ARTIFICIAL LIGHTWEIGHT AGGREGATE PRODUCTION FROM RICE HUSK AND RICE HUSK ASH

Saifur Rahman Ruman*[1], Abu Zakir Morshed[2] and Abhishek Sarkar[3]

[1] GraduateStudent, Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh, e-mail: ruman.kuetce17@gmail.com
[2] Professor, Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh, e-mail: azmorshed@ce.kuet.ac.bd
[3] Postgraduate Student, Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh, e-mail: sarkar1701019@gmail.com

***Corresponding Author**

ABSTRACT

The global demand for construction materials is rising, depleting natural resources. Concrete aggregates are generated from natural resources. Yet, natural resources are few. Continuous consumption threatens all life on earth by depleting these natural resources. Using industrial waste as a sustainable alternative is a major challenge in this area. Rice husk ash (RHA) is a by-product of rice milling that includes a considerable amount of amorphous silica and might be used to make silica gel through a series of chemical and physical processes. The heating of a 1M concentration of Sodium Hydroxide(NaOH) solution yields good silica gel. Rice husk and rice husk ash are utilised as lightweight aggregates in construction materials by partially substituting conventional aggregates to reduce the end product's weight. Natural fine aggregate is sieved at a specific portion (#16 passing - #30 retained and #30 passing - #50 retained) and replaced with a similar sieved portion of rice husk ash. This study attempts to use rice husk ash as a partial replacement for fine aggregate in concrete. The performance of the concrete was assessed in terms of its compressive strength, Rapid Chloride Permeability Test (RCPT), and sulphate resistance test. Control concrete had 18.0 MPa and 27.6 MPa compressive strength after 7 days and 28 days, respectively. In contrast, 25% RHA ash-containing concrete had 15.5 MPa and 23.5 MPa compressive strength after 7 days and 28 days, respectively. In the sulphate solution, the mortar cube's compressive strength was higher than that of the control specimen, and the concrete with 25% ash content showed more resistance inRCPT and less expansion in the Sodium Sulphate(Na_2SO_4) solution.

Keywords:*Rice Husk Ash, Silica Gel, Artificial Lightweight Aggregate, Compressive Strength, Sulphate Resistance of Mortars.*

1. INTRODUCTION

Historically, civilisations like the Roman and Egyptian ones have utilised concrete as a building material for thousands of years. Concrete is a durable and versatile building material that can be used for roads, buildings, bridges, and dams. Concrete is a composite material that is used for various construction works, and its aggregates are executed from natural resources (Chabannes et al., 2014). Aggregates are a fundamental component of concrete as they cover the majority of the volume of the concrete mix, which contributes tothe material's strength and durability.About 8-12 million tons of natural aggregates are needed each year for concrete production, and aggregates make up about 70% of the volume of concrete.As a result, the amount of naturally available aggregates is gradually decreasing. In this study, lightweight aggregates were made from rice husk and rice husk ash, which is anindustrial waste (Sajjad Hossain & Morshed, 2020).

The rice husk is the outer layer of the rice grain, which is separated during the milling process. The residue that results from burning rice husk in a regulated environment is known as rice husk ash (RHA).Due to the unique properties of rice husk ash, it is a suitable lightweight aggregate for usage in construction projects in Bangladesh. Rice husk ash is a lightweight substance that can be used to reduce the overall weight of building materials and concrete.Concrete's strength and durability are increased by adding RHA as an aggregate (Prasad & Pandey, 2012). Furthermore, using RHA lessens the need for cement in the building sector, which decreases the cost of making concrete and lessens the damaging effects that CO_2 emissions from the manufacturing of cement have on the environment (Bui et al., 2005; Hwang & Wu, 1989). When making lightweight concrete, mortar, and other building materials, RHA can replace conventional aggregates, including sand, gravel, and crushed stone.These materials are more insulating, lighter, and have reduced heat conductivity.

Utilising rice husk ash in construction can help reduce the amount of waste transported to landfills and the environmental effect that the building industry leaves behind because it is a renewable resource that is often abandoned as junk. In Bangladesh, using rice husk ash as a lightweight aggregate has a number of advantages, such as decreased overall weight, enhanced insulation, more local availability, and less environmental impact overall (Abbas et al., 2019a). This is why it is an important part of Bangladesh's building industry, and over the coming years, its utilisation is expected to only grow.

Silica that lacks a clearly defined crystal structure is known as amorphous silica. It also contains high calcium, potassium, and magnesium levels, among other minerals and trace elements. Silica gel can be prepared from rice husk ash by thermal treatment. The produced silica gel is then used on the surface of the rice husk, which makes it non-biodegradable, andthat rice huskis used as an aggregate ratio in the concrete mix to produce artificial lightweight aggregate. The specific ingredients of RHA can vary based on a number of factors, such as where the rice husks come from, how they burn, and the processing techniques employed. Cement hydrates produce calcium hydroxide, which is combined with materials called pozzolans to generate compounds with cementitious properties. A typical pozzolanic material that can be used in concrete in place of sand is rice husk ash (RHA). Studies show that adding RHA to concrete can lengthen its life, reduce permeability, and boost compressive strength (Rahman et al., 2018). However, its effectiveness may be impacted by factors like the standard of RHA, the amount of sand it replaces, and the overall mix design. Using rice husk ash (RHA) in concrete not only uses a waste product but also lessens the requirement for regular sand, which is sometimes taken out of riverbeds, creating environmental problems.

The procedure of creating artificial lightweight aggregates using rice husk and rice husk ash gathered from a local rice mill factory is the primary subject of this study. This study attempts to use rice husk ash as a partial replacement for fine aggregate in concrete. The performance of the concrete can be assessed in terms of its compressive strength, rapid chloride permeability test, and sulphate resistance test.

2. METHODOLOGY

The sequential process for producing artificial lightweight aggregate includes gathering materials, determining the attributes of the materials, mix design, casting the specimen, and carrying out various tests. A specific sieve analysis ((#16 passing - #30 retained and #30 passing - #50 retained) was conducted for fine aggregates. After that, sand was replaced by rice husk ash, and mould was prepared according to the mix design.

The production of fine aggregate from rice husk ash is shown in Figure 1.

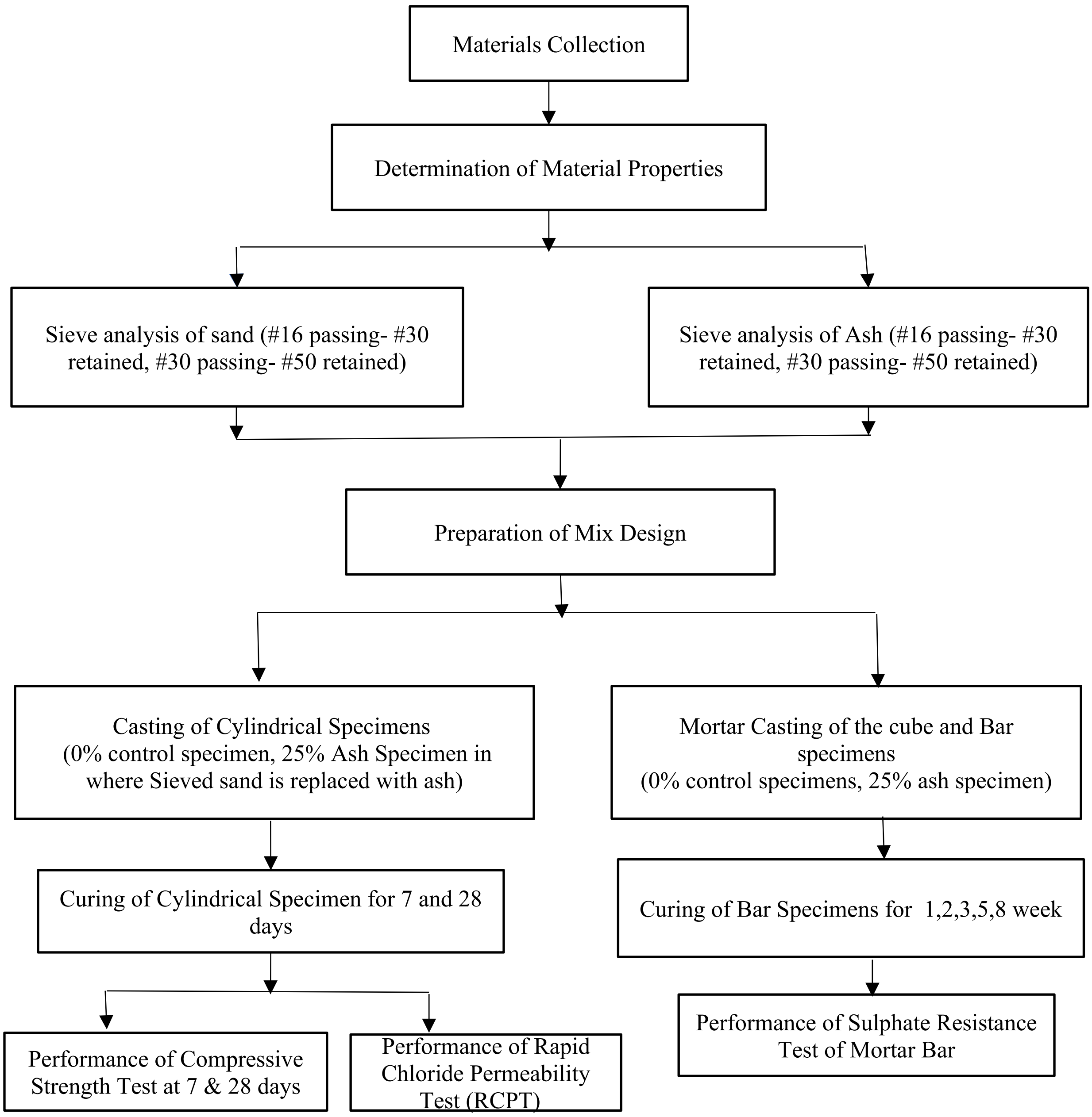

Figure 1: Flow Chart Showing Steps of Experimental Works

2.1 Production of Aggregate from Rice Husk

Initially, 10 g of rice husk ash was added to various volumes and concentrations of sodium hydroxide solution (most solutions were 2.0 M = 165 mL, 1.0 M = 330 mL, and 0.5 M = 660 mL). The mixture was then heated in a muffle furnace oven at 350°C for 5 or 10 minutes. The solution was filtered through a filter paper, and the carbon residue was rinsed away with 100 mL of deionised water. Both the filtrate and the washing were cooled to room temperature. The resulting solution was adjusted to pH 7.0 with concentrated sulfuric acid and incubated for 48 hours to stimulate silica gel formation. The produced silica gel was applied to the surface of the rice husk. Silica gel from rice husk is used on the surface of rice husk, which is then used as the aggregate ratio in the concrete mix. Then, artificial aggregate was prepared and compared with natural aggregate. The full procedure is presented in Figure 2.

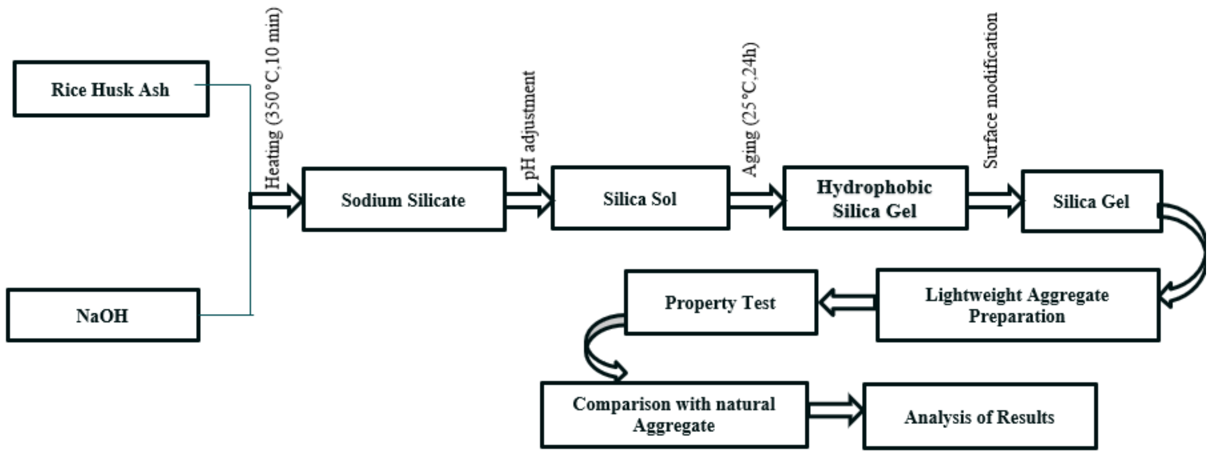

Figure 2: Production of Artificial Lightweight Aggregate

2.2 Materials

The outer covering of the rice grain separated during the milling process is known as rice husk. Rice husk ash (RHA) is the residue produced when rice husk is burned in a controlled environment. Silica (SiO_2) and a few other minerals and chemicals make up the majority of the composition of rice husk ash. After being gathered from the auto-rice mill sector, rice husk ash was spread out on the ground and allowed to sun-dry. Sylhet sand was used for fine aggregate, and stone chips were used as coarse aggregate. Ordinary Portland cement was used as a binder.

2.3 Preparation of Silica Gel

In a thermo-resistant plastic container, 10 g of rice husk ash was added to various volumes and concentrations of sodium hydroxide solution (most solutions were 2.0 M = 165 mL, 1.0 M = 330 mL, and 0.5 M = 660 mL because these solutions provide the minimum amount of NaOH necessary to produce sodium silicate with a SiO_2/Na_2O ratio of 1.0). The mixture was then heated in a muffle furnace oven at 350°C for 5 or 10 minutes.

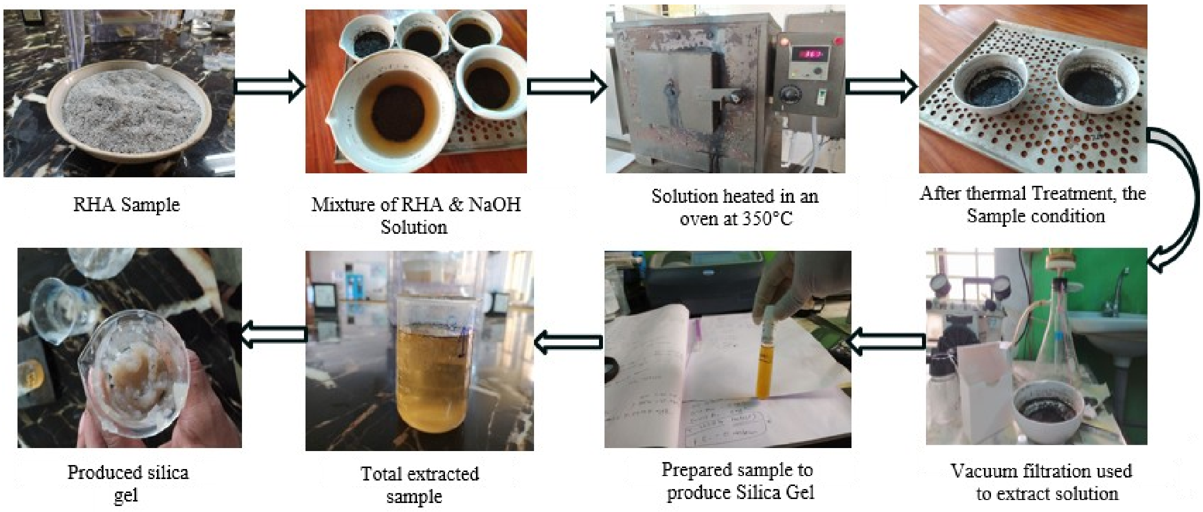

Figure 3: Stepwise Preparation of Silica Gel

2.4 Determination of Material Properties

The determination of aggregate and rice husk ash unit weight in compact or loose condition is covered by ASTM Test Method C-29. ASTM Test Method C 127 specifies the specific gravity of fine aggregates and rice husk ash, with the bulk specific gravity or apparent specific gravity being used to express the specific gravity, as shown in Table 1.

The measurement of the moisture content of aggregates and rice husk ash is covered by the test method ASTM C 566. To calculate the moisture content, 500 g of fine aggregates and 300 g of rice husk ash were collected. The ASTM C 136 test method determines the fineness modulus of aggregates and rice husk ash. The Fineness modulus (FM) is an empirical factor that provides a ready index of a material's coarseness or fineness.

Table 1: Mix Ratio of Concrete

Properties	Values
Cement: Fine Aggregate (FA): Coarse Aggregate (CA) Ratio	1:2:3
Water: Cement (w/c) Ratio	0.57
Nominal maximum size of Coarse aggregate	19.0 mm

2.5 Specimen Preparation

2.5.1 Casting of Cylindrical Specimens

Two groups of concrete cylinders with dimensions of 100 mm in diameter and 200 mm in height were cast, as shown in Figures 4(a) and 4(b).The compressive strength (shown in Figure 4(c)) and rapid chloride permeability (shown in Figure 4(d)) of these specimens were determined. The sieved (#16 passing - #30 retained, and #30 passing - #50 retained) sand was replaced with 25% sieved (#16 passing - #30 retained, and #30 passing - #50 retained) rice husk ash for the production of artificial lightweight aggregate.

Figure 4(a): 0% Rice Husk Ash

Figure 4(b): 25% Rice Husk Ash

Figure 4(c): Compressive Strength Test

Figure 4(d): Rapid Chloride Permeability Test

2.5.2 Casting of Mortar Specimens

To determine the sulphate resistance of the control sample and the 25% rice husk ash samples, casting was done to create 21 cube specimens and 6 mortar bar specimens, as shown in Figure 5. The ratio of cement to sand in the mix used to cast the mortar specimens was 1:2.75, and the water-to-cement ratio was 0.485. In this case, sand was replaced by 25% of rice husk ash. The concrete specimen casting schedule is presented in Table 2, which was calculated from the mix design.

Figure 5: Mortar Bar Specimens

Table 2: Concrete Specimen Casting Schedule

Shape of the Specimens	Type of Specimens	No. of Specimens	Size of the Specimens
Cylindrical Specimens	0% Rice Husk Ash	24	100 mm × 200mm
	25% Rice Husk Ash	24	
Mortar Cube Specimens	0% Rice Husk Ash	21	50 mm × 50mm × 50mm
	25% Rice Husk Ash	21	
Mortar Bar Specimens	0% Rice Husk Ash	3	25mm × 25mm × 285mm

25% Rice Husk Ash	3

3. RESULT AND DISCUSSION

3.1 Physical Properties of Materials

Physical qualities of materials are features that may be observed or measured without altering the composition of the material. Specific gravity, fineness modulus, and the density of concrete are determined for the control specimen and the sample containing 25% RHA, as presented in Table 3. The density of the control specimen concrete is 2477 Kg/m^3, and RHA-containing concrete is 1968 Kg/m^3.

Table 3: Physical Properties of Materials

Materials	Materials Properties	Unit	Value
Fine Aggregate	Specific Gravity	-	2.58
	Water Absorption	%	3.57
	Fineness Modulus	-	2.84
	Unit Weight	Kg/m^3	1686.1
Rice Husk Ash	Specific Gravity	-	1.26
	Water Absorption	%	95.3
	Fineness Modulus	-	1.86
	Unit Weight	Kg/m^3	250.74

3.2 Compressive Strength of Concrete

Figure 6 displays the results of compressive strength testing conducted on a concrete specimen containing 0% ash as well as a concrete specimen containing 25% ash. It is clear from the results that the specimen with 25% ash has a lower compressive strength than the specimen with 0% ash. Lower bonding strength and higher water absorption in RHA might be the reasons behind the lower compressive strength. At the end of the 28-day curing period, the control specimen is supposed to have a compressive strength of 30 MPa. At 7 days, the compressive strength of the ash-free concrete specimen was found to be 18.03 MPa, and at 28 days, this value increased to 27.62 MPa. On the other hand, the compressive strength of concrete containing 25% ash at 7 days is 15.48 MPa, and at 28 days, it increases to 23.53 MPa. The compressive strength of concrete specimens after 28 days is strikingly similar to the intended compressive strength.

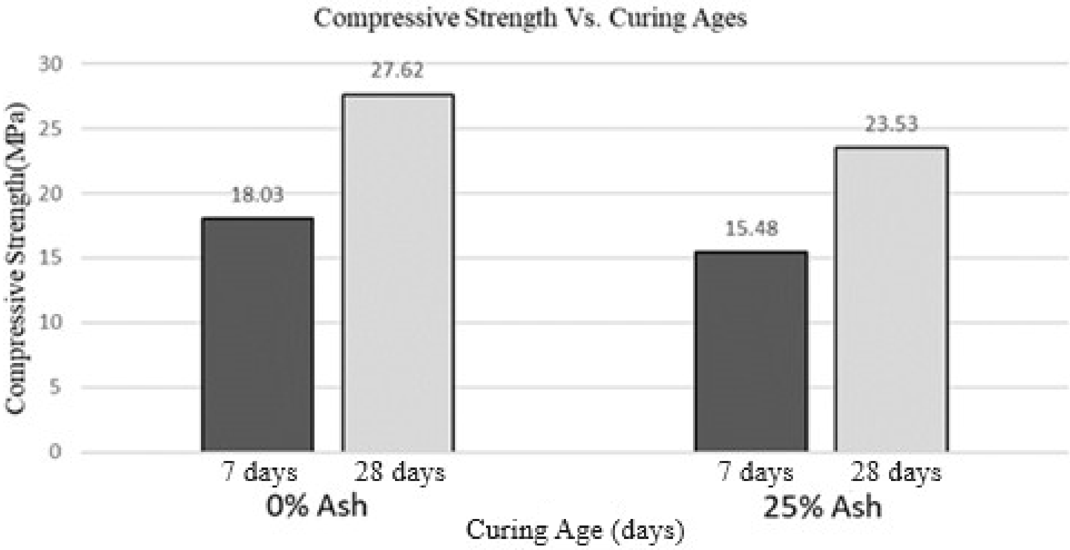

Figure 6: Comparison of Compressive Strength of 0% Ash and 25% Ash Concrete Specimens.

3.3 Rapid Chloride Permeability

At ages 7 and 28 days, the chloride ion penetration was measured by the total charge that travelled through a concrete cylinder with a slice that was 2 inches thick and lasted for 6 hours. Figure 7 illustrates the amount of passing current in relation to time for concrete containing either 0 or 25% ash for a period of 6 hours.

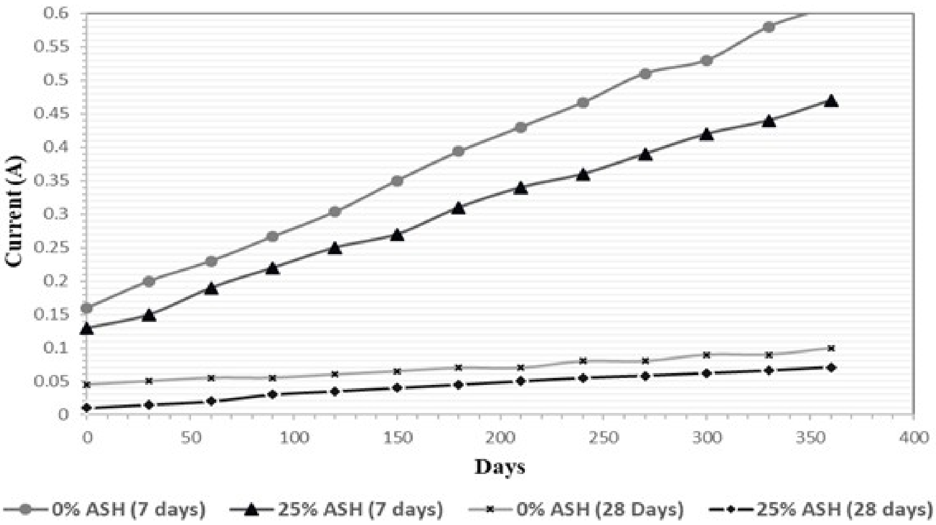

Figure 7: Amount of Current Passing with Time

During the test, a voltage of sixty volts was applied continuously for six hours. The data are measured at regular intervals of one-quarter of an hour. According to the findings, the rate of change in passing current is approximately linear with respect to time for both 0% and 25% ash at various ages. RHA-containing concrete showed greater resistance in RCPT as it has lower permeability, and a denser microstructure is produced through the pozzolanic reaction of RHA in concrete.

The variation in rapid chloride permeability at different ages is depicted in Figure 8 for samples containing 0% and 25% ash, respectively. According to the findings, the total passing charge (in coulomb) in the specimen containing 0% ash is greater than that in the specimen containing 25% ash when compared to time. The figure demonstrates that the total passing charge in coulombs varies from 8361 C to 1507.5 C at 7 and 28 days, respectively, for 0% ash. On the other hand, for 25% ash, the figure demonstrates that the passing charge in coulombs varies from 6552 C to 929.70 C at 7 and 28 days, respectively. As a result, it can be seen that the total passing charge is greater after 7 days and lower after 28 days; the total passing charge falls with increasing amounts of time.

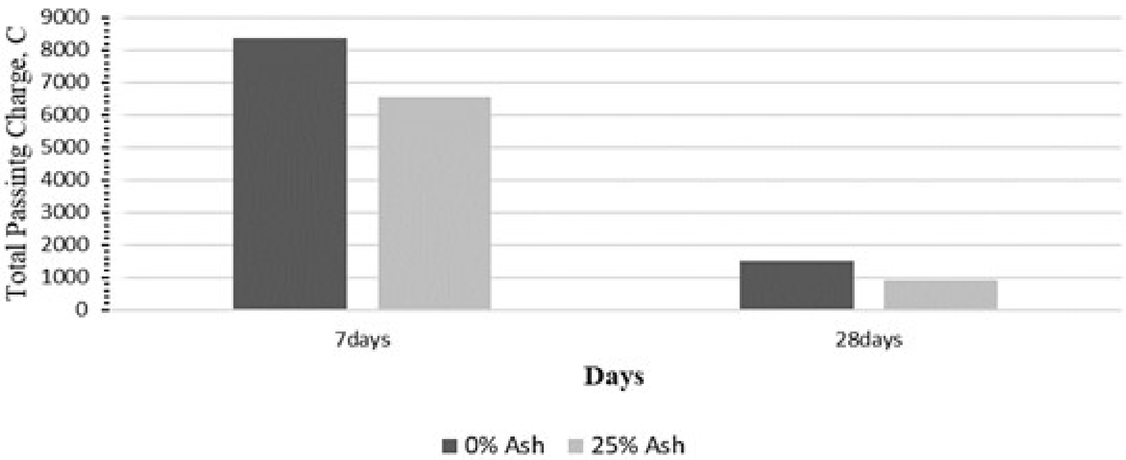

Figure 8: Comparison of Rapid Chloride Permeability of 0% Ash and 25% Ash Concrete Specimens

3.4 Sulphate Resistance of Mortars

The ability of a mortar mixture to resist the deleterious effects of sulphate ions present in the surrounding environment is referred to as sulphate resistance. The ASTM C1012 test is used to evaluate the sulphate resistance of mortars by exposing them to a sodium sulphate solution and monitoring any weight or expansion changes.

3.4.1 Compressive Strength Variation in Sulphate Solution

Sulphate attack occurs when sulphate ions react with the cement paste in the mortar, resulting in the formation of compounds that can cause expansion, cracking, and, ultimately, a loss of strength. These compounds form when sulphate ions react with the cement paste in the mortar. Figure 9 shows the relationship between compressive strength variation in a sulphate solution with time, and it is observed that the highest compressive strength of the cube specimen in the 4th week is 28.2 MPa and 31.7 MPa for 0% ash and 25% ash, respectively.

It is noted that beyond an immersion period of 28 days, the compressive strength of mortars decreased, likely due to the deterioration caused by the sulphate solutions. This could be attributed to the higher water-to-cement ratio used in this study, variations in cement characteristics, and a longer curing period of the cubes in a lime solution before soaking in the sulphate solution. Figure 9 shows that the control mortars containing no RHA had lower compressive strengths throughout the testing period than the mortars containing RHA. Due to the pozzolanic reaction in rice husk ash-containing mortar cubes, pores are reduced, which increases in strength. After 28 days, due to the formation of sulphate compounds causing expansion and cracking of cubes, the strength is reduced for both specimens.

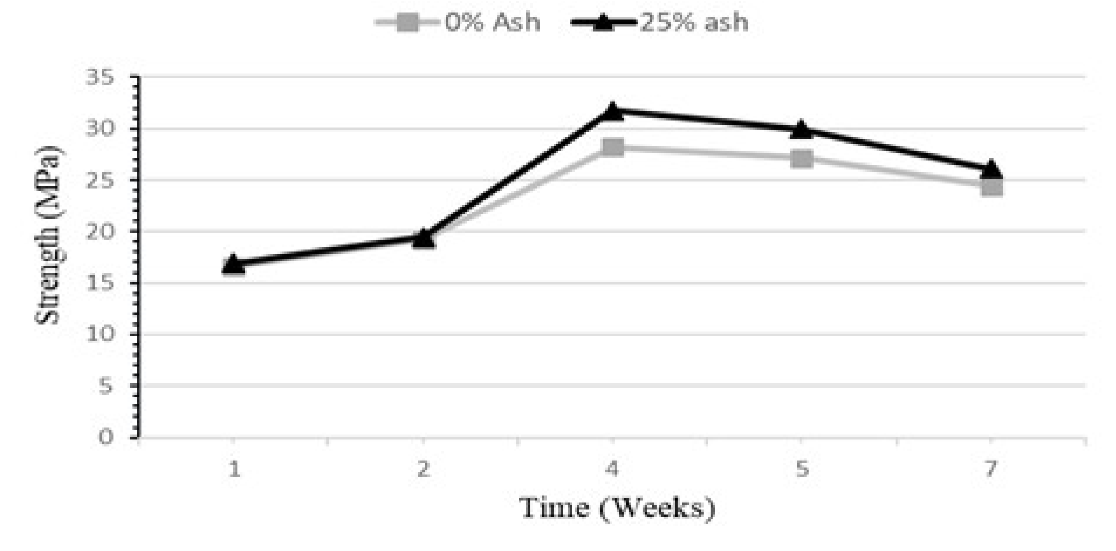

Figure 9: Compressive Strength vs Time of 0% Ash and 25% Ash Mortar Specimens

3.4.2 Length Change of Mortar Bars in Sulphate Solution

According to the data presented in Figure 10, the expansion of the mortar bars is proportional to the length of time they were immersed in sodium sulphate. This suggests that prolonged contact with sodium sulphate causes mortars to degrade continuously. The low permeability of the cement matrix at such a low water-to-cement ratio (w/cm) is likely the primary cause of this issue. Both permeability and the chemical resistance of the binder are important considerations governing the sulphate resistance of concrete. Previous research has shown that concrete with low permeability possesses better sulphate resistance than concrete with high permeability, and both of these factors are crucial in determining the sulphate resistance of concrete (Khatri &Sirivivatnanon, 1997).

It appears that the Portland cement binder can withstand sulphate assault on its own due to its lower permeability; therefore, the use of pozzolan may not be necessary even at low w/cm ratios. Up to a duration of immersion of 56 days, it was discovered that the mortars containing RHA-25% showed somewhat less expansion than the control mortars, which did not contain any RHA. From the graph, it is seen that the highest length change of the mortar bars specimen in the 8th week is 1.116% for the 0% ash mortar bar specimen. RHA-containing mortar bars showed less expansion in the Na_2SO_4 solution due to lower alkali content and higher resistance to sulphate attack.

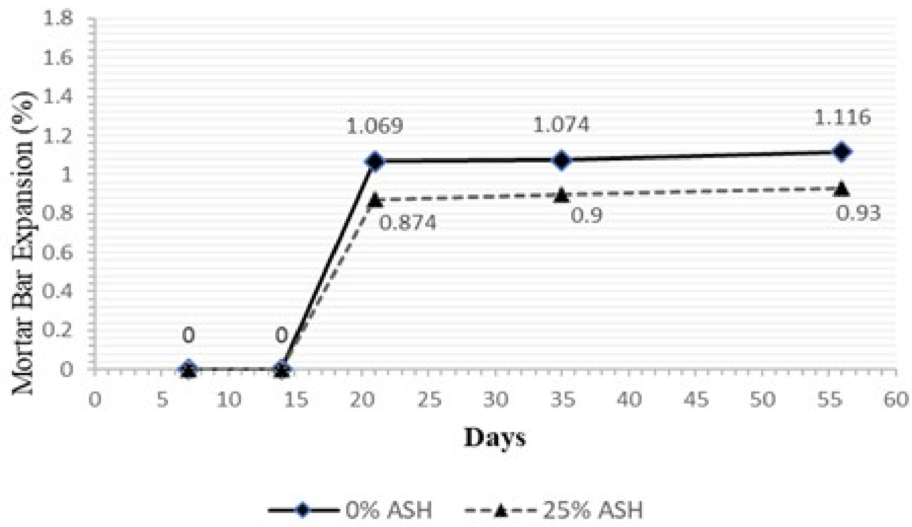

Figure 10: Expansion Vs Time of 0% Ash and 25% Ash Concrete Specimens

4. CONCLUSIONS

The primary purpose of this study is to generate lightweight aggregate from rice husk and rice husk ash. Another key objective is to investigate the properties of lightweight and natural aggregates. The following is a summary of the key conclusions based on the experimental results:

- The compressive strength of the concrete specimen containing 25% ash is close to the desired strength.
- The rapid chloride permeability of artificial aggregate concrete is lower than that of the control specimen concrete.
- Heating a 1M concentration of NaOH solution yields good silica gel. Silica gel from rice husk is used on the surface of rice husk, which is then used as the aggregate ratio in the concrete mix. Further studies are required in this part.
- The expansion behaviour of the mortar bar is linear over time, and artificial aggregate mortar has a smaller percentage of expansion than natural aggregate mortar.
- After being immersed in a sulphate solution for up to 28 days, the compressive strength of the 25% ash mortar cube specimen is greater than that of the control specimen.

ACKNOWLEDGEMENTS

The authors express their gratitude to Khulna University of Engineering and Technology (KUET), Bangladesh, for providing laboratory facilities and financial support. Special thanks to Lanbanchara Auto Rice Mill Factory for supplying the raw materials.

REFERENCES

Abbas, N., Khalid, H. R., Ban, G., Kim, H. T., & Lee, H. K. (2019). Silica aerogel derived from rice husk: An aggregate replacer for lightweight and thermally insulating cement-based composites. *Construction and Building Materials*, *195*, 312-322.

Ahmed, A., & Kamau, J. (2017). Performance of Rice Husk Ash Concrete in Sulphate Solutions. *Research & Development in Material Science*, *2*(1).

Bui, D. D., Hu, J., &Stroeven, P. (2005). Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and concrete composites, 27(3), 357-366.

Chabannes, M., Bénézet, J. C., Clerc, L., & Garcia-Diaz, E. (2014). Use of raw rice husk as natural aggregate in a lightweight insulating concrete: An innovative application. *Construction and Building Materials*, *70*, 428-438.

Hossain, M. S., & Morshed, A. Z. (2020). Artificial lightweight aggregate production using rice husk ash. In *Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020)* (pp. 1-7).

Hwang, C. L., & Wu, D. S. (1989). Properties of cement paste containing rice husk ash. Special Publication, 114, 733-762.

Khatri, R. P., Sirivivatnanon, V., & Yang, J. L. (1997). Role of permeability in sulphate attack. *Cement and concrete research*, *27*(8), 1179-1189.

Prasad, R., & Pandey, M. (2012). Rice husk ash as a renewable source for the production of value added silica gel and its application: an overview. *Bulletin of Chemical Reaction Engineering and Catalysis*, *7*(1), 1-25.

Rahman, A. K. M. L., Barai, A., Sarker, A., &Moniruzzaman, M. (2018). Light weight concrete from rice husk ash and glass powder. *Bangladesh J Sci Ind Res*, *53*(3), 225-232.