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Rice Husk Ash (RHA) and Sugarcane Bagasse Ash (SCBA) as Partial Replacement of Cement for Concrete Hollow Block (CHB)

ABSTRACT

Many research had established the use of major crops as an additive and/or replacement in the construction. This study utilized and determined the optimum amount of rice husk ash (RHA) and sugarcane bagasse ash (SCBA) as partial replacements of cement in a 1:4 ratio of cement to sand mixture in developing concrete hollow blocks (CHB) by testing its compressive strength, water absorption, and fineness of cement mixture. Five set-ups were identified in this paper in terms of percentage replacement on the amount (0%,

2.5%, 5%, 7.5%, and 10%). The result showed an increase in fineness residue from 0%-10% cement mixture. The compressive strength test results showed an increase in compressive strength of 0-10%, with a significant drop at 7.5%. On the other hand, water absorption test displayed an increase in moisture content from 0% to 10% replacement. 86.67% have met the DPWH and ASTM strength requirement, and all cement mixtures are below 10%, not exceeding the minimum requirement. Further analyses of the results were discussed as well. In conclusion, 5% each of RHA and SCBA was used the optimum replacement to cement in terms of compressive strength for non-load-bearing CHBs.

Keywords: *fineness, compressive strength, water absorption*

1. THE PROBLEM AND A REVIEW OF RELATED LITERATURES AND STUDIES

1.1 Introduction

Concrete has been varyingly changing over time. It had been in the service of humankind for hundreds of years, yet its specification has long been a significant cause of conflict between engineers, contractors, and suppliers. Much of the conflict, mainly due to its performance and structure, is primarily a result of the rising litigious world in which modern construction takes place.

In modern days, concrete was more than just a simple mixture of cement, water, and aggregates. Now, it is often incorporated with mineral components as admixtures (ANON, 2008). Admixtures are materials used in concrete production that is added in a small volume to the concrete during mixing to improve one of the concrete's properties or the other (Adinna et al., 2019). There are several existing chemicals and minerals used as admixtures, among these were pozzolanas.

A pozzolana can be defined as siliceous or aluminous compound which has no cementitious property; however, with the presence of calcium hydroxide or lime, it acquires a cementitious property. Pozzolanas can be produced naturally or artificially. Natural pozzolanas, such as volcanic ash, and tuffs, were now obsolete because of the emergence of many artificial pozzolanas.

In this study, rice husk ash (RHA) and sugarcane bagasse ash (SCBA) were used as a raw material in the production of concrete hollow block (CHB). According to the study by the group of Glushankova (2018), RHA's silica content ranges from 90 to 97%, indicating a highly pozzolanic nature. In addition, SCBA is acknowledged as a pozzolanic material because of its typical silica content around 65% of its weight (Mangi et al, 2017).

Rice is classified as one of the most produced crops in the Philippines. Rice husk is the by-product of milling rice, contributing to approximately 20% of the rice's total weight.

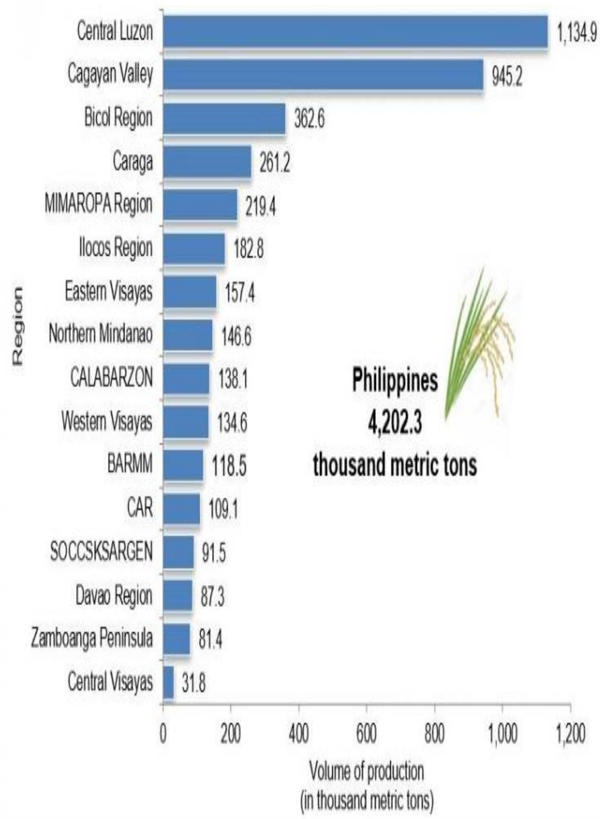

Figure-1: Volume of Palay Production by Region Philippines, Second Quarter 2022 by Philippine Statistics Authority (2022)

Figure 1 showed the production of Palay in the Philippines during the second quarter of 2022. According to the Philippine Statistic Authority (PSA), the Philippines produced 4,202.3 thousand metric tons of rice in the second quarter of 2022. Central Luzon was the most significant contributing region in rice production, with 1,134.9 thousand metric tons of rice produced. Compared to the same quarter in 2021, Central Luzon accumulated an increase of 8.9% in rice production. Nueva Ecija contributed more than half (69.8%) of the region's rice production in the second quarter of 2022. Bulacan, Pampanga, and Tarlac followed with 8.0%, 7.6%, and 6.6%, respectively. The remaining provinces of Central Luzon share the remaining 8%. In the second quarter of 2022, Central Luzon shows an increase of 100.5 thousand metric tons (9.7%) in irrigated rice production. Meanwhile, Central Luzon has a decrease of 7.3 thousand metric tons (85.5%) in rain fed rice production.

Table-1: Volume of Palay Production by Province, Central Luzon, Second Quarter 2021 and 2022 by Philippine Statistics Authority (2022)

Reg/Prov	Volume of Production (in metric tons)		Percent Change
	Q2 2021	Q2 2022	
Central Luzon	**1, 041.7**	**1, 134.9**	**8.9**
Aurora	37.3	34.4	(7.7)
Bataan	25.2	29.1	15.2
Bulacan	90.1	91.3	1.3
Nueva Ecija	700.7	791.9	13.0
Pampanga	88.1	86.0	(2.4)
Tarlac	79.8	75.1	(6.0)
Zambales	20.4	27.2	33.0

On the other hand, sugarcane is also considered one of the most produced crops in the Philippines. Sugarcane comprises approximately 36% juice, 30% sugarcane bagasse, and 34% straws and leaves. According to the Philippine Statistics Authority (PSA), the Philippines produced 1,880 thousand metric tons of sugarcane in the third quarter of 2022. Western Visayas is the most significant producing region, with 1,740 thousand metric tons (92.4%) of sugarcane. Compared to the same quarter in 2021, the Philippines has an increase of 78.8% in sugarcane bagasse. In 2021, Central Luzon contributed 549.6 thousand metric tons of sugarcane production. Tarlac contributed more than three-fourths (84.1%) of the region's production in 2021. Pampanga and Nueva Ecija follow with 12.7%, and 2.9%, respectively. More than 90% of the harvested sugarcane is used in centrifugal sugar production. The remaining percentage is used to produce ethanol, muscovado, and vinegar.

Table-2: Volume of Production of Top Produced Other Crops by Province in Central Luzon: 2021 by Philippine Statistics Authority (2021)

Province	Volume of Production (in Thousand Metric Tons)						
	Sugarcane	Onion	Coconut	Banana	Sweet Potato	Mango	Tomato
Central Luzon	549.6	121.5	100.9	51.8	50.1	48.1	32.1
Aurora	-	-	94.2	3.4	3.0	-	0.1
Bataan	0.8	0.1	3.8	1.2	3.2	3.3	0.4
Bulacan	0.0	0	0.5	18.4	0.7	7.2	4.5
Nueva Ecija	16.2	117.1	0.9	7.5	1.6	10.0	18.4
Pampanga	69.9	-	0.2	3.1	3.1	5.3	3.8
Tarlac	462.4	4.3	0.6	5.6	35.8	2.6	4.4
Zambales	0.2	0.02	0.6	12.6	2.7	19.7	0.6

Rice husk and sugarcane bagasse are agricultural waste products that have a lot of research done to provide usage and reduce waste. Among these researches, the usage of rice husk and sugarcane bagasse as fuels in their respective fields is notable. Around 85 kt of sugarcane bagasse ash (SBCA) is produced annually due to the Philippines adopting the bagasse-fired cogeneration plants (Jamora et al., 2019). SCBA's main components are silica, alumina, and ferrite, with 45-80%, 2-15 %, and 1-10%, respectively (Kolawole et al., 2021). Rice husk, like sugarcane bagasse, is being used as a substitute for coal in the energy production for rice mills and household lightning. Rice husk ash (RHA) is the by-product of using rice husk in energy production. RHA's main component is amorphous silicon oxide which contributes to around 83-90% of its content (Pode, 2016).

The usage of organic materials as an alternative in the construction industry has been one of the main focuses of research in the past decade. The result of this research can be categorized into products that reduce waste and products that improve the quality of construction material's quality. Some of the most common topics in this research involve cement and concrete hollow blocks (CHB). Cement and CHB are the most common and integral materials in the construction industry.

Silica, one of the significant components in cement and in making CHB, helps increase materials' engineering properties. RHA and SCBA, two by-product materials with relatively high silica content, are good candidates for making cement and CHB. In their effect on cement and cementitious material, research has been done on the usage of RHA and SCBA. Using RHA and SCBA as alternative raw material is an area of research with barely any study.

The researchers produced concrete hollow block (CHB) that is not only environmentally friendly but can also compete in the market.

1.2 Review of Related Literatures

1.2.1 Rice Husk as an Agricultural Waste

Rice is one of the major grains produced worldwide. During the production of rice, rice kernel is milled and will yield around 20% of its weight as rice husk. Rice husk is the natural covering of the rice kernel. For nations with high production of rice, rice husk contributes as a big part of agricultural waste. Rice husk are sometimes burned through burning or as a fuel in cogeneration plants, thus producing rice husk ash (RHA).

The generated RHA weight is expected to be 18% of the rice kernel total weight. The high volume of waste rice husk and RHA covers a sizable landfill area and can cause environmental pollution issues. Alternative usage of rice husk and RHA are continually being studied to lessen its impact to the environment because the rice husk production is expected to rise by 1.1% (Mosaberpanah & Umar, 2020).

According to Philippine Statistics Authority, the country has produced 4, 202.3 thousand metric ton of rice kernel in the second quarter of 2022. The country has approximately produced 840.46 thousand metric ton of rice husk or 756.41 thousand metric ton of RHA. This agricultural waste gives a heavy burden on the remaining landfills of the country and can introduce a number of environmental issues.

1.2.2 Sugarcane Bagasse as an Agricultural Waste

Sugarcane is one of the most planted crops all over the world. After the extraction of sugar juice in the sugarcane, sugarcane bagasse is created. Sugarcane bagasse accounts for 46% of the weight of the sugarcane without straws and leaves. Sugarcane bagasse ash (SCBA) is created after the sugarcane bagasse is used as a fuel in cogeneration plants for sugar making. The production of SCBA has continuously increasing because of the increase need for ethanol and sugar.

The increasing amount of SCBA has put an accumulating stress on landfill. The amount of aluminum, chromium, plumb, and phenol in the SCBA has exceeded the permitted amount in the solubilization test. Combine with the low nutritional value, SCBA is not qualified to be used as fertilizers. Using SCBA as a fertilizer may lead to heavy metal permeating the earth and contaminating the soil and ground water. This has the potential to start major social and health issues (Xu et al., 2018).

1.2.3 RHA as a Partial Cement Replacement

RHA's potential to be used as supplementary cementitious material in various building materials came from its large porous structure that reduces the self-weight of concrete and has good insulating properties. The high silica content of RHA is advantageous in making concrete. In addition, the nano-silica of RHA have the capacity to increase the early strength and durability of concrete. RHA also shows strong pozzolanic characteristics, which increased the impermeability and strength of concrete.

Due to the finer pore structure and increased pozzolanic characteristics, concrete mix with 20% RHA displayed lower porosity, water absorption, and shrinkage during autogenous drying, chloride penetration, carbonation, corrosion potential, acid and sulfate attack, and higher electrical resistivity (Amran et al., 2021).

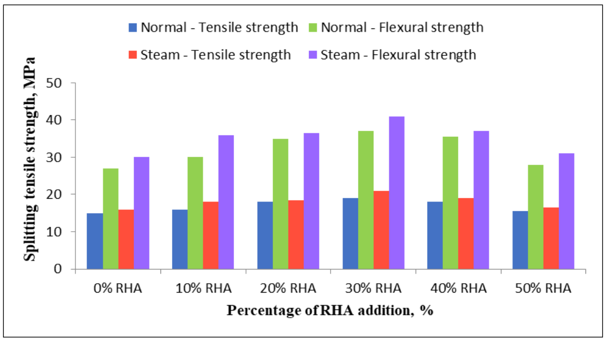

Figure-2: Splitting Tensile Strength Levels with Different levels of RHA Replacement by Amran et al. (2021)

Figure 2 showed results of various tensile and flexural strength test with different levels of RHA replacement. The RHA replacement of 30% exhibited the highest results in all aspects while the lowest results in all aspects was the 50% RHA replacement.

Silica fume is one of the major materials in the production of concrete. Due to its high cost and the significant demand for silica fume from numerous manufacturing sectors, including the power sector, automotive, aerospace, and construction industries, a lot of research effort is used in finding alternative material to replace or partially replace silica fume. RHA is one of the proposed alternatives for silica fume because of the highly reactive silica concentration and tiny particle size of the material. The RHA is formed by slow burning and cooling of rice husk and achieving a below 5% carbon content. Rice husk has a mineral make-up of cellulose, lignin, silicon dioxide, hemicellulose, holocellulose, and triacetylmethane. The breakdown of this components during burning gives the RHA the high silica concentration comparable to silica fume (Ojedokun, 2018).

1.2.4 SCBA as a Partial Cement Replacement

A study is made in development of SCBA as cement substitute material for concrete. The study has found several conclusions that prove that SCBA has the capacity to be used as cement substitute material. SCBA in concrete provides greater compressive strength in comparison to the strength of a normal concrete. The usage of SCBA in concrete can reduce waste and conserve energy. The addition of SCBA as substitute cement material in SCBA enhances the workability of fresh concrete. This reduces the price for concrete production because the concrete will no longer need super-plasticizer (Mangi et al., 2017).

Table-3: Compressive Strength of Concrete for M15 (1:2:4) by Mangi et al. (2017)

OPC % replacement with SCBA	Compressive Strength (N/mm^2)			Avg. Compressive Strength (N/mm^2)		
	7 days	14 days	28 days	7 days	14 days	28 days
0%	17.30	18.50	24.11	16.025	18.19	23.805
	14.75	17.88	23.50			
5%	18.89	21.95	27.20	17.645	20.56	26.775
	16.40	19.17	26.35			
10%	17.54	20.62	24.67	16.805	19.35	24.16
	16.07	18.08	23.65			

Finely powdered SCBA has been studied to be used as partial substitute for cement. The effects of integrating SCBA's various quartz content with cement pastes and mortars' characteristics. In the study by the group of Andreão, SCBA with high carbon concentration is collected and cleaned with water. The study has obtained two types of ashes: top wash SCBA with low quartz content and bottom wash SCBA with high quartz concentration. The control ash that was obtained was compared to both ashes. The SCBA samples underwent conjugate burning recalcination before being finely ground. Results reveal that top SCBA was more active, reaching a greater pozzolanic activity, whereas bottom SCBA had more crystalline phases. Due to heterogeneous nucleation and exothermic hydration processes, SCBA cement generated more heat during hydration, according to isothermal calorimetry. SCBA helped to refine the pore structure, according to mercury intrusion porosimetry. The mechanical strength results showed that SCBA might partially replace cement, improving the engineering qualities and sustainability of cement-based products (Andreão et al., 2019).

Concrete made with SCBA is 20% stronger than the controlled sample concrete made with cement mixes. SCBA blended concrete is compared to fly ash blended concrete with the same level of replacement. SCBA blended concrete is discovered to have greater resistance to chloride, air, and water permeability compare to fly ash blended concrete. Processed SCBA creates excellent pozzolanic characteristics, which increased the impermeability and strength of concrete (Bahurudeen et al., 2016).

1.2.5 RHA and SCBA Estimated Cost as a Material for Cement Industry

The Philippines have produced 312.57 kilotons of RHA and 73.81 kilotons of SCBA from cogeneration plants in the year 2020. The estimated cost of RHA waste of the cogeneration plants was around 278.01-340.93 PHP/40-kg bag and for the SCBA was around 49.23-269.66 PHP/40-kg bag. This estimated cost has taken into consideration international shipment, and labor used for the collection of the ashes. It was noted that the cost of RHA and SCBA can be reduced by five times if the transportation is only within the region of the cogeneration plants, making a bigger margin for profit if the ashes became commercialized. By using RHA and SCBA in cement industry can also contribute to the greenhouse gases emission reduction and provides support for the utilization of agricultural waste resources in-line with the green energy policies (Jamora et al., 2023).

1.3 Statement of the Problem

The researchers developed a non-load bearing concrete hollow block (CHB) with rice husk ash (RHA) and sugarcane bagasse ash (SCBA) as partial replacement of cement. Specifically, it sought to answer the following questions:

1. What are the materials needed in the development of non-load bearing CHB?
2. What is the optimum amount of RHA and SCBA as partial replacement of cement for the development of non-load bearing CHB?
3. How may the partially replaced cement be tested in terms of its fineness in percentages of:
    a. 2.5%,
    b. 5%,
    c. 7.5% and,
    d. 10%?
4. How may the non-load bearing CHB be tested in terms of its compressive strength and water absorption?

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of the study was to develop a non-load bearing concrete hollow block using varying amounts of rice husk ash (RHA) and sugarcane bagasse ash (SCBA) as raw materials.

1.4.2 Specific Objectives

1. To assess the fineness of the cement mixture with RHA and SCBA in percentages of:
    a.) 2.5%,
    b.) 5%,
    c.) 7.5%, and
    d.) 10%.

2. To assess the compressive strength and water absorption capacity of modified concrete hollow blocks utilizing different percentage replacements of rice husk ash (RHA) and sugarcane bagasse ash (SCBA)
3. To identify the ideal ratio of sugarcane bagasse ash (SCBA) and rice husk ash (RHA) in concrete hollow blocks, as well as the number of curing days required to achieve the best results.
4. To determine the most cost-effective CHB sample in terms of its analyzed cost average net compressive strength.

1.5 Significance of the Study

The results of the study give benefits to the following stakeholders:

Construction Industry - the development of cost-efficient and stronger CHB will create a new alternative choice in terms of construction material.

Community - in coordination with the community, this research can open a probable new source of income to the members of the community.

Future Researchers - this research can act as a new source of information and reference to inspire future researches ad studies.

1.6 Scope and Limitations

1.6.1 Scope

This research focused on assessing and evaluating RHA and SCBA as partial substitutions of cement in producing non-load-bearing CHB. The dimension of CHB was 40 cm by 20 cm by 10.16 cm (15.75 inches by 7.87 inches by 4 inches). The concrete mix ratio was 1 part of Portland cement to 4 parts of sand. Accordingly, RHA and SCBA substituted parts were 2.5%, 5%, 7.5%, and 10% with 1:1 ratio of the total Portland cement.

Assessment of the cement mixture was done through fineness test by the use of sieve test. A controlled sample was used to compare the results attained through experimentations. The CHB underwent curing in various days to achieve a more extensive result. The assessment lasted three curing periods; 7 days, 14 days, and 28 days. The assessment and evaluation were done using compressive strength test via Universal Testing Machine (UTM), water absorption test via 24-hour water submersion, and cost analysis via cost-effectiveness analysis.

1.6.2 Limitations

The CHB produced was mainly non-load bearing. Concrete blocks were frequently made of Class C (1:4) cement-sand concrete mix. This study did not use cement-to-sand ratios of other class proportions A, B, and D. Testings of cement mixtures and CHB samples, which was not indicated in the study, were not used. The cost of labor and use of equipment were not included in the computation for the cost-effectiveness analysis. Furthermore, other types of cost analysis were not utilized. Other properties of the raw materials were not utilized.

1.7 Conceptual Framework

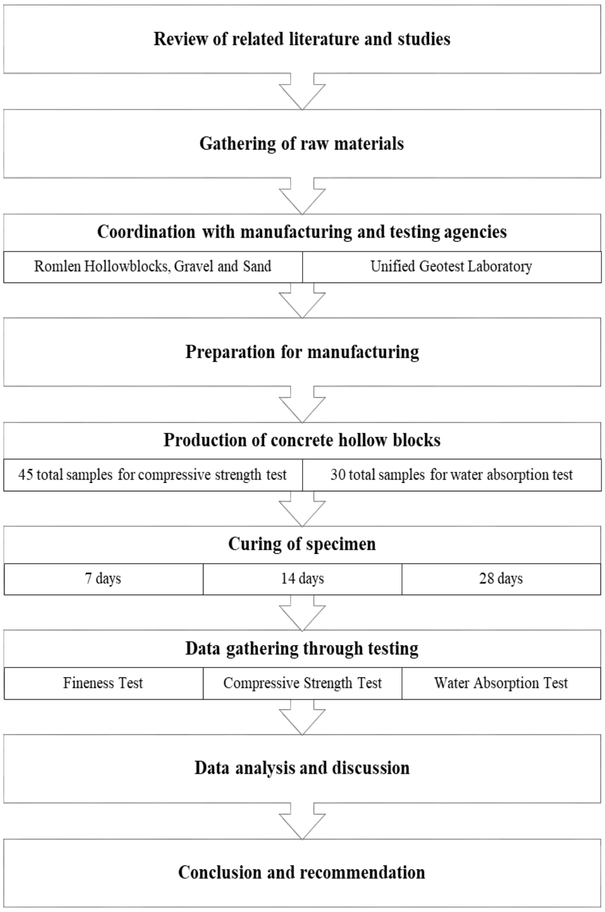

Figure-3: Conceptual Framework

1.8 Definition of Terms

The following words were defined in accordance to their conceptual meaning:

Admixture. A component that was added to concrete mixtures in addition to the main ingredients: cement, sand, aggregates, and water to alter the engineering qualities used.

Compressive Strength. A material or structure's capacity to withstand weights that tend to shrink in size.

Compressive Strength Test (CST). A technique for evaluating materials to determine how much pressure they can take in compression before breaking.

Concrete. A dense and complex building material that may be spread or poured into molds and was made of cement, sand, water, and crushed stone or gravel. When it hardens, it forms a mass that resembles stone.

Concrete Hollow Block (CHB). A rectangular block of standardized size called a "concrete masonry unit" was used in building construction.

Concrete Mixture. A combination with a typical ratio for cement, sand, aggregate and water is 1:2:3, 1:3:3, or 1:2:4.

Curing. A procedure that keeps concrete's moisture content stable to prevent shrinkage and crumbling.

Fineness Test. Performed to evaluate the cement's hydration, evolution, and strength growth rate.

Flexural Strength. The stress in a material immediately before it fails a flexure test is referred to as the bending strength or modulus of rupture.

Load. Pressure within or exerted on a substance, including weight and stress.

Portland Cement. Binding substance produced as a finely powdered gray powder by burning and grinding a combination of limestone.

Pozzolana. Siliceous and aluminous materials can produce compounds with characteristics resembling cement in the presence of water at room temperature while having little to no cementitious capabilities.

Rice Husk Ash (RHA). An agricultural byproduct produced when rice shells were burned at a regulated temperature.

Sieves/Sieve Sets. Used to determine the gradation or particle distribution of aggregates such as sand and gravel.

Sugarcane Bagasse Ash (SCBA). A residue obtained from burning sugarcane bagasse.

Water Absorption. The ability of any material to absorb a certain amount of moisture or liquid.

Water Absorption Test (WAT). The assessment of how much water or liquid a material absorbed under specified circumstances, such as material, chemical exposure, and content.

2. METHODOLOGY

This chapter encompassed procedures that present the rice husk ash and sugarcane bagasse ash as a partial replacement of cement in the concrete mixture in manufacturing of concrete hollow blocks as well as other materials, preparation, design, and tests that were done to gather data.

2.1 Phase 1 – Methodological Framework

2.1.1 Research Design

An experimental research method was conducted throughout this study wherein a specimen set-up with fundamental components was used as a control variable, with other set-ups having varying replacement percentages. Data was collected by testing trials to meet the study's objectives that were analyzed and evaluated thoroughly.

2.1.2 Methods of Testing

The cement containing the raw materials was tested. The test consisted of Fineness Test. In addition, testing of the concrete hollow blocks was completed at every end of the curing period. Two tests were executed in this study: Compressive Strength Test and Water Absorption Test.

2.1.2.1 Fineness Test

The fineness test, specifically the sieve test, was performed to determine the quality of the cement in terms of fineness in line with the American Society for Testing and Material (ASTM) C786-10. The standard requirement for the fineness of cement mixture was 90% of its total weight passed through the no. 200 (0.075mm) sieve based on the specifications of IS: 4031-1996.

a. 100 grams of cement was weighed accurately. This served as the weight of the cement (W_1).
b. The cement was carefully placed in the #200 sieve while breaking down any lumps in the sample.
c. The sieve was shaken continuously horizontally for 15 minutes.
d. After 15 minutes, the remaining cement within the sieve was weighed accurately. This served as the weight of the residue (W_2).
e. Computation for the percentage fineness of the cement was done using the following formula:

$$\text{Percentage of Fineness} = \frac{W_1 - W_2}{W_1} \times 100\%$$

2.1.2.2 Compressive Strength Test

The compressive strength test was performed to determine the average strength capacity and the maximum load a concrete hollow block can withstand in line with the Department of Public Works and Highways (DPWH) Specification 1046.4 – Strength Requirements and American Society for Testing and Materials (ASTM) C140-03 and C129. The minimum average net compressive strength of three units for non-load bearing CHB was 600 psi (4.14 MPa).

a. Fifteen specimen blocks were examined after curing for 7, 14, and 28 days. According to the DPWH, Specification 1046.3.7 Sampling and Testing for Concrete Hollow Blocks and Louvers - Method of Sampling for Quality Test, three (3) trials were ran from each setup. After the specimen is ready, the net area of the concrete hollow block is measured and computed; the entire area was not considered.
b. One specimen at a time was placed on the compressive strength testing machine consisting of two steel bearing blocks, one solid and supporting the concrete unit and the other moving and transferring the load to the concrete block when the load was applied.
c. The load at which the concrete hollow block unit failed was recorded for the three trials of each set-up.
d. Computation for the net compressive strength of each set-up was done using the following formula:

$$\text{Net Compressive Strength} = \frac{\text{Maximum Load at Failure}}{\text{Net Area}}$$

2.1.2.3 Water Absorption Test

The concrete hollow block's water absorption test was performed to determine how much water the sample absorbed after curing. This was in line with American Society for Testing and Materials (ASTM) C129. The maximum average water absorption percentage for non-load bearing CHB was 12% conforming to the specifications of NIS 583:2004.

a. For 24 hours, ten hollow concrete blocks were entirely immersed in water after every curing period.
b. After 24 hours, the samples were taken out of the water and left to dry for a maximum of 30 minutes or until no more water was dripping from the sample. A weighing scale was used to calculate the mass of varying amounts of rice husk ash and sugarcane bagasse ash as raw materials.
c. After each sample had been weighed, the recorded values were denoted as W_1, or the wet mass of sample.
d. Each sample was then oven-dried for 24 hours and weighed accordingly. The values recorded were denoted as W2, or oven-dried weight.
e. The percentage of water can be calculated using the formula:

$$\text{Water Absorption Percentage} = \frac{W_1 - W_2}{W_2} \times 100\%$$

2.2 Phase 2 – Data Collection

2.2.1 Materials

The following list was the raw materials used in the study for the preparation of samples:

Rice Husk Ash (RHA)

Rice husk is an agricultural waste material. It was then turned into ash upon acquirement. The rice husk ash was used as a partial replacement of cement in the development of concrete hollow blocks.

Sugarcane Bagasse Ash (SCBA)

Sugarcane bagasse is an agricultural waste material. It was then turned into ash upon acquirement. The sugarcane bagasse ash was used as a partial replacement of cement in the production of concrete hollow blocks.

Portland Cement

Type 1T Portland cement, conforming to American Society for Testing and Materials C595 (ASTM C595), was used as a binder to set and bind materials together. It was the material being replaced in various percentages.

Sand

Sand is a mixture of tiny particles of rocks and other granular materials. It was used as a fine aggregate in this study providing strength and stability in the development of concrete hollow blocks.

Water

Water is a significant material used in binding the cement mixture and aggregates together. Clean and potable water was the standard requirement for the concrete mixture. It was a key component in determining the mixture’s consistency in producing concrete hollow blocks.

2.2.2 Tools and Equipment

In this study, both hand tools and equipment were utilized in the preparation of samples, and gathering data significant for the study were listed as follows:

2.2.2.1 Tools

Brush. An object with bristles used as a cleaning tool. It was used to clean the sieve no. 200 in this study.

CHB Steel Plate. Oiled size 4 steel plates were used to prevent the fresh CHB from sticking in the molder.

Container. A plastic round open container that was used as a vessel for small portions of rice husk ash and sugarcane bagasse ash.
Electronic Weighing Scale. An electronic device used in measuring the weight of an object in smaller quantity. It was used to measure the weight of the ashes for proportioning in the fineness test.

Sack. A small or large container known for storing rice and other ingredients or materials. It was used as a container for the rice husk ash, sugarcane bagasse ash, and cement mixture.

Scoop. A spoon-like object made of various materials. It was used in picking and transferring rice husk ash and sugarcane bagasse ash to another container.
Shovel. A huge spoon-like object with long handle used in digging, transferring, and/or throwing manageable sizes of materials. It was used in transferring cement and sand to another container.

Sieve. A set of sieves is used for particle size distribution of a mixture sample. In this study, no. 200 (0.075 mm) sieve was used in performing the fineness test and separate unwanted particles.

Weighing Scale. A tool used in measuring the weight of large objects or quantities. It was used in proportioning the cement mixture for the development of concrete hollow blocks.

2.2.2.2 Equipment

Concrete Mixer. A huge machine used to combine the cement mixture with the other materials such as aggregates (sand), and water forming homogenous mixture.

CHB Molder Machine. A machine used in producing concrete hollow blocks. It was used to form 4” CHB in batches of 4 blocks.

Compression Machine. A machine designed to apply compressive loads to CHB samples. It was used to measure the compressive strength of the samples with rice husk ash and sugarcane bagasse ash.

Drying Oven. A machine used in drying tools, equipment, and/or materials by heat. It was used to dry the samples in getting their oven-dried weight.

Sieve Shaker. An automated machine used in shaking the sieve in constant force by vibrating. It was used in the sieve analysis in this study.

2.3 Phase 3 – Data Analysis and Evaluation

2.3.1 Experimental Design Proportion

In this study, five different sample variants with three curing times were produced and put to the test. In line with the study's general objective, the design and evaluation of the properties of CHB with the use of rice husk ash and sugarcane bagasse ash as raw material were in intervals of 0%, 5%, 10%, 15%, and 20% amount replacement. One part of cement was used in every four parts of sand (1:4 ratio) in the concrete mixture, and a 1:0.4 cement-to-water ratio was utilized as well, wherein the amounts of sand and water tied with the total amount of cement, rice husk ash and sugarcane bagasse ash combined present in the mixture. The concrete hollow blocks were labeled as experimental samples namely; #0, #1, #2, #3, and #4 according to the proportions.

Table-4: Design Mixture of Concrete Hollow Block Sample

Material	Concrete Mixture Weight Proportion, kg				
	#0 (0%)	#1 (2.5%)	#2 (5%)	#3 (7.5%)	#4 (10%)
Portland Cement	25	23.75	22.5	21.25	20
Rice Husk Ash	0	0.625	1.25	1.875	2.5
Sugarcane Bagasse Ash	0	0.625	1.25	1.875	2.5
Sand	100	100	100	100	100
Water	10	10	10	10	10

2.3.2 CHB Samples

This section explained how to make concrete hollow block (CHB) specimens step-by-step. The process was divided into four essential steps: manufacturing the rice husk ash and sugar cane bagasse ash, weighing and mixing the concrete, creating the samples, and making the curing.

2.3.2.1 Preparation of Rice Husk and Sugarcane Bagasse

1. Cleaning the rice husk and sugarcane bagasse upon collection includes removing any dirt that may have accumulated on the material.
2. The burning process was done in two separate vessels. This process was carried out until the rice husk and sugarcane bagasse turned into ash that could pass through the no. 200 (0.075 mm) sieve or be cement-like in terms of particle size.
3. The ashes were then placed in a separated lidded container and kept in a dry place for the following process.

2.3.2.2 Proportioning and Mixing

This study used a cement-to-sand ratio of 1:4, along with a cement-to-water ratio of 1:0.4. Then, using the aforementioned tools, materials were measured by weight.

Thorough mixing was crucial in this study, as the materials should be able to bind with each other and create the optimum paste for uniformity of the mixture. The following steps were followed:

1. Computation for the percentage equivalent of the Portland cement to rice husk ash and sugar cane bagasse ash was done before manufacturing, which was measured using a weighing scale.
2. The measured dry materials were then transferred to a location where mixing was performed. Four mixtures were made in preparation for the varying percentage replacements on concrete hollow blocks.
3. After mixing, water was added gradually to the material combination to establish a uniform mixture and to create the proper cement-water paste without letting the mixture become too thin.
4. The molding process began when the concrete mixture is transferred to a container.

2.3.2.3 Production of Concrete Hollow Blocks

A molder machine with four molds at a set was used to produce the samples of concrete hollow blocks, which were labeled accordingly.

1. A concrete mixture was prepared for the molding process.
2. To maintain a homogenous mixture and prevent settlements, the material was stirred again before pouring over the mold.
3. After that, the mixture was poured into a hollow block molder.
4. The excess concrete mixture was removed from the open face of the mold with a piece of metal to obtain a clean and flat top. The metal was passed across the exposed surface to smooth it out.
5. The machine carries out compaction in six to eight cycles according to DPWH Specification 1046.3.2. The molded blocks were removed when the process is complete and deposited at the curing location.

2.3.2.4 Curing

By keeping the moisture level of the concrete constant, the curing process prevents cracking. It also prevents concrete shrinkage and surface deterioration and significantly contributes to concrete's durability.

1. By allowing the blocks to dry for approximately 72 hours after molding, all 75 samples containing different cement to RHA and SGCA were sprayed with water, covered with a plastic sheet, shaded, and checked on a regular basis.
2. At every end of the 7, 14, 28 days curing periods, 15 pieces of concrete hollow blocks (5 pieces per set-up) were carried out for testing while the remaining blocks were left to continue with the curing process.

2.4 Cost-Effectiveness Analysis

This section discussed the cost-effectiveness of the CHB samples in terms of its average net compressive strength and cost. The breakdown of the costs for the materials used in the production of non-load bearing hollow blocks were shown.

3. RESULTS AND DISCUSSIONS

The results collected from the mechanical procedures in the preceding chapter were presented in tables and graphs, including the data description, analysis, findings, and interpreted outcomes based on the study's objectives.

3.1 Data Description

This study considered two general data, the first from a control variable and the second from the experimental group variable. Raw data were acquired through equipment and testing procedures detailed in Chapter 2. The mean value of maximum load applied with three trials per sample for the compressive strength test is used in assessing the compressive strength test of each set-up in terms of net area. Furthermore, the testing center’s laboratory personnel measured and verified weight in grams, and the agency and the proponents computed the results.

3.2 Data Analysis and Findings

Three different mechanical tests were conducted throughout the curing period of this paper, the Fineness Test, Compressive Strength Test and Water Absorption Test. Results gathered from the equipment used in the process were as follows:

3.2.1 Fineness Test

Fineness Test of the Cement is a procedure that checks the fineness of cement particles as it passes through no. 200 sieve. The fineness test of the cement is a way to determine if the cement mixture is acceptable to be used in the creation of concrete. The fineness of the cement mixture is correlated for the early strength development of concrete, workability, and durability of concrete. This study subjected plain cement and cement mixed with RHA and SCBA through analysis. The resulting residue after sieving must not exceed 10% as for the specification of IS: 4031.

Table-5: Fineness Test Result

Sample Identification	Weight Of Mixture (W1), g	Weight In Pan (W2), g	Percentage of Fineness, %
#0	100	6	94
#1	100	8	92
#2	100	8	92
#3	100	8	92
#4	100	10	90

The results of the fineness test of the cement were specified in Table 5. The untouched cement has a residue percentage of 6%. Three of the four experimented cement mixtures, #1, #2 and #3, have exhibited the same residue percentage of 8%. The worst performing of among the tested samples is the experimented cement mixture #4, having a barely passing residue percentage result of 10%. All the tested cement mixtures have not exceeded the 10% maximum residue percentage and they can be used as a material in making CHB.

3.2.2 Compressive Strength Test

A Universal Testing Machine (UTM) is usually used to perform Compressive Strength Test to determine the maximum amount of compressive load applied before fracturing the material, which is the concrete hollow block in this study. Based on the paper's objectives, samples underwent 7, 14, and 28 days of curing and the set-up's compressive strength average. Under the Department of Public Works and Highways (DPWH) Standard Specification for ITEM 1046 – Masonry Work (1046.4 Strength Requirements) and Standard Specification for Non-load bearing Concrete Masonry Units 31 (ASTM C129), the compressive strength (average net area minimum) should be 4.14 megapascal (600 psi) for an average of 3 units and 3.45 megapascal (500 psi) for an individual unit.

Table-6: Compressive Strength Test Result at 7-Day Curing Period

Sample Identification	Net Area (mm^2)	Machine Reading (kN)	Compressive Strength			
			psi	Ave. psi	MPa	Ave MPa
#0	24 470	138.34	820	744.67	5.65	5.13
		128.51	762		5.25	
		110.05	652		4.50	
#1	24 470	93.46	554	582.33	3.82	4.02
		95.90	568		3.92	
		105.53	625		4.31	
#2	24 470	118.94	705	805	4.86	5.55
		150.22	890		6.14	
		138.41	820		5.66	
#3	24 470	105.63	626	651.33	4.32	4.49
		102.49	607		4.19	
		121.66	721		4.97	
#4	24 470	94.78	562	558	3.87	3.85
		86.55	513		3.54	
		101.13	599		4.13	

The compressive strength test results for the seven-day cured CHB samples were specified in Table 6 as shown. In the table, samples were specified containing 2.5%, 5%, 7.5%, and 10% of both RHA and SCBA replacement and a controlled sample without any replacement. The controlled CHB sample was recorded to have obtained an average of 744.67 psi or 5.13 MPa. The experimental CHB sample #2, with an average compressive strength of 805 psi or 5.55 MPa, exhibited an increase of 8.10% in compressive strength compared to the controlled CHB samples. However, the experimental CHB samples #1, #3, and #4 achieved a lower average compressive strength in comparison to the controlled CHB samples. The experimental CHB sample #1 was recorded to have obtained an average compressive strength of 582.33 psi or 4.02 MPa. The experimental CHB sample #3 was recorded to have acquired an average compressive strength of 651.33 psi or 4.49 MPa. The experimental CHB sample #4 was recorded to have gained an average compressive strength of 558 psi or 3.85 MPa.

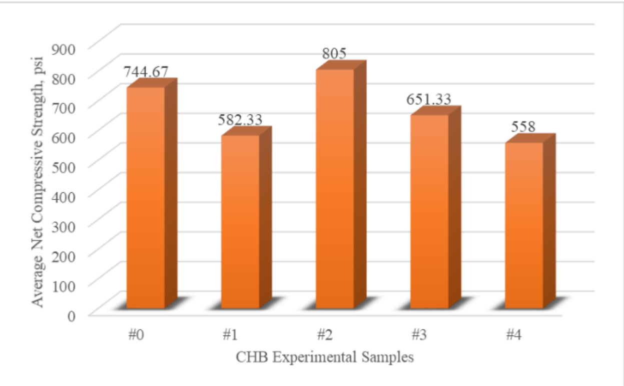

Figure-3: Compressive Strength Test Result at 7-Day Curing PeriodFigure 3 shows the average strength of the set-ups accumulated through the seven-day curing period test. The experimental CHB sample #2 displayed the highest average compressive strength test. It is followed by the controlled samples, and experimental CHB samples #1, #3, and #4. Only experimental sample # 2 surpassed the compressive strength recorded from the controlled samples, with Experimental CHB #3 exceeding the 600psi or 4.14 MPa standard requirement for non-load bearing as per DPWH 1046.4 – Strength Requirements and ASTM C129.

Table-7: Compressive Strength Test Result at 14-Day Curing Period

Sample Identification	Net Area (mm^2)	Machine Reading (kN)	Compressive Strength			
			psi	Ave. psi	MPa	Ave. MPa
#0	24 470	121.18	718	826.67	4.95	5.7
		145.20	860		5.93	
		152.29	902		6.22	
#1	24 470	114.39	678	733.67	4.67	5.06
		120.42	714		4.92	
		136.48	809		5.58	
#2	24 470	129.17	765	864	5.28	5.96
		151.67	899		6.20	
		156.67	928		6.40	
#3	24 470	106.41	631	615.67	4.35	4.24
		112.84	669		4.61	
		92.32	547		3.77	
#4	24 470	113.48	672	660.67	4.64	4.56
		104.18	617		4.26	
		117.01	693		4.78	

The compressive strength test results for the fourteen-day cured CHB samples were specified in Table 7 as shown. The controlled CHB samples were recorded to have obtained an average compressive strength of 826.67 psi or 5.7 MPa. The experimental CHB samples #2, with an average compressive strength of 864 psi or 5.96 MPa, exhibited an increase of 4.52% in compressive strength compared to the controlled CHB samples. However, the experimental CHB samples #1, #3, and #4 achieved a lower average compressive strength than the controlled CHB samples. The experimental CHB samples #1 were recorded to have obtained an average compressive strength of 733.67 psi or 5.06 MPa. The experimental CHB samples #3 were recorded to have acquired an average compressive strength of 615.67 psi or 4.24 MPa. The experimental CHB samples #4 were recorded to have gained an average compressive strength of 660.67 psi or 4.56 MPa.

The results from the fourteen-day curing period test exhibited nearly the same behavioral pattern, except for the experimental CHB sample #3, compared to the results from the seven-day curing period test. The controlled CHB samples and experimental CHB samples #1, #2, and #4 have displayed an increase in average compressive strength compared to the seven-day curing period test results. Meanwhile, the experimental CHB sample #3 showed a lower compressive strength than the seven-day curing period test results.

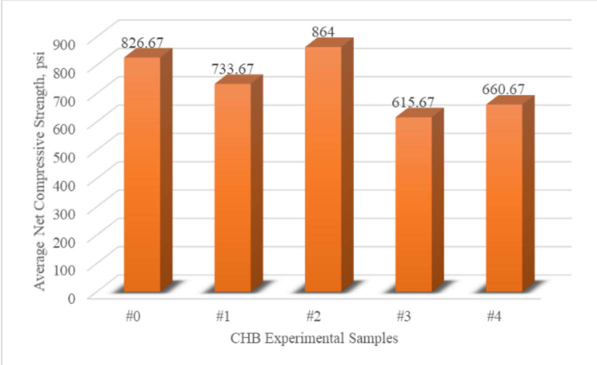

Figure-4: Compressive Strength Test Result at 14-Day Curing Period

In Figure 4, the highest average compressive strength is achieved by the experimental CHB sample #2, similar to the seven-day curing period test results. It is followed by the controlled CHB samples, and experimental CHB samples #1, #3, and #4. Despite having lower average compressive strength than controlled CHB samples, the average compressive strength of experimental CHB samples #1, #3, and #4 have exceeded the 600 psi or 4.14 MPa minimum requirement for non-load bearing CHB conforming to DPWH 1046.4 – Strength Requirements and ASTM C129.

Table-8: Compressive Strength Test Result at 28-Day Curing Period

Sample Identification	Net Area (mm^2)	Machine Reading (kN)	Compressive Strength			
			psi	Ave. psi	MPa	Ave. MPa
#0	24 470	135.84	805	925.33	5.55	6.38
		160.21	949		6.55	
		172.40	1022		7.05	
#1	24 470	140.69	834	874	5.75	6.03
		166.12	984		6.79	
		135.69	804		5.55	
#2	24 470	158.23	938	959.33	6.47	6.62
		182.58	1082		7.46	
		144.77	858		5.92	
#3	24 470	120.45	714	733.33	4.92	5.05
		127.03	753		5.19	
		123.63	733		5.05	
#4	24 470	137.85	817	786.67	5.63	5.42
		130.22	772		5.32	
		130.13	771		5.32	

The compressive strength test results for the 28-day cured CHB samples were specified in Table 8, as shown. The controlled CHB samples were recorded to have obtained an average compressive strength of 925.33 psi or 6.38 MPa. The experimental CHB samples #2, with an average compressive strength of 959.33 psi or 6.62 MPa, exhibited an increase of 3.23% in compressive strength compared to the controlled CHB samples. However, the experimental CHB samples #1, #3, and #4 achieved a lower average compressive strength than the controlled CHB samples. The experimental CHB samples #1 were recorded to have obtained an average compressive strength of 874 psi or 6.03 MPa. The experimental CHB samples #3 were recorded to have acquired an average compressive strength of 733.33 psi and 5.05 MPa. The experimental CHB samples #4 were recorded to have obtained an average compressive strength of 786.67 psi and 5.42 MPa.

The results from the 28-day curing period test exhibited the same behavioral pattern in comparison to the results from the seven-day curing period test. All samples have displayed an increase in average compressive strength compared to the two previous curing period test results, making this round of results the highest for all group samples.

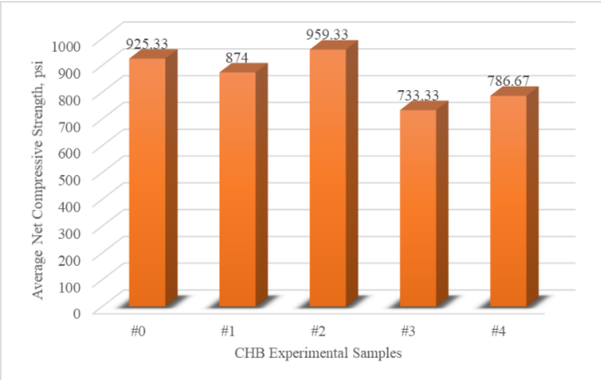

Figure-5: Compressive Strength Test Result at 28-Day Curing Period

In Figure 5, the highest average compressive strength was achieved by the experimental CHB sample #2, similar to the two previous curing period test results. It was followed by the controlled CHB samples, and experimental CHB samples #1, #3, and #4. Despite having lower average compressive strength than controlled CHB samples, the average compressive strength of experimental CHB samples #1, #3, and #4 have exceeded the 600 psi or 4.14 MPa minimum requirement for non-load bearing CHB conforming to DPWH 1046.4 – Strength Requirements and ASTM C129.

3.2.3 Water Absorption Test

One of the practiced in investigating the durability of concrete was by performing a water absorption test. Determining the moisture content of the specimen enables the developer to identify its porosity, which was inversely proportional to its level of compactness. The more the pores prevalent in the specimen, the more water it will absorb making an observation that it was less dense. This study subjected the sample CHB to analysis after 7, 14, and 28 days. The water absorption for concrete hollow blocks should be 12% as per Nigerian Industrial Standard (NIS 583:2004).

Table-9: Water Absorption Test Result at 7-Day Curing Period

Sample Identification	Wet Mass, g	Oven-Dried Weight, g	Water Absorption, %	Water Absorption Average, %
#0	9465	8804	7.51	7.95
	9220	8507	8.38	
#1	9296	8634	7.67	7.38
	9632	8994	7.09	
#2	9035	8189	10.33	9.59
	9256	8504	8.84	
#3	9393	8732	7.57	7.64
	9459	8783	7.70	
#4	9288	8838	5.09	5.16
	9412	8945	5.22	

The water absorption test results for the seven-day sample were specified in Table 9. The experimental sample #4 recorded to have obtained the lowest average percentage of 5.16%. The controlled CHB and experimental samples #1, #3 and #4 have exhibited greater absorption average, which indicate that these set-ups absorbed more water than experimental sample #4. All samples were determined to have not exhibited the 12% maximum water absorption requirement in accordance to Nigerian Standard NIS 583:2004.

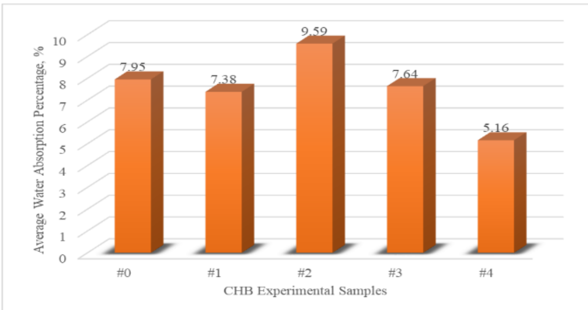

Figure-6: Water Absorption Test Result at 7-Day Curing Period

In Figure 6, experimental sample #4 was recorded to have obtained the lowest average percentage of 5.16%. The controlled CHB and experimental samples #1, #3, and #4 have exhibited more excellent water absorption averages, which indicates that these set-ups absorbed more water than experimental sample #4. All samples were determined to have not displayed the 12%

maximum water absorption requirement following Nigerian Standard NIS 583:2004.

Table-10: Water Absorption Test Result at 14-Day Curing Period

Sample Identification	Wet Mass, g	Oven-Dried Weight, g	Water Absorption, %	Water Absorption Average, %
#0	9903	9120	8.59	9.02
	9531	8708	9.45	
#1	9515	9001	5.71	6.45
	9111	8501	7.18	
#2	9238	8611	7.28	6.85
	8965	8425	6.41	
#3	9432	8725	8.10	7.61
	9304	8686	7.11	
#4	9304	8686	7.11	7.15
	9425	8794	7.18	

The water absorption test results for the fourteen-day cured samples were specified in Table 10, as shown. Experimental sample #1 was recorded to have obtained a water absorption average of 6.45%. The controlled CHB sample, with a water absorption average of 9.02%, was 2.57% higher in water absorption than the experimental sample #1. However, the experimental CHB samples #2, #3, and #4 achieved a higher water absorption average than the controlled CHB samples. The experimental CHB sample #2 was recorded to have obtained a water absorption average of 6.85%. The experimental CHB sample #3 was recorded to have acquired a water absorption average of 7.61%. The experimental CHB sample #4 was recorded to have gained a water absorption average of 7.15%.

The fourteen-day curing period test results showed an increased and decreased water absorption average. The controlled CHB and experimental sample #4 exhibited an increased water absorption average compared to the seven-day curing period test result. On the other hand, experimental samples #2, #3, and #4 recorded a lower water absorption average than the seven-day curing period test results.

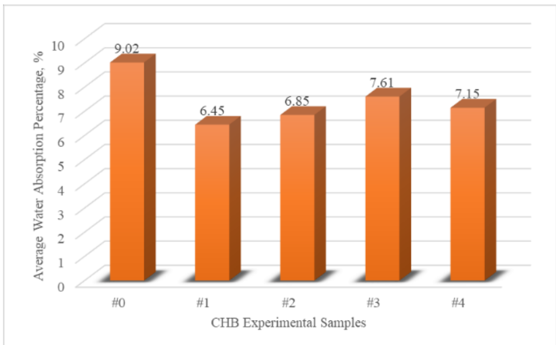

Figure-7: Water Absorption Test Result at 14-Day Curing Period

In Figure 7, the controlled CHB sample recorded the highest value compared to the experimental CHB samples. Experimental sample #4, which had the lowest water absorption average during the seven-day curing period, showed an increase of 1.99%, making it second to the highest. It was followed by experimental samples #2, #3, and #4. All values were still below the 12% maximum standard water absorption percentage as per NIS 583:2004.

Table-11: Water Absorption Test Result at 28-Day Curing Period

Sample Identification	Wet Mass, g	Oven-Dried Weight, g	Water Absorption, %	Water Absorption Average, %
#0	9533	8374	12.16	11.69
	9380	8329	11.21	
#1	9553	8527	10.74	10.03
	9470	8588	9.31	
#2	9076	8108	10.67	11.73
	9388	8188	12.79	
#3	8811	7822	12.64	12.04
	9162	8222	11.43	
#4	9309	8278	12.45	12.18
	8835	7784	11.90	

The water absorption test results for the fourteen-day cured samples were specified in Table 11, as shown. Experimental sample #1 was recorded to have obtained a water absorption average of 10.03%. The controlled CHB sample, with an absorption average of 11.69%, was 1.66% higher in water absorption than the experimental sample #1. However, the experimental CHB samples #2, #3, and #4 achieved a higher water absorption average than the controlled CHB samples. The experimental CHB sample #2 was recorded to have obtained a water absorption average of 11.73%. The experimental CHB sample #3 was recorded to have acquired a water absorption average of 12.04%. The experimental CHB sample #4 was recorded to have gained a water absorption average of 12.18%.

The results from the twenty-eight-day curing period showed an increase in all samples compared to those from the fourteen-day curing period.

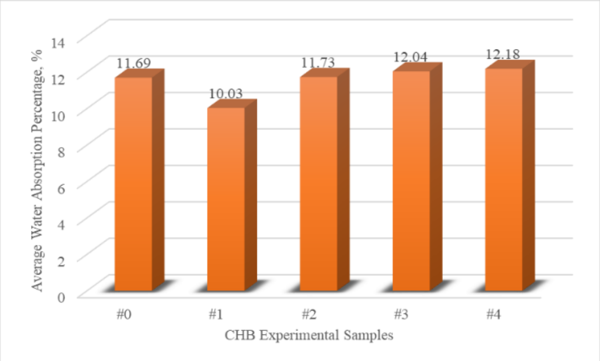

Figure-8: Water Absorption Test Result at 28-Day Curing Period

In Figure 8, the lowest water absorption average was achieved by the experimental CHB sample #1, similar to the result from the fourteen-day curing period. It was followed by the controlled CHB and experimental CHB samples #2, #3, and #4. Only three samples with less than 12% computed values have met the standard code maximum water absorption percentage in compliance with NIS 583:2004.

3.2.4 Cost-Effectiveness Analysis

Table-11: Water Absorption Test Result at 28-Day Curing Period

Sample Identification	Cement	RHA	SCBA	Sand	Water	Cost per Concrete Mix	Cost per Piece
#0	₱ 135	0	0	₱ 26	₱ 10	₱ 171	₱ 11.4
#1	₱ 128.25	₱ 4.34	₱ 0.77	₱ 26	₱10	₱169.36	₱ 11.29
#2	₱ 121.5	₱ 8.69	₱ 1.54	₱ 26	₱ 10	₱ 167.73	₱ 11.18
#3	₱ 114.75	₱ 13.03	₱ 2.31	₱ 26	₱ 10	₱166.09	₱ 11.07
#4	₱ 108	₱ 17.38	₱ 3.08	₱ 26	₱ 10	₱ 164.45	₱ 10.96

Table 12 showcased the cost analysis of the CHB samples. The retail cost of a CHB with an average net compressive strength of 500 psi was 22.50 pesos based on market analysis made by Cabarle and Pablo (2023). The controlled sample #0 has the highest analyzed cost of 11.4 pesos, while the experimental sample #4 has the lowest analyzed cost of 10.96 pesos. The experimental sample #2, the highest average net compressive strength result sample, has an analyzed cost of 10.18 pesos. These analyzed costs only take into consideration the acquisition cost for RHA and SCBA, and cost of the materials used in production. The additional cost for profit and equipment used in the production are not included in the analyzed cost. This was compensated by the gap in between the cost of commercialized CHB and the analyzed cost of the experimental CHB by more than double its amount.

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of all the findings, the conclusion of the study as well as the recommendations of the researchers that can be taken into consideration for the utilization as a reference for future researchers with the same line of a design study for the betterment of the topic, and other practices for the paper and theme.

4.1 Summary

In accordance with the objectives of this study, the following were the summarized findings based on the results gathered through testing and the key points leading to the conclusion:

a) Cement mixture from 0% to 20% replacement passed at least 90% of the mixture through the no. 200 (0.075mm) sieve.
b) A decrease in compressive strength was observed from 0% to 5%, increased from 5% to 10%, and decreased from 10% to 20% cement replacement.
c) Test results showed that the 10% replacement of cement exhibited the highest compressive strength among all mixtures across the three curing periods.
d) The average compressive strength of experimental sample #2 as 10% replacement of cement within the seven-day, fourteen-day, and twenty-eight-day curing period was 5.55 MPa, 5.96 MPa, and 6.62 MPa, respectively.
e) The highest average compressive strength of experimental sample #2 with 6.62 MPa in the twenty-eight-day curing period has a 59.90% increase from the average net area minimum compressive strength as per DPWH Standard Specification 1046.4 – Strength Requirements for average 3 units classified as a non-load bearing CHB.
f) Experimental sample #4 displayed the lowest average compressive strength, among all the samples in the three curing periods, with 3.85 MPa in the seven-day curing period which did not meet the minimum requirement.
g) The lowest average water absorption percentage recorded was 5.16% during the seven-day curing period, and the highest average water absorption percentage was 12.18% at twenty-eight-day, which was experimental sample #4.
h) Experimental sample #1 exhibits the lowest water absorption percentages among all the samples in most cases, mainly at 14-day and 28-

day curing period, with 6.45% and 10.03% respectively.

i) The samples mixed with RHA and SCBA during the 28th day curing period test exhibit an increase in water absorption percentage as the amount of RHA and SCBA increases.

j) The experimental sample #4 had the lowest analyzed cost with 9.6 pesos while the controlled sample had the highest analyzed cost with 11.4 pesos.

4.2 Conclusions

This study leads to the following conclusions:

a) Cement mixture with 0%-20% partial replacement of cement was suitable for the production of Concrete Hollow Blocks (CHB).

b) With the compressive strength test, all samples met and exceeded the minimum compressive strength of 4.14 MPa (600psi) as per DPWH Standard Specification 1046.4 – Strength Requirements.

c) All samples can be considered as non-load bearing CHB.

d) Experimental sample #2 with 5% RHA and 5% SCBA was the ideal ratio as a partial replacement of cement that consistently acquired the highest average compressive strength test result at all the curing period with 6.62 MPa (959.33 psi) as the highest strength at twenty-eight-day curing period.

e) Experimental sample #4 with 10% RHA and 10% SCBA as partial replacement of cement consistently attained the lowest compressive strength test average result at all curing period with 3.85 MPa (558 psi) as the most insufficient strength at the seven-day curing period.

f) With the optimal curing period for this study recorded at the most prolonged duration of 28 days, the compressive strength of blocks was not solely dependent on the length of the curing period; instead, the handling and treatment of these masonry units as well as environmental factors play a significant role in influencing their engineering behaviors.

g) Experimental sample #4 had the lowest average water absorption percentage with 5.16% at the seven-day curing period and the highest average water absorption percentage with 12.18% at twenty-eight-day curing period.

h) 86.67% of all samples had acquired less than 12% average water absorption meeting the standard requirement as per NIS 583:2004.

i) The usage of partial replacement of Portland cement should not be more than 5% RHA and 5% SCBA for optimal results.

j) The compressive strength of the experimental samples showed an upward trajectory for #1 and #2and demonstrated a dip in performance in the remaining samples. This concludes that sample #2, 5% RHA and SCBA, was the optimal mixture combination and can be utilized as a leading specimen for future studies.

k) The experimental sample #2, with an analyzed cost of 10.50 pesos and obtaining a maximum of 6.62 MPa (959.33 psi), was the most cost-effective among all the samples.

4.3 Recommendations

The following were the specific recommendations listed for the future researchers who aspire to continue the study or tackle the same topic and/or the same field of thesis:

a) Execute further in-depth study on the cement mixture with the same percentage replacements such as setting time test and consistency test.

b) Perform and analyze further testing such as thermal test, block density test, and other feasible assessments on using RHA and SCBA in concrete hollow blocks.

c) Explore a different design mixture type or class ratio for the concrete hollow blocks with the use of the same replacement intervals and assessing its properties.

d) Attempt to use other equal percentage replacements focusing around 10% (9%, 11%, etc.) for determining a better engineering behavior.

e) Increase the number of days for the curing period, such as 60 or 90 days.

f) For the whole curing process, make sure to have a huge space for the experimental samples to be submerged in water before its testing.

g) Include the cost of labor and use of equipment for the production of non-load bearing CHB in the cost-analysis.

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