T., 2023. Mortar and concrete: precursors to modern materials, *International Journal of Architectural Heritage*, pp. 1–24.

Zakaria, N. *et al.*, 2023.Workability and Compressive Strength of Mortar with Addition of Rice Husk Ash (RHA) as Partial Cement Replacement in Engineered Cementitious Composite (ECC),' *IOP Conference Series Earth and Environmental Science*, 1135(1), p. 012052.

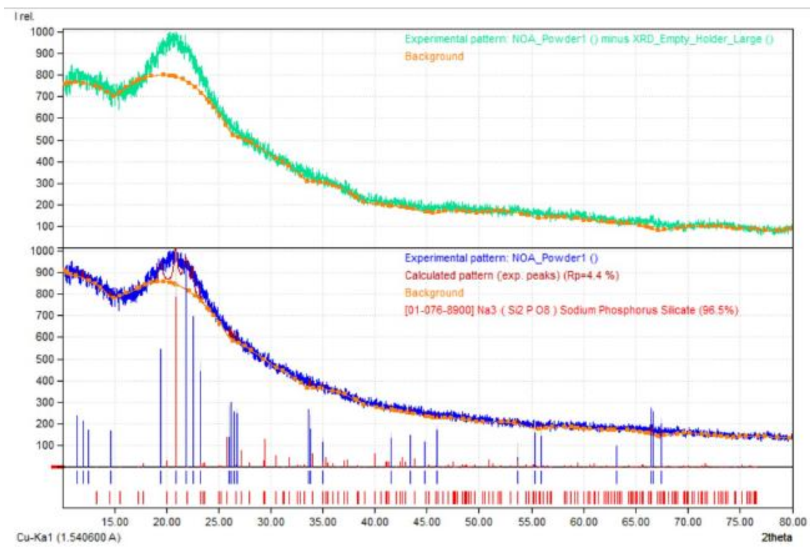
APPENDIX

Appendix 1: XRD pattern of RHA without acid treatment

Degree of crystallinity analysis

Profile area	*Counts*	*Amount*
Total area	3385682	100.00%
Diffraction peaks	150003	4.43%
Background	3235679	95.57%
Instrumental background	892103	26.35%
Amorphous phases	2343575	69.22%

Degree of crystallinity (DOC) = 6.02%
Amorphous content (weight %) =93.98%

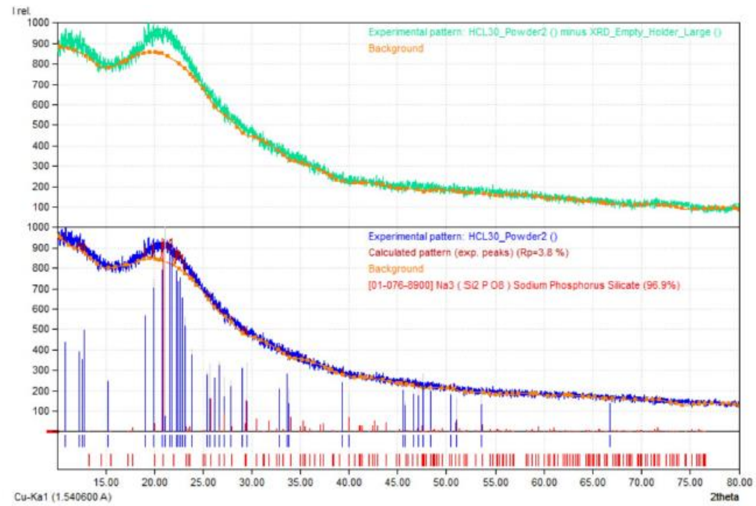


Appendix 2: XRD pattern of RHA leached by HCL in 30h

Degree of crystallinity analysis

Profile area	*Counts*	*Amount*
Total area	3745442	100.00%
Diffraction peaks	131934	3.52%
Background	3613508	96.48%
Instrumental background	892103	23.82%
Amorphous phases	2721404	72.66%

Degree of crystallinity (DOC) = 4.62%
Amorphous content (weight %) =95.38%

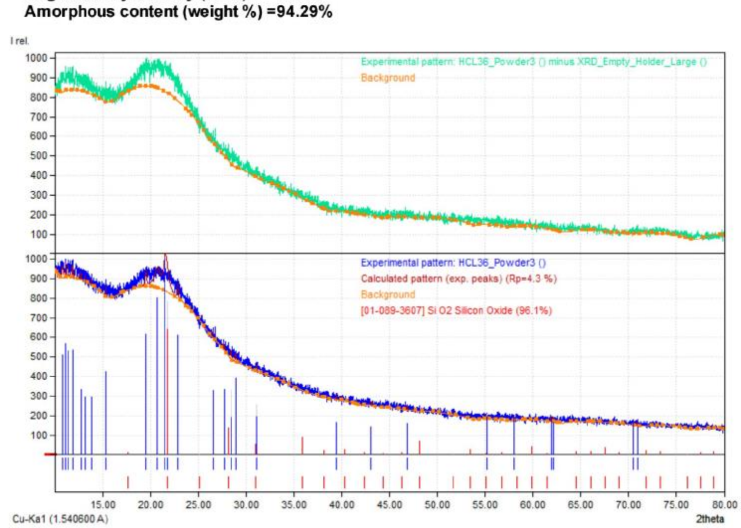


Appendix 3: XRD pattern of RHA leached by HCL in 36h

Degree of crystallinity analysis

Profile area	*Counts*	*Amount*
Total area	3522182	100.00%
Diffraction peaks	150101	4.26%
Background	3372081	95.74%
Instrumental background	892103	25.33%
Amorphous phases	2479978	70.41%

Degree of crystallinity (DOC) = 5.71%
Amorphous content (weight %) =94.29%

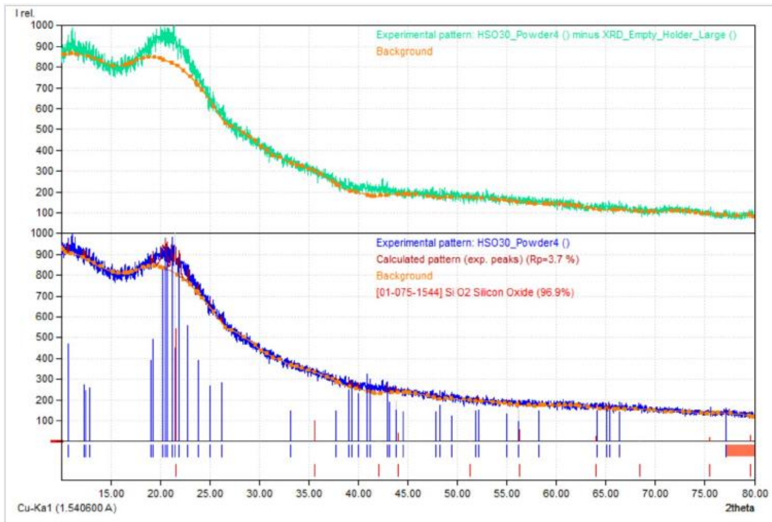


Appendix 4: XRD pattern of RHA leached by H2SO4 in 30h

Degree of crystallinity analysis

Profile area	*Counts*	*Amount*
Total area	3625110	100.00%
Diffraction peaks	115565	3.19%
Background	3509545	96.81%
Instrumental background	892103	24.61%
Amorphous phases	2617442	72.20%

Degree of crystallinity (DOC) = 4.23%
Amorphous content (weight %) =95.77%

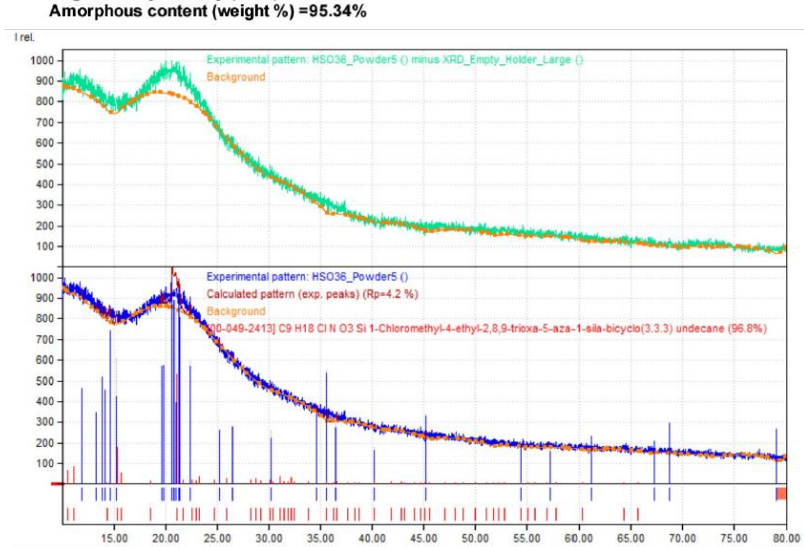


Appendix 5: RHA leached by H2SO4 in 36h

Degree of crystallinity analysis

Profile area	*Counts*	*Amount*
Total area	3665656	100.00%
Diffraction peaks	129328	3.53%
Background	3536328	96.47%
Instrumental background	892103	24.34%
Amorphous phases	2644225	72.14%

Degree of crystallinity (DOC) = 4.66%
Amorphous content (weight %) =95.34%

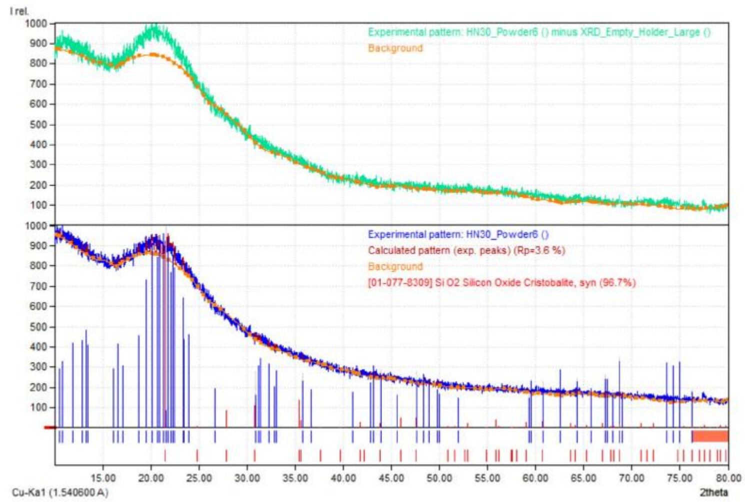


Appendix 6: XRD pattern of RHA leached by NHO3 in 30h

Degree of crystallinity analysis

Profile area	***Counts***	***Amount***
Total area	3660558	100.00%
Diffraction peaks	126250	3.45%
Background	3534308	96.55%
Instrumental background	892103	24.37%
Amorphous phases	2642205	72.18%

Degree of crystallinity (DOC) = 4.56%
Amorphous content (weight %) =95.44%

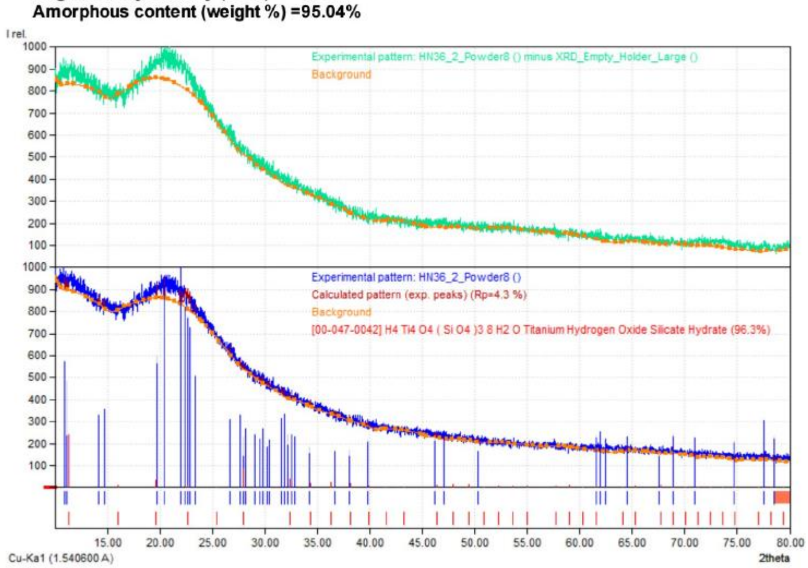


Appendix 7: XRD pattern of RHA leached by NHO3 in 36h

Degree of crystallinity analysis

Profile area	***Counts***	***Amount***
Total area	3699478	100.00%
Diffraction peaks	139226	3.76%
Background	3560252	96.24%
Instrumental background	892103	24.11%
Amorphous phases	2668149	72.12%

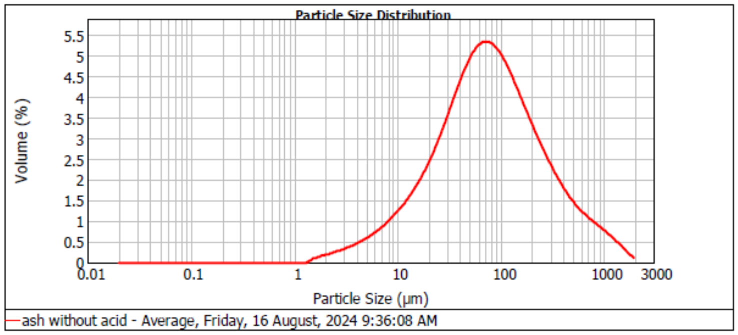
Degree of crystallinity (DOC) = 4.96%
Amorphous content (weight %) =95.04%



Appendix 8: particle size of RHA without acid treatment

Concentration:	Span :	Uniformity:	Result units:
0.0437 %Vol	4.889	1.63	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.189 m²/g	31.822 um	156.392 um	

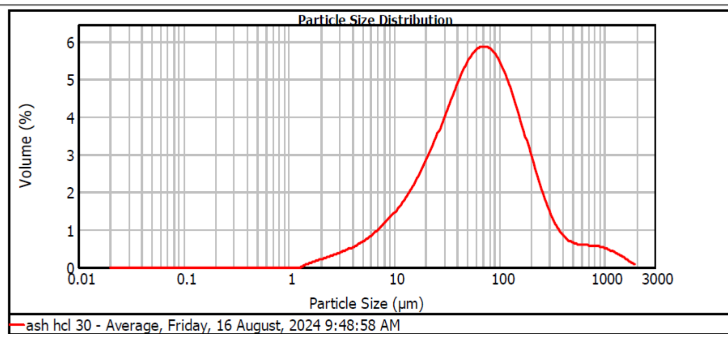
d(0.1): 14.457 um   d(0.5): 74.452 um   d(0.9): 378.491 um



Appendix 9: Particle size of RHA leached by HCL in 30h

Concentration:	Span :	Uniformity:	Result units:
0.0392 %Vol	3.578	1.41	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.212 m²/g	28.299 um	119.380 um	

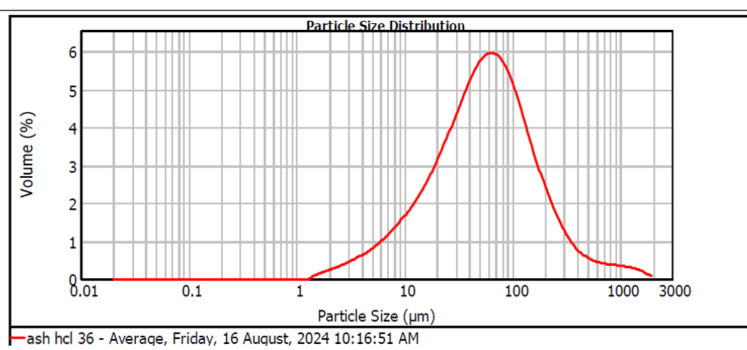
d(0.1): 12.812 um   d(0.5): 63.076 um   d(0.9): 238.508 um



Appendix 10: Particle size of RHA leached by HCL in 36h

Concentration:	Span :	Uniformity:	Result units:
0.0354 %Vol	3.553	1.39	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.237 m²/g	25.352 um	103.900 um	

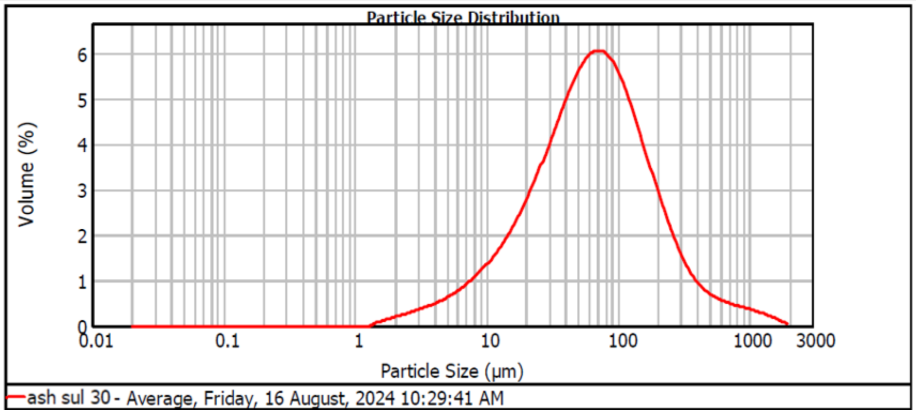
d(0.1): 11.229 um   d(0.5): 55.472 um   d(0.9): 208.308 um



Appendix 11: Particle size of RHA leached by H2SO4 in 30h

Concentration: 0.0398 %Vol	**Span :** 3.461	**Uniformity:** 1.29	**Result units:** Volume
Specific Surface Area: 0.205 m²/g	**Surface Weighted Mean D[3,2]:** 29.240 um	**Vol. Weighted Mean D[4,3]:** 113.498 um	

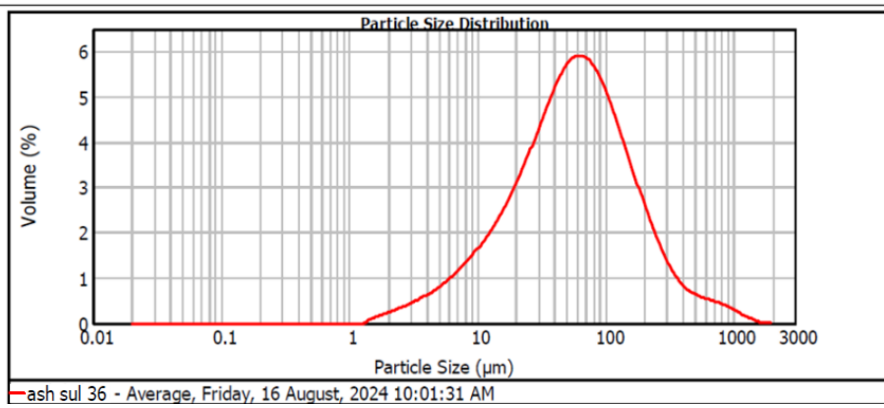
d(0.1): 13.557 um **d(0.5):** 63.652 um **d(0.9):** 233.866 um



Appendix 12: Particle size of RHA leached by H2SO4 in 36h

Concentration: 0.0387 %Vol	**Span :** 3.569	**Uniformity:** 1.29	**Result units:** Volume
Specific Surface Area: 0.234 m²/g	**Surface Weighted Mean D[3,2]:** 25.618 um	**Vol. Weighted Mean D[4,3]:** 99.632 um	

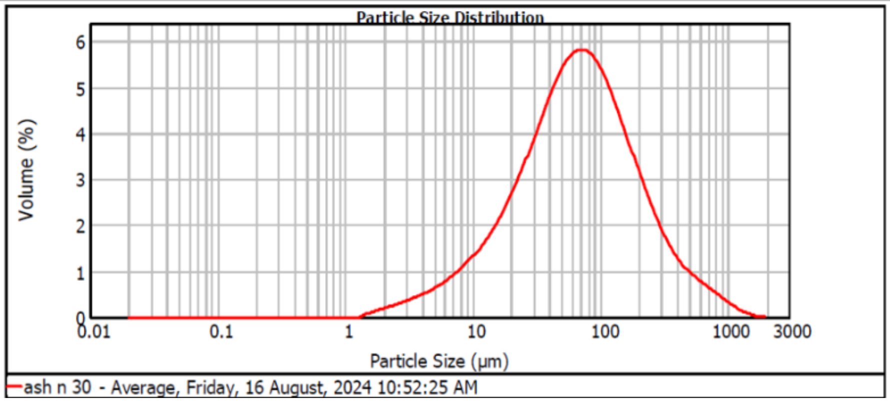
d(0.1): 11.344 um **d(0.5):** 56.383 um **d(0.9):** 212.578 um



Appendix 13: Particle size of RHA leached by NHO3 in 30h

Concentration:	Span :	Uniformity:	Result units:
0.0413 %Vol	3.748	1.28	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.202 m²/g	29.697 um	116.456 um	

d(0.1): 13.643 um   d(0.5): 66.041 um   d(0.9): 261.179 um



Appendix 14: Particle size of RHA leached by NHO3 in 36h

Concentration:	Span :	Uniformity:	Result units:
0.0365 %Vol	3.943	1.48	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.225 m²/g	26.676 um	117.205 um	

d(0.1): 11.859 um   d(0.5): 59.789 um   d(0.9): 247.633 um