



Research Article

Combined effect of rice husk ash and animal bone powder on strength and permeability of concrete

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ABSTRACT

Concrete is a key component of construction, and its demand is rising quickly along with infrastructural development. Although cement and aggregates are still essential components for making concrete, the production of cement greatly increases CO₂ emissions, necessitating the use of substitute materials to lessen the impact on the environment. As partial cement substitutes, rice husk ash (RHA) and animal bone powder (ABP) are viable alternatives. Animal bones, which are especially common in areas with high cattle populations, and rice husks, a byproduct of paddy production, are frequently discarded despite having useful qualities that can be used to improve concrete. With an emphasis on how they affect the material's permeability and strength, this thesis investigates the addition of RHA and ABP to concrete. Different RHA and ABP replacement amounts are examined through controlled experimentation to ascertain how they affect the properties of concrete following a predetermined curing period. The goal of this research is to determine the ideal combination that strikes a balance between environmental advantages and performance. In addition to improving the qualities of concrete, using RHA and ABP helps with waste management and pollution control. This strategy may help with sustainable building methods, reduce CO₂ emissions, and encourage efficient use of resources by lowering dependency on conventional cement.

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1. Introduction

Of all the building materials used worldwide, concrete is the most widely used due to its distinct benefits over other materials (Swaminathan et al. 2021). An estimated 6 billion tonnes of ordinary concrete are manufactured annually worldwide (Mymrin et al. 2018). Unquestionably, cement plays a crucial role as the only binder in concrete, forming a solid substance that can support loads. It is vital to note that ordinary Portland cement has been a crucial component of concrete for over 200 years in the building industry (Ren et al. 2017). According to reports, the production of one tonne of Portland cement results in around one tonne of greenhouse gas emissions, and the cement manufacturing process accounts for 2% to

8% of the world's power usage (Zeyad et al. 2020). Cement is an essential component of concrete, and its production contributes approximately 5% to 8% of global carbon dioxide emissions (Alex et al. 2016). Waste materials such as rice husk ash, coconut shell, and fuel ash from palm oil are the most practical option for cement binders as they contain high pozzolanic property which supply reactive silica (Winnefeld et al. 2022). The goal is to reduce waste by using agricultural and industrial by-products as alternative binders, offering an environmentally friendly solution to waste management that avoids harmful and costly disposal methods like incineration and landfilling (AlBiajawi et al. 2022). The evolving lifestyle of modern society has resulted in the generation of various types of waste, which can impact the environ-

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ment at different scales if not managed properly (Derki and Akpınar 2023). In recent years, there has been a significant surge in research efforts focused on waste recycling, encompassing both investigative studies and practical implementations (Çelik et al. 2024; Şengel et al. 2022; Canbaz et al. 2021). Each tonne of rice typically yields 200 kilograms of rice husks, which when fully burned, create 40 kg of rice husk ash (RHA). Nearly 320,000 tonnes/year of RHA might be generated in the area, according to a hard estimate, hence suitable alternative disposals need to be prepared to prevent negative environmental effects (Zerbino et al. 2011). According to world rice production by country, about 36.4 million metric tonnes, third in the world (Table 1). Again 513.68 million tonnes of rice are produced in worldwide (Khanal 2021).

About 20% of rice's weight is made up of rice husk. Furthermore, every year, about 150 million tonnes of rice husk are produced (Kordi et al. 2024). Rice husk ash, rich in silica, can replace a portion of cement in concrete, improving its mechanical and durability properties by up to 30% (Zerbino et al. 2011). RHA is a highly reactive pozzolanic substance that is produced by burning rice at temperatures below 700 °C in a regulated marine environment. Its content of amorphous silica is high (Jaya et al. 2012). Animal bones, often discarded as waste from the meat industry, can be repurposed as partial replacements for fine or coarse aggregates in concrete. This approach not only helps reduce environmental pollution

but also explores the potential for producing high-quality concrete structures using crushed animal bones, as researched by various scientists. (Petrounias et al. 2021). According to Department of Livestock Services of Bangladesh (2024) (Table 2), total cattle production in Bangladesh is about 24.856 million and total ruminant production in Bangladesh is about 57.143 million (Salim 2022).

Table 1. World rice production by country (10³ tonnes) (World Population Review 2024).

Country	2021	2020	2019
China	212,843	211,860	209,614
India	195,425	186,500	174,717
Bangladesh	56,945	54,906	54,586
Indonesia	54,415	54,649	54,604
Vietnam	43,853	42,765	43,495
Thailand	33,582	30,231	28,618
Myanmar	24,910	25,983	26,270
Philippines	19,960	19,295	18,815
Pakistan	13,984	12,630	11,120
Brazil	11,661	11,091	10,369
Cambodia	11,410	11,248	10,886
Japan	10,525	10,469	10,527

Table 2. Livestock population of Bangladesh (in million) (Salim 2022).

Name of species	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Cattle	23.488	23.636	23.785	23.935	24.086	24.238	24.391	24.545	24.700	24.856
Buffalo	1.457	1.464	1.471	1.478	1.479	1.486	1.493	1.500	1.508	1.516
Sheep	3.206	3.270	3.335	3.401	3.468	3.537	3.607	3.679	3.752	3.827
Goat	25.439	25.602	25.766	25.931	26.100	26.267	26.435	26.604	26.774	26.945
Total ruminant	53.590	53.972	54.357	54.745	55.133	55.528	55.926	56.328	56.734	57.143

In the year 2022, Bangladesh produced 209,016 thousand tonnes of meat from cattle and buffalo. From 1973 to 2022, Bangladesh's production of beef and buffalo meat increased at an average yearly rate of 1.04%, from 137,047 thousand tonnes to 209,016 thousand tonnes (Bangladesh Production of Beef and Buffalo Meat, 1961-2023 - knoema.com, 2024). One of the waste materials taken out of butchered animals (cows and oxen) is bone, which has a high calcium concentration. Conversely, calcium oxide makes up 60% to 67% of portland cement (Getahun and Bewket 2021). If deemed appropriate, using cow bones in place of fine aggregate will aid in environmental cleanup and the transformation of waste into wealth. When working with concrete, one might assume that the ratio of cement to water is inversely proportional to the concrete's strength, provided that full compaction is maintained at a specific age and standard temperature (Neville and Brooks 1987). A study on rice husk ash (RHA) as a Portland cement substitute found that 10-15% RHA optimizes mortar strength. Lower temperatures yield amorphous RHA, enhancing strength through

calcium silicate hydrate (C-S-H) gel formation. Higher RHA levels above 10% reduce strength due to limited calcium hydroxide (Ca (OH)₂) and increased porosity. White RHA, burnt below 800 °C, showed the best performance, especially in seawater, due to more C-S-H gel but is constrained by Ca (OH)₂ availability for the reaction. The ideal RHA content for cement mortar is around 15% for balanced strength and binder properties (Zhao et al. 2022). The study used river sand and 20mm crushed rock as aggregates, borehole water, and Portland composite cement for testing. Animal bone ash, processed through drying and controlled burning, was mixed in proportions of 1:2:4 with a 0.6 water-to-cement ratio. Cast specimens measured 150mm cubed. Over 28 days, compressive strength peaked at 23.43 N/mm² with 5% bone ash, but dropped to 16.49 N/mm² at 20%. The findings suggest that up to 5% animal bone ash is viable for lightweight structures, as higher percentages weaken the material (Zhao et al. 2022). The study indicates that replacing cement with animal bone powder (ABP) in concrete reduces compressive, split tensile, and flexural

strengths as ABP content increases. For control samples (0% ABP), compressive strength increased with age, peaking at 33.63 MPa at 28 days. However, with 5%, 10%, 15%, and 20% ABP, compressive strength significantly declined. Similarly, split tensile and flexural strengths also decreased with higher ABP percentages. The study found that 5% ABP replacement yielded comparable strength to the control, and 10% ABP replacement achieved required strength standards, making up to 10% ABP viable without compromising concrete strength (Teshome et al. 2019). The study shows that replacing cement with animal bone powder (ABP) reduces concrete strength and workability as ABP dosage increases. An optimal 10% ABP replacement maintains acceptable strength and workability, making it the best balance for concrete mixes while ensuring desired performance characteristics (Makebo 2019). In this study, four concrete mix ratios were created, with one control mix (0% RHA) and three mixes containing 10%, 15%, and 20% rice husk ash (RHA) as partial cement substitutes. The water volume (225.5 kg/m³), coarse aggregates (590 kg/m³), fine aggregates (910 kg/m³), superplasticizer concentration (1%), and water-to-binder ratio (0.41) remained constant. Each mix produced nine cubes (150x150x150 mm) and nine cylinders (300x150 mm) for compressive and tensile strength tests at 7, 28, and 56 days. Rapid chloride permeability tests at 28 days showed reduced ion penetration with higher RHA content, except at 20% RHA. The 10% RHA mix demonstrated exceptional chloride ion resistance (Chopra et al. 2015).

2. Research Significance

This study explores the replacement of cement with Rice Husk Ash (RHA) and Animal Bone Powder (ABP) to assess sustainable advantages in construction, focusing on resource conservation, waste management, environmental impact, energy efficiency, and cost reduction. By substituting cement with RHA and ABP, limestone consumption is reduced, supporting resource conservation and sustainability. RHA, typically used in landfills, decomposes slowly and offers limited ecological benefits, while ABP, rich in calcium oxide, can be managed more effectively as a binding agent, reducing solid waste issues. Environmentally, using RHA and ABP as partial cement replacements decreases carbon emissions from cement production, lessening greenhouse gases. Lower cement demand conserves energy, while the local availability and low cost of RHA and ABP help to minimize construction expenses. This research thus presents RHA and ABP as viable, sustainable alternatives to traditional cement in construction.

3. Materials and Method

3.1. Experimental materials

To get desired quality of silica from RHA it needs to burn at the temperature of 700 °C to 800 °C. Fresh rice husk cannot deliver silicious material required for developing proper chemical bond.

Animal Bone contains calcium which is required to transform as calcium oxide. So, it is required to apply heat about 300 °C to 400 °C. Applying heat also helps to remove biological organism.

3.1.1. Rice husk ash processing

RHA is frequently utilized as a supplemental cementitious material (SCM) in concrete applications to partially replace portland cement. RHA is rich in silica which acts as pozzolanic compound that can chemically react with calcium hydroxide (Ca(OH)₂) in the presence of water. Calcium hydroxide generated during cement hydration, resulting in the formation of more calcium silicate hydrate (C-S-H) gel. This procedure lowers the heat of hydration and the possibility of an alkali-silica reaction (ASR) while also increasing the concrete's strength, durability, and chemical resistance. Because RHA is a byproduct of the combustion and rice milling processes, it reduces waste and greenhouse gas emissions, making it an environmentally beneficial substance. The application of this material in building processes promotes environmentally friendly building practices and efficient use of resources.

After collection of raw rice husk, it was heated at 700 °C to 800 °C in gas furnace. Then it was sieved through #100 sieve to mix with cement for mix design. Silicon was the main element after oxygen in RHA. The chemical composition of the utilized rice husk ash is provided in Table 3.

Processed rice husk ash is shown in Fig. 1 and chemical analysis test result is presented in Fig. 2 which was conducted in JCM-6000PLUS machine.

Table 3. Chemical composition of the utilized RHA.

Element	Mass (%)	Atom (%)
O	70.99	81.27
Si	24.76	16.15
Na	0.13	0.10
Mg	1.98	1.49
S	0.18	0.10
Ca	0.17	0.08
Al	---	---
K	1.58	0.74
Fe	0.22	0.07



Fig. 1. Rice husk ash (RHA).

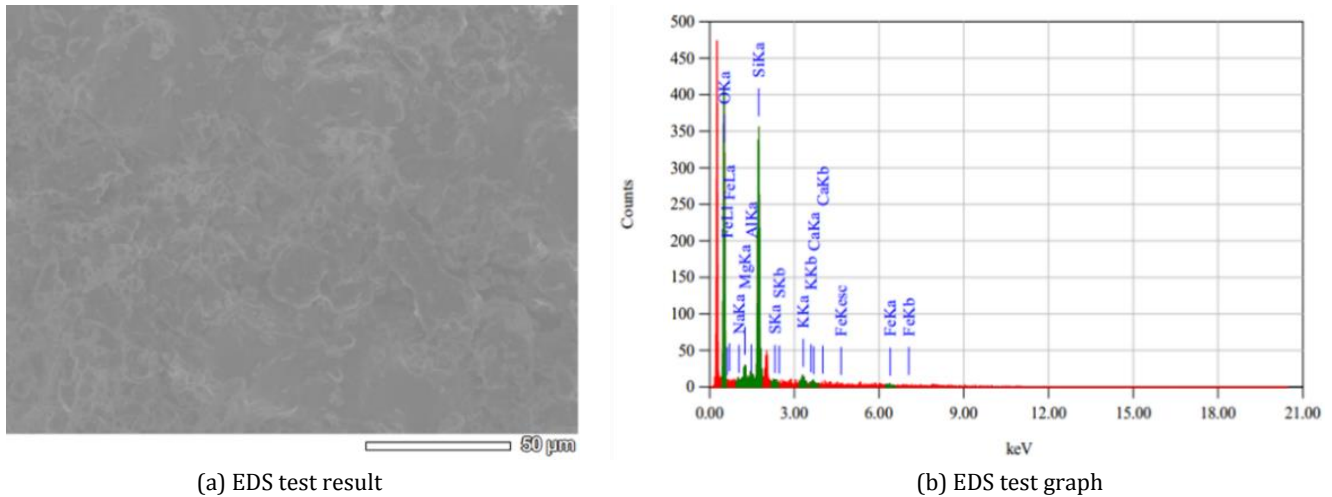


Fig. 2. Chemical analysis of rice husk ash (instrument: JCM-6000PLUS).

3.1.2. Animal bone powder processing

Animal bones are processed and pulverized into a fine powder, which is known as animal bone powder. Usually, to make it, animal bones are cleaned, dried, and burned to remove biological materials. Then, the bones are ground into a fine powder. Animal bone powder is a significant addition to a variety of industries, including agriculture, animal feed, and construction materials. It is rich in minerals including calcium and phosphorus. Animal bone powder has the potential to provide advantages including increased strength and durability when used in place of some of the cement in concrete mixes.

After collection of ABP, it was sun-dried for 2 to 3 days. Then it was grounded through grinding machine and made smaller pieces of size. It was further grounded and sieved into powdered consistency. Next it was heated 300 °C to 400 °C to remove biological organism and calcinated. Then it was sieved again to mix with cement for mix design. The chemical composition of the animal bone powder is provided in Table 4.

Table 4. Chemical composition of the ABP.

Element	Mass (%)	Atom (%)
O	68.43	83.60
Ca	27.93	13.62
Na	0.48	0.41
Mg	1.32	1.06
Al	0.75	0.54
Si	1.09	0.76
K	---	---
Fe	---	---

Processed animal bone powder is shown in Fig. 3 and chemical analysis test result is presented in Fig. 4 which was conducted in JCM-6000PLUS machine.

3.1.3. Cement

Cement, a hydraulic binder, or finely powdered inorganic components combined with water to create a paste that sets and hardens through hydration reactions and processes and maintains its strength and stability even in the presence of water (Atiş and Karahan 2009).

All 27 cement family products covered by EN 197-1 (2011) are further categorized into five primary cement types. For this study CEM-I/BM (Ordinary Portland Cement (OPC)) was used and collected from the concrete laboratory of Civil Engineering Department, RUET, Rajshahi.

3.1.4. Sand

The key component of concrete made of crushed stone or natural sand is fine aggregate. They were mostly utilized to close in spaces left by the coarse aggregate. Sand of FM (2.36) was utilized for this project's fine aggregate.

3.1.5. Coarse aggregate

As natural crushed stone that was passed through 19.0 mm sieve and retain on 12.7 mm sieve was employed in this project (as per ASTM C136 2005).



Fig. 3. Animal bone powder (ABP).

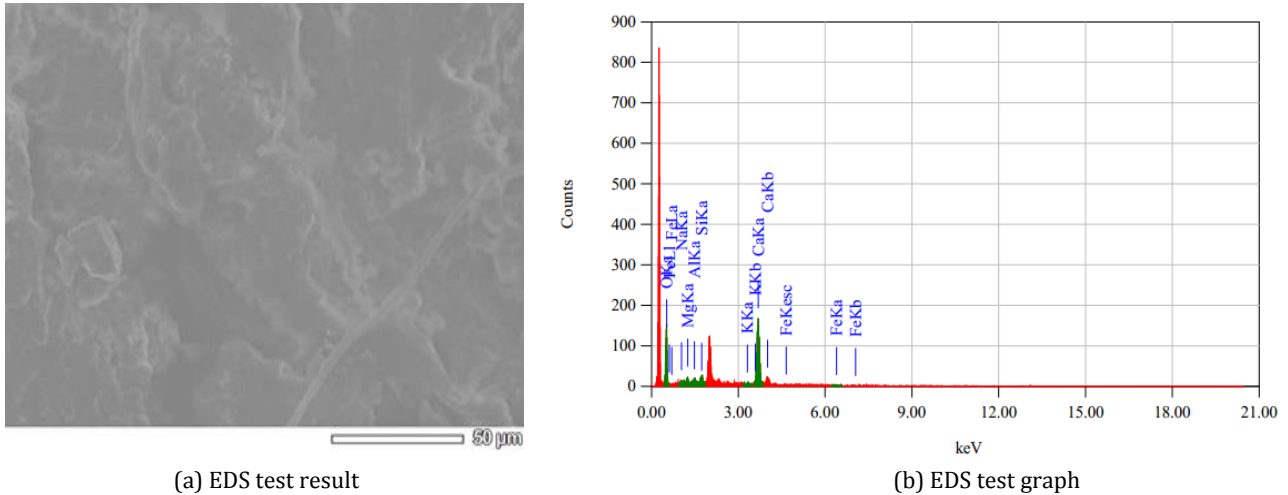


Fig. 4. Chemical analysis of animal bone powder (instrument: JCM-6000PLUS).

3.2. Sample preparations

3.2.1. Specimen size

A total of 9 types of composition were created using batched by weight method for conducting two tests, each of the compositions had different amounts of ABP and RHA by replacing fine aggregate. Before mixing, the various components of concrete are typically propor-

tioned by weight or volume, a process known as batching. According to this study, the most often utilized technique for producing concrete in Bangladesh and the majority of developing countries is batching by weight.

The unit weight of each concrete specimen was measured after 28 days curing in SSD condition. Table 5 provides an overview of all experimental parameters and displays the entire experimental schedule.

Table 5. Experimental parameters for the test specimens.

Test name	Specimen size (cylindrical)	Curing ages
Compressive strength test	100 mm x 200 mm	28 days
Water permeability test	100 mm x 200 mm	28 days

3.2.2. Concrete mixing and casting

Cylinders (100mm diameter x 200mm height) for compressive strength and water permeability test. For every combination, 3 cylindrical samples were prepared for compression test as well as for water permeability test. For mixing from 12.7 mm to 19 mm size of NCA were used.

9 types of concrete mix were prepared replacing Cement (by weight) with different proportion of ABP and RHA. The mix proportions of different compositions of

ABP and RHA with their water cement ratio are described in Table 6.

Before casting the NCA was soaked in water for 24 hours then dried in room temperature for SSD condition. All the specimens were casted according to ASTM C39 (2021). After the mixing the slump value of each mix was noted. Test specimens were completed with a steel trowel after casting. Every test specimen was kept in storage for 24 hours. Then the casing of each cylindrical sample was removed. The preparation of concrete cylinders and the slump value test are shown in Figs. 5 and 6.

Table 6. Different compositions of ABP and RHA.

Combination	ABP	RHA	Cement (OPC)	W/C ratio
1	0%	0%	100%	0.5
2	0%	5%	95%	0.5
3	0%	10%	90%	0.5
4	5%	0%	95%	0.5
5	5%	5%	90%	0.5
6	5%	10%	85%	0.5
7	10%	0%	90%	0.5
8	10%	5%	85%	0.5
9	10%	10%	80%	0.5

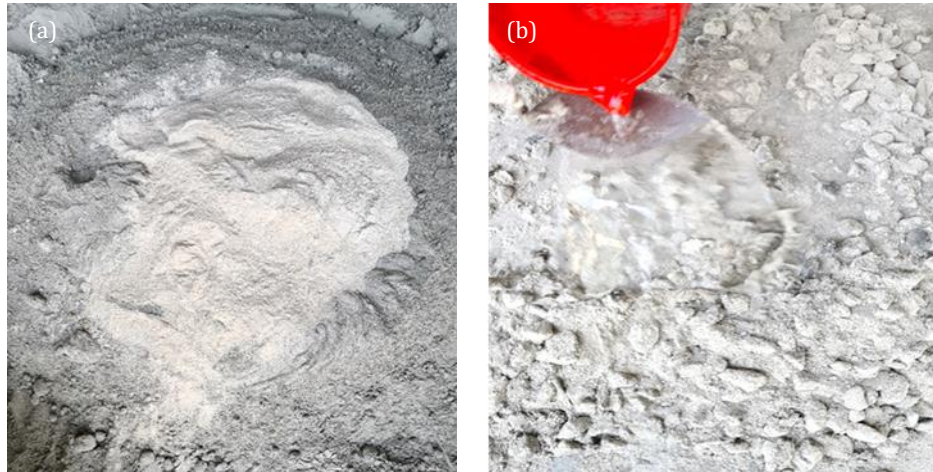


Fig. 5. Mixing of concrete for casting: (a) Mixing dry ingredient; (b) Adding water with mix.



Fig. 6. Measuring the slump value of the concrete mix.

3.2.3. Curing procedure

The pond method of curing was used in which the cylindrical sample were totally immersed in water throughout the curing period. After being cured in water for 28 days, the specimens were removed, and a cutting machine was used to smooth the cylinder's top and bottom surfaces. Cutting process and curing of concrete (after smoothing) is shown in Fig. 7.

3.3. Test methods

3.3.1. Standards for tests

In this investigation, batched by weight have been adopted as the most commonly used method in concrete production in Bangladesh and most developing nations (Table 7).



Fig. 7. (a) Cutting of specimen; (b) Ponding method for curing of specimen.

Table 7. Standards for tests.

Test name	Standards
Compressive strength test	ASTM C39 (2021)
Water permeability test	IS 516 (2018)

3.3.2. Unit weight of sample

After the curing process, the sample was removed from the water and allowed to dry at ambient temperature for half an hour in order to remove any remaining water from the cylinder. The sample was weighed in a balance and the weight was noted in order to assess the sample's unit weight or density. Load measurement was done in weight machine which is shown in Fig. 8.

The unit weight or density of the sample is carried by Eq. (1).

$$\rho = \frac{M}{V} \quad (1)$$

where M is the mass or weight, and V is the volume of the sample.



Fig. 8. The load-measuring method of the test specimen.

3.3.3. Compressive strength test

Compression strength is the ability of concrete to bear loads applied to it without breaking or deflecting. It is possible to evaluate compression strength while adhering to multiple codes, including IS 516 (2018), BS EN 12390-3 (2019), and ASTM C39 (2021). The compression test was carried out in this work, per ASTM C-39 (2021). The compressive strength of the cylindrical specimens was determined using a 2000kN compression machine. The samples were added one at a time. The specimen's composition was recorded before to applying load, and the highest load the specimen could withstand was subsequently noted. Eq. (2) determines the concrete cylinder's ultimate compressive strength after 28 days of curing.

$$f = \frac{F}{A} \quad (2)$$

where F is the recorded load, and A is the cross sectional area of the cylindrical specimen.

The ASTM C39 (2021) test technique involves placing concrete cylinders under a compressive axial load at a rate that stays within a specified range until failure happens. The specimen's compressive strength is determined by dividing the maximum load reached by the specimen's cross-sectional area. This shows the sample both during and after the compression test, as well as the testing apparatus used for the test. It also indicates the sample's failure pattern. Fig. 9 shows the breaking of mould during compressive strength test.

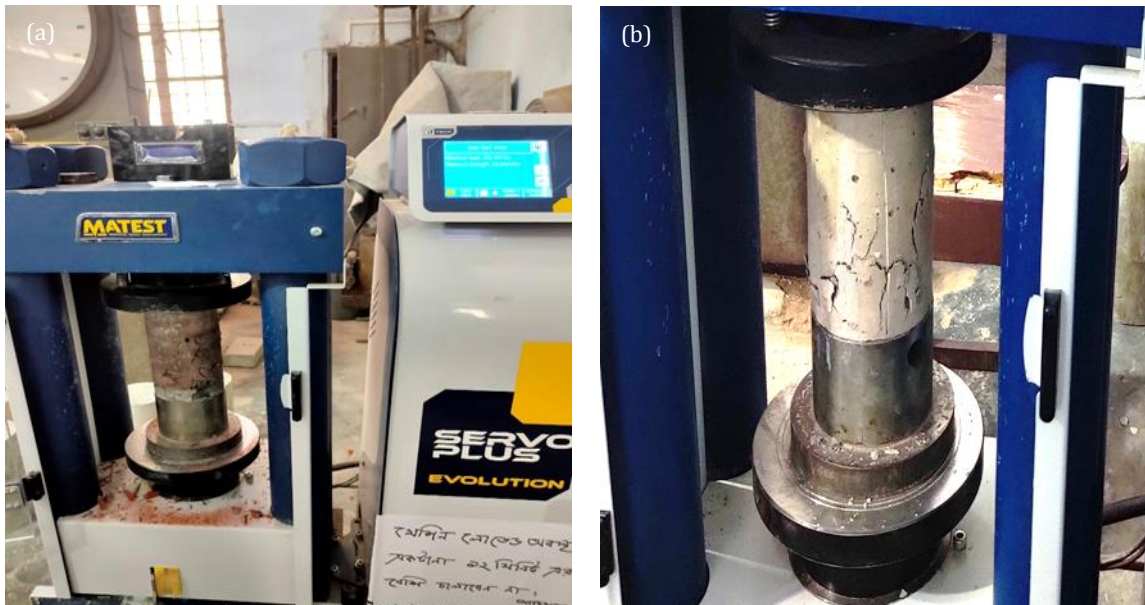


Fig. 9. Sample during compressive strength test.

3.3.4. Water permeability test

Before testing, the specimens were removed from the curing environment and allowed to equilibrate to room temperature. Surface irregularities or imperfections was carefully smoothed or corrected to ensure uniform con-

tact with testing equipment. The water permeability test apparatus typically consists of a chamber or container capable of holding the specimen, along with a water supply system and pressure monitoring equipment. The cylindrical concrete specimen is securely placed in the testing apparatus, ensuring that there are no leaks or gaps

between the specimen and the apparatus walls. Water is then applied to one side of the concrete specimen under controlled pressure. This pressure simulates the hydraulic head or hydrostatic pressure that the concrete would experience in service conditions. The pressure is gradually increased until it reaches the desired level for testing. It was 5 kg/sq.mm for this test procedure. Then the specimens were brought out and sent to UTM for split testing. After splitting, the depth of water entered into the concrete specimen is measured in millimeter scale.

Fig. 10 presents the water permeability testing machine and Fig. 11 shows the procedure of different steps during conducting of the water permeability test.

4. Results and Discussion

All the data that are found from strength test and permeability test, workability test, unit weight test are organized here in different tables. Analyzing these data, the effectiveness of our experiment is discussed based on test results.



Fig. 10. Water permeability testing machine.



Fig. 11. Water permeability test procedure: (a) Specimen placing; (b) Splitting; (c) Marking; (d) Measuring.

4.1. Workability

Table 8 provides an overview of the specimen's slump value. Here the results for 5%B-5%R slump value is the best match for the purpose of the research.

From Table 8 and Fig. 12, workability is observed to increase as the percentage of animal bone powder in concrete rises, but it decreases when the percentage of rice husk ash in concrete increases. It is due to the rice husk ash is a siliceous material which can increase the bond strength in cement to make bond and harden faster. On the other hand, animal bone powder contains CaO that will tend to make strong chemical bond that shows higher slump value.

Therefore, presence of excess amount of ABP can increase workability but excess RHA decreases workability. RHA and ABP also worked as filler materials in concrete by filling voids between coarse and fine aggregates, leading to improved density and reduced porosity.

Table 8. Slump values of different concrete mixes.

Concrete mix	Slump value (mm)
0%B-0%R	76
5%B-0%R	79
0%B-5%R	73
5%B-5%R	74
0%B-10%R	69
10%B-0%R	82
10%B-5%R	81
5%B-10%R	83
10%B-10%R	86

B: Animal bone powder; R: Rice husk ash

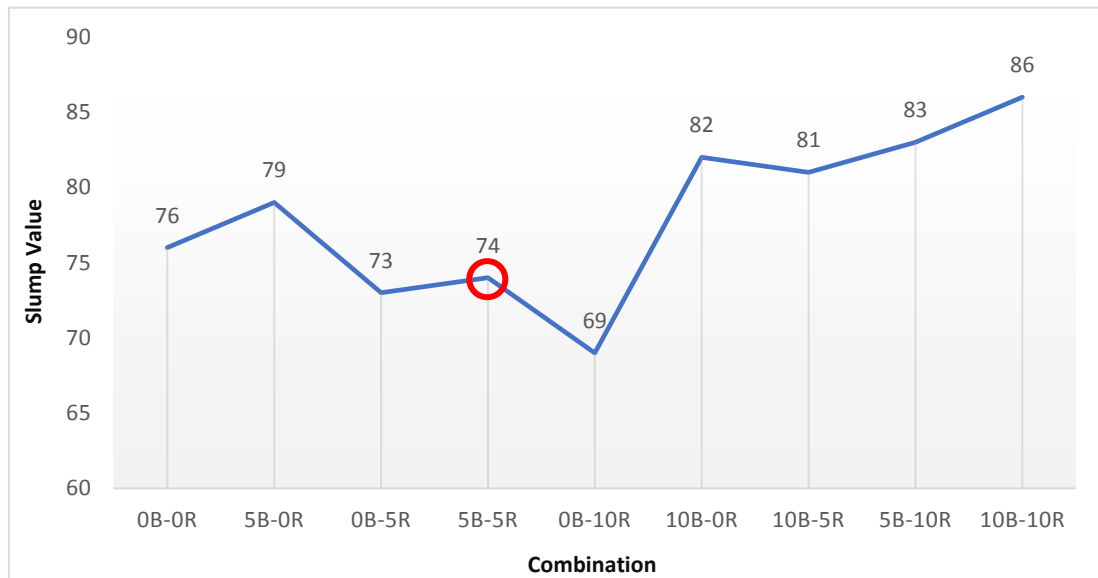


Fig. 12. Workability of concrete with the partial replacement of cement by ABP and RHA.

4.2. Unit weight

Table 9 provides the results that 5%B-5%R weight value is the best match for the purpose of the research.

From Table 9 and Fig. 13, it was observed that specific weight decreases with the increment of RHA and ABP. The unit weight decreases more when ABP is used as a partial replacement. We can come to a decision that unit weight of RHA is more than ABP and it reduces the weight of the structure.

4.3. Compressive strength

The test for compressive strength complies with the code that was previously covered in the above chapter. Table 10 provides the results that 5%B-5%R compressive strength value is the best match for the purpose of the research.

Table 9. Unit weight of cylindrical concrete specimens.

Concrete mix	Unit weight (g/cm ³)
0%B-0%R	2.409
5%B-0%R	2.318
0%B-5%R	2.367
5%B-5%R	2.373
0%B-10%R	2.369
10%B-0%R	2.271
10%B-5%R	2.245
5%B-10%R	2.241
10%B-10%R	2.255

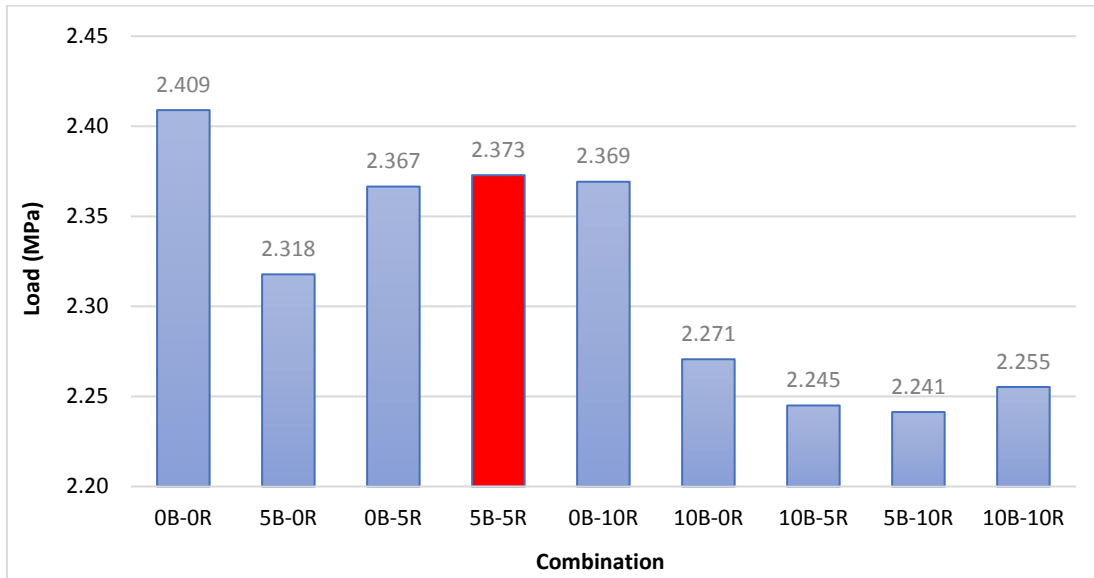


Fig. 13. Unit weight of different concrete mix with RHA and ABP (28 days of age).

Table 10 and Fig. 14 demonstrates that as the amount of RHA and ABP replacement for cement increases, the compressive strength of concrete after 28 days of curing increases for some combination and then decreases for other combination. This may be due to when RHA and ABP is sufficient amount to react and make C-S-H gel then strength increases and when it is much more then strength decreases.

Minimum concrete strength for structural application of reinforced concrete must be 20 N/mm². However, for structures up to 4 story, the minimum concrete strength may be decreased to 17 N/mm² (BNBC 2020).

According to this code, we can use the combination of 5%B-5%R and 0%B-5%R for the sufficient strength and 5%B-0%R AND 0%B-10%R for the low strength concrete. Other combination can be used for the light weight structure.

Table 10. Variation of compressive strength of concrete replacing cement with ABP and RHA.

Concrete mix	Avg. comp. strength (MPa)
0%B-0%R	21.73
5%B-0%R	19.47
0%B-5%R	22.25
5%B-5%R	22.87
0%B-10%R	17.66
10%B-0%R	14.31
10%B-5%R	15.22
5%B-10%R	15.76
10%B-10%R	13.51

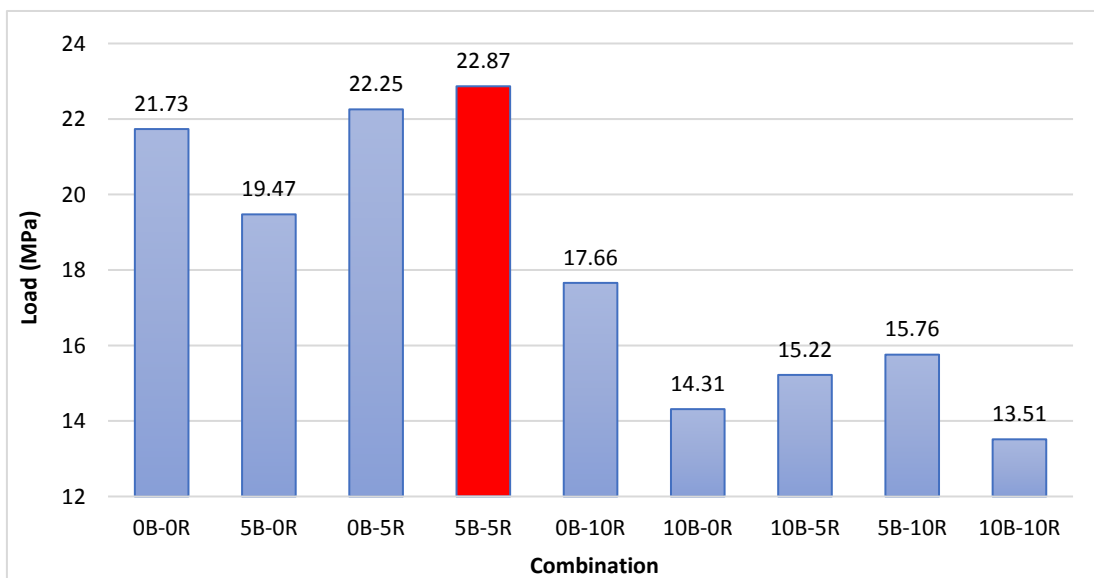


Fig. 14. Compressive strength of different concrete mix after 28 days curing.

4.4. Water permeability

The test for water permeability complies with the code that was previously covered in the above chapter. Table 11 provides the results that 5%B-5%R permeability value is the best match for the purpose of the research. RHA and ABP is sufficient amount to react and make C-S-H gel then permeability decreases and when it is much more then permeability decreases which is shown in Table 11 and Fig. 15.

4.5. Combined effect of permeability and strength

From Table 12 and Fig. 16, it can be seen that as the RHA and ABP both are used up to 5% the strength and permeability increases. When the amount goes beyond that then the compressive strength and the permeability usually decreases. For some specific and special cases, we can use the low permeable and low strength concrete. For the replacement of both 5%, we get the most impressive result.

Table 11. Variation of water permeability of concrete replacing cement with ABP and RHA.

Concrete mix	Avg. permeability (mm)
0%B-0%R	9.1
5%B-0%R	8.9
0%B-5%R	8.2
5%B-5%R	7.4
0%B-10%R	9.5
10%B-0%R	10.2
10%B-5%R	11.5
5%B-10%R	10.9
10%B-10%R	13.2

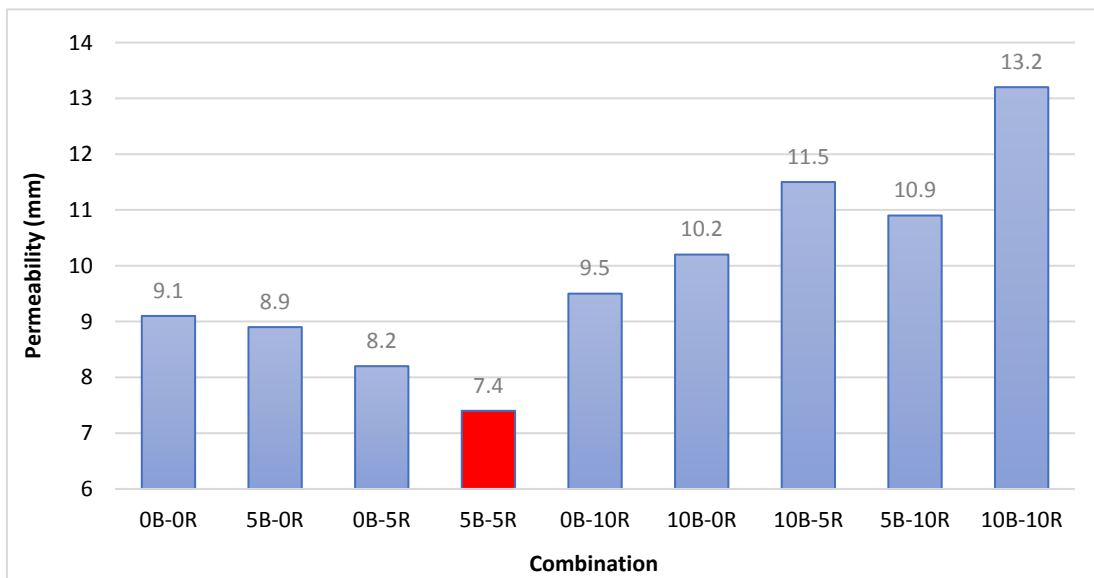


Fig. 15. Water permeability of different concrete mix after 28 days curing.

Table 12. Combined result of replacing cement with RHA and ABP.

Concrete mix	Avg. comp. strength (MPa)	Avg. permeability (mm)
0%B-0%R	21.73	9.1
5%B-0%R	19.47	8.9
0%B-5%R	22.25	8.2
5%B-5%R	22.87	7.4
0%B-10%R	17.66	9.5
10%B-0%R	14.31	10.2
10%B-5%R	15.22	11.5
5%B-10%R	15.76	10.9
10%B-10%R	13.51	13.2

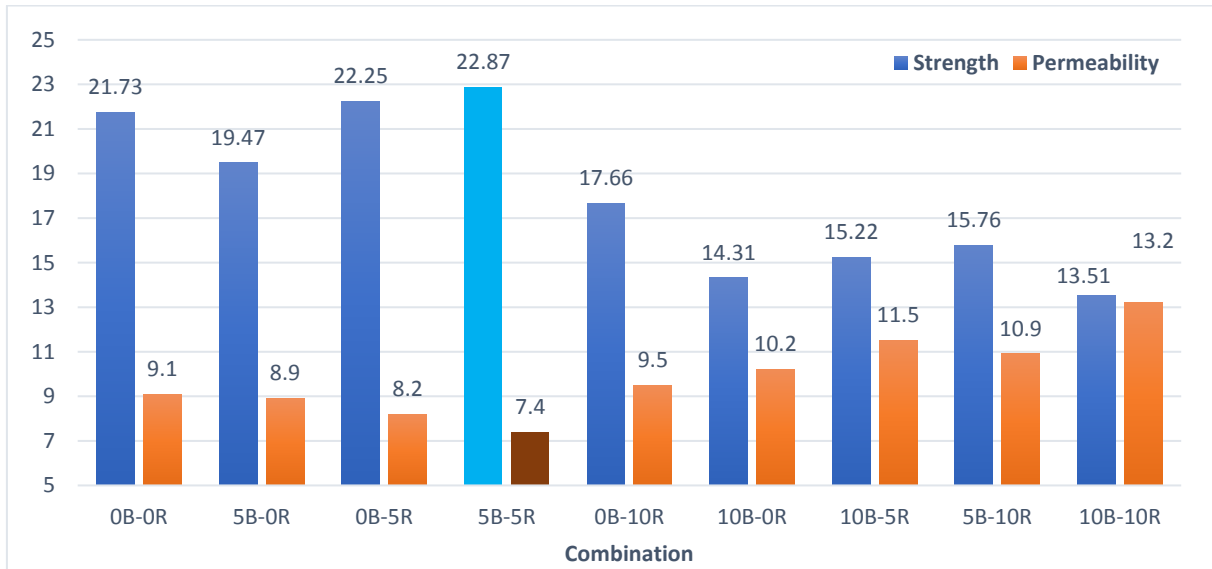


Fig. 16. Combined effect of ABP and RHA concrete mix after 28 days curing.

In consideration with the literature review, it can be seen that in these two different tests conducted for RHA and ABP separately the strength is higher up to 5%, sometimes up to 10% replacement of the materials. Permeability decreases for the increase of RHA but increase for the increment of ABP. However, in this experiment both the ingredient has been mixed and the result found for the 5% RHA and 5% ABP provides the best result in terms of strength and permeability.

5. Conclusions

The analysis focused on the compressive strength and water permeability of the replacement of ABP and RHA in some portion of cement, examining the result with varying percentage of ABP and RHA (0%, 5%, 10%). The samples exhibited the following characteristics:

- Compared to a concrete cylinder the compressive strength of concrete, 5% RHA and 5%ABP-5%RHA curing for 28 days, yielding values of 22.25 MPa, 22.87 MPa respectively. These recorded compressive strengths represent the average maximum strengths achieved in the study.
- Compared to a concrete cylinder permeability of concrete, with the incorporation of cement by at the combination RHA and ABP of preferred percentages of 5%ABP-0%RHA, 0%ABP-5%RHA, 5% ABP-5% RHA at 28 days, resulting in 8.9mm, 8.2mm, 7.4mm respectively. The recorded results show that increase in compressive strength decreases in permeability.
- Compared to unit weight, the unit weight gradually decreases as the combination of RHA and ABP increases. From the test result it is observed that unit weight of the concrete containing RHA relatively higher than concrete containing ABP. The workability decreases with the reduction of the amount of the cement.

By testing the cylindrical specimen containing RHA and ABP we can observe that the compressive strength of concrete containing 5% RHA and 5% ABP increases by

more than 3% than that of contain cement. For the specimen that contain only 5% RHA increases the strength by more than 2.5%. If we consider about the water permeability of concrete then the concrete specimens contain only 5% RHA, only 5% ABP, 5% ABP-5% RHA improves its permeability approximately by 2.20%, 9.89% and 18.68%. This phenomenon occurs when the ABP and RHA construct C-S-H gel that is liable for the larger compressive strength. Larger C-S-H gel helps to restrict the water permeability. RHA also works as a finer filler particle. That also helps to minimize the porous structure of the concrete leads to less permeability. When the more partial material is added then the strength decreases due to insufficient amount of reactant is present for proper chemical reaction. That also leads to the make the structure more porous leads to more permeable to water.

Due to limitation of time the study was concluded only with the observation of workability, unit weight, compressive strength, permeability of concrete. Perhaps, the study can be further enriched with the following additional work:

- Investigation of strength behavior of concrete using ABP and RHA in replacement of cement above 10-30 percent by weight.
- Observation of the flexural behavior of concrete by split tensile test using ABP and RHA in replacement of cement up to a certain percentage.
- The test was performed for cylindrical specimen, but it can be also performed for cubical specimen.
- Further work should be done to cover rapid chloride penetration test, water absorption, freeze-thaw durability and abrasion etc.
- Inspection of mechanical strength properties of concrete using different properties such as silica fume, fly ash, ceramic particle, egg shale etc.
- Different water cement ratio can be used.
- Evaluation of concrete's durability and life cycle assessment with the addition of different combination of ABP and RHA seems they are environmentally friendly.

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Conflict of Interest

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Author Contributions

All of the authors made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; were involved in drafting the manuscript or revising it critically for important intellectual content; and gave final approval of the version to be published.

Data Availability

The datasets created and/or analyzed during the current study are not publicly available, but are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the ethics committee of Rajshahi University of Engineering and Technology. All methods were performed in accordance with relevant guidelines and regulations.

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