Strength Properties of Foamed Concrete Containing Blends of Rice Husk Ash (RHA)

Rizwan Ahmad Khan¹, Seema², Aditya Kumar Tiwary³
¹Department of Civil Engineering, Z H College of Engg. & Tech., Aligarh Muslim University, Aligarh, U.P., India
²,³Department of Civil Engineering, Chandigarh University, Mohali, Punjab, India

Abstract: The present study was planned to study the influence of Rice Husk ash (RHA) on fresh and hardened properties of foamed concrete. The percentage replacement levels of RHA for fine aggregates (FA) were 0%, 5%, 10%, 15% and 20%. Production of light weight concrete was carried out with foam which was produced indigenously using a foaming agent (Foamtech). The theoretical density of foamed concrete containing 0% replacement level of Rice husk ash (RHA) was kept to be equal to 1300 ± 50 kg/m³. The actual density observed for foamed concrete containing 0% replacement level of RHA during experimental analysis was 1317 kg/m³. At curing age of 7, 14, 28, 56, and 90 days, the hardened foamed concrete cube specimens of size 100 mm × 100 mm × 100 mm were evaluated for compressive strength and 150 mm × 300 mm for split tensile strength. At a curing age of 28 days, the cube specimens were also examined for water absorption and dry density. For all of the foamed concrete mixes, the cement and fine aggregate content were kept the same. The water-cement ratio was maintained at 0.5. The only difference among all the mixes was the replacement level of RHA 5%, 10%, 15% and 20%. The amount of foaming agent was varied according to the replacement levels of RHA to ensure good workability of paste. All the results of various properties were compared with the control mix. It may be noted that 0% replacement level of RHA with FA has been considered a control mix. The maximum and minimum compressive strengths, split tensile strengths and dry densities were shown by control mix and mix containing 20% replacement level of RHA respectively. On the other hand, the minimum and maximum water absorption capacities were shown by control mix and mix containing 20% replacement level of RHA respectively.

Keywords: Foamed concrete; rice husk ash; compressive strength; split tensile strength

1. Introduction

A foaming ingredient traps air gaps in the mortar, making foam concrete a lightweight concrete manufactured from cement pastes or mortar. It has a high flow capacity, a low self-weight, a low aggregate consumption, a controlled low strength, and excellent thermal insulating properties. By carefully regulating the foam dosage, a wide range of densities (400-1600 kg/m³) of foamed concrete may be created for structural, partition, insulation, and filler grades. The manufacture of stable foam concrete mixtures is influenced by a number of parameters [1–3]. Foamed concrete is a non-segregating, extremely flowable concrete that can spread and fill formwork. Foamed concrete is a
solid made up of a cement mortar matrix and a minimum of 20% air space. It's created by utilizing prefabricated foam to include air gaps into the cement matrix. In comparison to conventional weight concrete, lightweight foamed concrete (LFC) has become a cutting-edge product for the construction sector, with benefits such as lighter densities ranging from 400 to 1600 kg/m³, improved fire protection [4–6], thermal and acoustic insulation, and more. Foamed concrete is lighter than ordinary concrete because artificial air bubbles are retained in the cement mortar by using an adequate foaming agent. It must be steady and consistent to prevent the separation of artificial air bubbles and cement mortar, which eventually impacts the hardened properties of newly mixed foamed concrete. The flow cone spread test is one of the techniques used to assess the consistency of freshly foamed concrete. This measurement is also connected to the rheological properties of freshly mixed materials [7–9]. In comparison to a cement–sand combination, substituting sand with coarse rice husk ash (RHA) as a filler in foamed concrete resulted in a 2.5-fold improvement in spread value, according to previous study. Fine aggregate’s varied particle shape and size are responsible for its increased consistency and workability. The finer rice husk ash increased the water to solid ratio, fulfilling the consistency criteria, when compared to sand [10,11]. The use of rice husk ash (RHA) as a sand substitute is a relatively new trend in concrete technology. Furthermore, in terms of sustainability, it will assist in resolving difficulties that might otherwise arise while disposing of garbage. Because disposal of the husks is a huge issue, and open heap burning is not an option due to environmental concerns, the bulk of husks are now being disposed of in landfills. The disposal of rice husks is an environmental issue, prompting the concept of replacing RHA for silica in cement production. The silica concentration of the ash is between 92 and 97%. Studies have also shown that adding sand replacement materials (RHA) into concrete considerably enhances the durability characteristics of the material. The use of pure Portland cement and sand is challenging to attain these characteristics [12–14].

The primary objective of this research was to see how Rice Husk Ash (RHA) influenced the fresh and hardened properties of foamed concrete. RHA replacement values for fine aggregates (FA) were 0%, 5%, 10%, 15%, and 20%. The hardened foamed concrete cube specimens of size 100 mm x 100 mm x 100 mm were tested for compressive strength and cylinder of size 150 mm x 300 mm for split tensile strength at curing ages of 7, 14, 28, 56, and 90 days. The cube specimens were also tested for water absorption and dry density after 28 days of cure. The cement and fine aggregate content of all of the foamed concrete mixtures were kept constant [15–17].

2. Materials

Cement, fine aggregate, rice husk ash, water, and a foaming agent were used to make the test specimens (FOAMTECH). In general, the materials met the standards stated in the applicable Indian Standard Codes. The following qualities were present in the materials utilized to create concrete examples [18–21].

2.1 Cement

Ordinary Portland cement (OPC) from a single lot was used throughout the study, which followed Indian Standard IS: 1489-1991. All of the tests followed the IS: 4031-1988 standards. Cement’s properties were damaged by moisture, thus it had to be kept dry.

2.2 Fine aggregate

As a fine aggregate, river sand was employed (FA). Before employing it in concrete, clumps of clay and other extraneous materials were removed.

2.3 Rice Husk Ash
Rice Husk Ash (RHA) is generated by partially or completely burning rice hulls as shown in Figure 1 and 2. It has homogeneous black granules and is porous and bulky. Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and micronutrients are all essential for crop growth. It is also devoid of pathogenic germs since it has been sterilized. It has several applications in agriculture, industry, and building. Aside from that, it's been discovered to have medicinal and domestic applications. Rice milling produces husk, which is a by-product. Approximately 78 percent of the weight of paddy is received as rice, broken grains, and bran during milling. Husk accounts for the remaining 22% of paddy weight. This husk is used to produce steam in rice mills during the parboiling process. This husk comprises around 75% organic volatile materials and the rest is inorganic. Rice husk ash is made up of 25% of the weight of the husk that is converted to ash during the fire process (RHA). The amorphous silica content of this RHA is between 85 and 90%. Table 1 shows the particle size distribution of rice husk ash.

Table 1. Fineness modulus of rice husk ash

| Sieve size | Mass retained (gm) | Percentage retained (%) | Percentage passing (%) | Cumulative % age retained |
|------------|--------------------|-------------------------|------------------------|--------------------------|
| 4.75mm     | 00                 | 00                      | 100                    | 00                       |
| 2.36mm     | 00                 | 00                      | 100                    | 00                       |
| 1.18mm     | 10                 | 4                       | 96                     | 4                        |
| 600µ       | 104                | 41.6                    | 54.4                   | 45.6                     |
| 300µ       | 75                 | 30                      | 24.4                   | 75.6                     |
| 150µ       | 35                 | 14                      | 10.4                   | 89.6                     |
| Pan        | 26                 | 10.4                    | Zone II                | 214.8                    |

Fineness modulus of Rice Husk Ash (RHA) = 214.8/100 = 2.148

RHA is generated in around 20 million tonnes per year. This RHA poses a significant environmental risk, inflicting harm to the land and the ecosystem in which it is deposited. There are a slew of ideas floating about on how to get rid of them using this RHA commercially, see figure 1 and 2.
2.4 Water

Both the water used to mix and cure concrete should be free of harmful elements. In most cases, potable water is sufficient for mixing and curing concrete. The water utilized in this study was potable tap water.

2.5 Foaming Agent

As illustrated in Figures 3 and 4, the foaming agent is made up of high-quality natural proteins and surfactants. Because the bubbles in sunshine foam are tiny small, the concrete will have the highest compressive strength. A foaming agent, such as a surfactant or a blowing agent, is a substance that aids in the production of foam. When present in tiny levels, a surfactant lowers the surface tension of a liquid (reducing the amount of effort required to generate foam) or enhances colloidal stability by preventing bubble coalescence. The gaseous portion of the foam is formed by a blowing agent.

![Figure 3. Foam](image1)

![Figure 4. Foaming agent](image2)

3. Methodology

3.1 Preparation of specimens

Compressive strength, water absorption and dry density of foamed concrete, and split tensile strength were evaluated using cube specimens of size 100×100×100 mm, while split tensile strength was tested using cylinder specimens of size 150×300 mm. As illustrated in Figures 5 and 6, the casting of the various specimens took performed in a lab environment using standard equipment. Cube samples were cast for each curing age (i.e., 7, 14, 28, 56, 90 days).
The quantities of different components, such as cement, fine aggregate, rice husk ash, foaming agent, and water, were kept available in appropriate proportions for each batch of concrete mix. Cement and rice husk ash were dry combined at first as shown in Figure 7 and 8. The resulting slurry was then thoroughly mixed with fine particles in a dry state. Following that, two-thirds of the total water needed to make the foamed concrete was added. The remaining one-third of the water was utilized to make foam. Following that, the foam formed in this manner was completely mixed with the paste made by combining cement, RHA, and FA. The following is a description of the foam creation method.

### 3.2 Mix design

Several trial mixes were made to test the mix's workability, and the following material amounts for the durable mix were subsequently finalized, as indicated in Table 2. To fulfil the requirements of workable mixtures, trials have been conducted.

| Table 2. Final mix proportions for foamed concrete |
|-----------------------------------------------|
| Cement | Fine Aggregates | Rice Husk | Water | Water for Foaming |
|--------|-----------------|-----------|-------|--------------------|

Figure 5. Self-designed foam generator

Figure 6. Foam obtained after agitation

Figure 7. Dry mix containing cement, RHA and FA

Figure 8. Fresh foamed concrete paste
### Properties of Ash and Foaming Agent

| %age Replacement | (Kg) | (Kg) | Ash (Kg) | (liters) mixing Foaming Agent (liters) | Agent (liters) |
|------------------|------|------|----------|----------------------------------------|---------------|
| 0                | 520  | 520  | 0        | 182                                    | 28            | 2.36          |
| 5                | 520  | 494  | 26       | 174.20                                 | 85.8          | 2.6           |
| 10               | 520  | 468  | 52       | 166.40                                 | 93.6          | 2.84          |
| 15               | 520  | 442  | 78       | 158.6                                  | 101.4         | 3.07          |
| 20               | 520  | 416  | 104      | 150.8                                  | 109.2         | 3.31          |

### 3.3 Compressive strength of Foamed Concrete

Compressive strength tests on concrete cubes of size 100×100×100 mm cast were done for each curing age to verify quality by obtaining the 28-day compressive strength. These tests were carried out in accordance with IS: 516-1959 utilizing a compression testing machine. The average of three samples was chosen as a typical value of compressive strength.

### 3.4 Splitting Tensile Strength

Cylinders having a diameter of 150 mm and a height of 300 mm were used in the experiment. Specimens were removed from the curing tank at 28, 56, and 90 days following water curing. The water was then allowed to drip down from the surface. The specimens were then put through their paces on a 200-tonne capacity Compression Testing Machine (CTM).

### 3.5 Water Absorption

The water absorption of concrete was tested in accordance with BS 1881: Part 122:1983 with the exception that the water temperature was 30°C rather than 20°C. The cubes were oven dried for three days at 105°C, with each one measuring no less than 25mm from any heating surface or each other. After being removed from the oven, each specimen is allowed to cool for one day in a dry, airtight container.

The sample is then weighed and immersed in a tank to a depth of 25±5 mm water over the top of the specimen. They were surface dried after being removed from the water and weighed on an electronic balance to the closest 0.01 g. As defined in the standard, the absorption value is the percentage mass gain over the original dry mass adjusted for surface area. The adjustment factor is 1.00833 since the specimens used in this study are 100 mm long. The findings are expressed to the closest 0.1 percent using the average values from three specimens.

### 4. Results and Discussion

#### 4.1 Compressive strength

A total of 75 cube specimens were compressed and evaluated for the five mixtures utilized in this study. Figures 9 and 10 show the results of the compressive strength tests performed on the foamed concrete mixes investigated in this study. Figure 8 shows the change of compressive strength with volume % of RHA as partial replacement of sand at various curing ages, while Table 3 shows the compressive strength of all five mixes cast in this study at various curing ages, namely 7, 14, 28, 56,
and 90 days. Figure 9 depicts how the outcomes of all RHA replacement levels differed from the control mix. It may be noted that foamed concrete with 0% RHA replacement has been taken as control mix for comparison of results. The results show in Figure 10 that a maximum decrease of 27.27% at a replacement level of 20% of RHA with FA at a curing age of 90 days. Similarly, Figure 9 also presents that a minimum decrease of 3.77% has been observed at 5% replacement level of RHA with FA at a curing age of 7 days. The results indicate that in general, amongst all the partial replacements of sand with RHA tested, the maximum compressive strength equal to 25.62 MPa is achieved at control mix and at all other replacements the compressive strength get decreased. Since we have to make a light weight concrete in this investigation and strength properties are not the prime objective of this study, so the results obtained at all the partial replacement of FA with RHA are comparable with the control mix.

![Figure 9. Compressive strength of foamed concrete mixes at various replacement levels of RHA](image1)

![Figure 10. Variation in cube compressive strength of FC at different RHA replacements w.r.t. control mix](image2)
4.2 Splitting tensile strength test

The results of splitting tensile strength tests on concrete specimens of various mixes cured at various ages are shown and discussed in this section. At 7, 14, 28, 56, and 90 days after curing, the splitting tensile strength test was done. The splitting tensile strength test results for all of the combinations at varied curing ages are shown Figure 11, also shows the variation in splitting tensile strength of concrete mixes after 7, 14, 28, 56, and 90 days when compared to a control mix (0 percent RHA replacement).

The splitting tensile strength test results of FC at different partial replacements of Fine Aggregates (FA) with RHA are shown in Figure 12 which indicates a maximum decrease of 28.57% at 20% replacement level of RHA w.r.t. control mix at a curing age of 90 days respectively. Similarly Figure 11 also represents that a minimum decrease has been observed at 5% replacement level of RHA w.r.t. control mix at a curing age of 7 days. In general trend formation, the splitting tensile strength results goes on decreasing as the percentage of replacement level increasing at all curing ages. Maximum splitting tensile strength of 2.79 MPa has been obtained from control mix at a curing age of 90 days. Similarly splitting tensile strength of 2.36 MPa, 2.33 MPa, 2.29 MPa and 2.17 MPa has been obtained at a replacement level of 5%, 10%, 15% and 20% respectively, at a curing age of 90 days. Since the study was carrying out to check not only the strength properties but to obtain a light weight concrete which can fulfill other criteria also i.e., thermal & sound insulation, decrement of lateral loads and to make non-hazardous concrete, so the decrease in strength can be taken into consideration.
4.3 Water absorption

Table 3 and Figure 13 represents the water absorption results of the foamed concrete at all replacement levels of RHA at all curing ages respectively. The results show that the control mix has lowest water absorption capacity of 15.20% and as the FA is partially replaced with RHA, the water absorption capacity goes on increasing significantly. The reason behind the increase in water absorption capacity of FC is the increased volume of finer particles of RHA which absorbs more water so to ensure good workability of fresh FC the foam concrete is increased at all the percentage replacements of RHA. Maximum percentage of water absorption i.e., 19.46% has been observed at 20% of replacement level of RHA after the curing time of 28 days. Average of three cube specimens have been taken for calculating water absorption of a particular mix at a curing age of 28 days.

Table 3. Water absorption capacity results

| Percentage of RHA (%) | Water absorption (%) | Percentage Increase (%) |
|-----------------------|----------------------|-------------------------|
| 0                     | 15.20                | -----                   |
| 5                     | 16.60                | 9.21                    |
| 10                    | 17.80                | 17.11                   |
| 15                    | 18.19                | 19.67                   |
| 20                    | 19.46                | 28.03                   |

Figure 12. Variation in split tensile strength of FC at different RHA replacements
Figure 13. Water absorption capacity of all the mixes containing RHA as partial replacement of FA

Figure 13 also represents the variation of all the mixes of FC containing partial volume fraction of RHA with respect to control mix. After a curing age of 28 days, the mix with 20% FA replacement showed a maximum improvement of 28.03% in water absorption capacity over the control mix. Similarly, the mixes containing 5%, 10%, and 15% of RHA as partial replacement of FA, respectively, increased by 9.21%, 17.11%, and 19.67% above the control mix.

4.4 Density

The results of dry density of all the mixes containing RHA as partial replacement of FA including control mix have been represented in Table 4 and Figure 14. Figure 14 shows the variation of density of FC mixes containing RHA as partial replacement of FA over the control mix.

Figure 14. Actual density of FC mixes containing RHA as a partial replacement of FA

Figure 14 shows that an actual density of 1317 Kg/m³ has been obtained by the control mix. Similarly, as the percentage of RHA replaced in the further mixes by FA, the actual density of the FC has been decreased. Table 4 shows that a minimum density value of 1219 Kg/m³ has been observed by the mix containing 20% of RHA as partial replacement of FA.

Table 4. Actual density results

| Percentage of RHA (%) | Density (Kg/m³) | Percentage Decrease (%) |
|-----------------------|----------------|-------------------------|
| 0                     | 1317           | -----                   |
| 5                     | 1269           | 3.78                    |
| 10                    | 1253           | 5.11                    |
| 15                    | 1227           | 7.33                    |
| 20                    | 1219           | 8.04                    |

Figure 15 shows the density variance of all the mixes including RHA as a partial substitution for FA in contrast to the control mix. The control mix exhibited a maximum gain of 8.04 percent above the mix containing 20% RHA as a partial substitution for FA. Similarly, the mix containing 5% RHA as a partial FA replacement increased by at least 3.78% above the control mix.
5. Conclusions

The following conclusions may be reached based on the extent of this investigation's work:

1. In general, there is a decrease in compressive strength with a maximum and minimum of 27.27% and 3.77% at 20% and 5% replacement level of RHA respectively. The maximum and minimum values of compressive strength obtained at 0% and 20% replacement of RHA after 90 days of curing are 25.62 MPa and 20.13 MPa.

2. There is a decrease in split tensile strength with a maximum and minimum of 28.57% and 18.22% at 20% and 5% replacement level of RHA respectively after curing age of 90 days. The maximum and minimum values of tensile strengths obtained at 0% and 20% replacement of RHA after 90 days of curing are 2.79 MPa and 2.17 MPa. Since the study was carried out to check not only the strength properties but to obtain a light weight concrete which can fulfill other criteria as well (thermal & sound insulation, decrement of lateral loads and to make non-hazardous concrete) so the decrease in strength can be taken into consideration.

3. The obtained results for water absorption indicate a general increase in the amount of water absorption with increase in percentage replacement level of FA with RHA. Minimum and maximum water absorption capacities of 15.20% and 19.46% are obtained at 0% and 20% replacement level of RHA respectively after curing age of 28 days. However, minimum and maximum percentage increase in water absorption w.r.t control mix are 9.21% and 28.03% at respective 5% and 20% replacement levels of RHA.

4. The density results show that maximum and minimum density values of 1317 Kg/m³ and 1219 Kg/m³ are observed for the mix containing 0% and 20% of RHA as partial replacement of FA respectively, after 28 days of curing age. In addition, the minimum and maximum percentage decrease in densities w.r.t control mix are 3.78% and 8.04% at 5% and 20% replacement levels of RHA respectively.

It may be noted that the conclusions listed above are particular to the type, particle size and percentage replacement of RHA as well as type and quantity of foaming agent used in this investigation and may not represent other types and quantities of RHA and foaming agent. Hence, there is a need to test other types of foaming agents available and different levels of percentage replacement of RHA, so as to obtain the strength parameters to generalize the results.
References

[1] Nicoara A I, Stoica A E, Vrabec M, Rogan N Š, Sturm S, Ow-Yang C, Gulgun M A, Bundur Z B, Ciucu I and Vasile B S 2020 End-of-life materials used as supplementary cementitious materials in the concrete industry Materials (Basel).

[2] Imam A, Kumar V and Srivastava V 2018 Empirical predictions for the mechanical properties of Quaternary Cement Concrete J. Struct. Integr. Maint. 3 183–96

[3] Kaur N and Irshad Malik M 2018 Influence of lime sludge on the compaction and strength properties of soil when mixed with RHA & polypropylene fiber Int. J. Civ. Eng. Technol. 9 693–9

[4] Mohit 2019 Application of sustainable cement alternatives in concrete Int. J. Eng. Adv. Technol. 9 6136–41

[5] Belawadikar S, Patil D S and Juneja A 2021 Use of Fly Ash as Weak Cementing Agent to Strengthen Marine Clay ed R K R S S K Patel S. Solanki C.H. Lect. Notes Civ. Eng. 134 85–94

[6] Malik M I and Tangri A 2020 Prominence of lime sludge, burnt brick dust and low density polyethylene on strength properties of soil J. Green Eng. 10 6230–7

[7] Srinivas D, Ramagiri K K, Kar A, Adak D, Noroozinejad Farsangi E and Dutta S 2021 Experimental characterization of quaternary blended mortar exposed to marine environment using mechanical strength, corrosion resistance and chemical composition J. Build. Eng. 42

[8] Kaur G, Singh N, Rajor A and Kushwaha J P 2021 Deep eutectic solvent functionalized rice husk ash for effective adsorption of ofloxacin from aqueous environment J. Contam. Hydrol. 242

[9] Steven S, Restiawaty E and Bindar Y 2021 Routes for energy and bio-silica production from rice husk: A comprehensive review and emerging prospect Renew. Sustain. Energy Rev. 149

[10] Rithuparna R, Jitin V and Bahurudeen A 2021 Influence of different processing methods on the recycling potential of agro-waste ashes for sustainable cement production: A review J. Clean. Prod. 316

[11] de Matos Costa A R, Lima J C, dos Santos R, Barreto L S, Henrique M A, de Carvalho L H and de Almeida Y M B 2021 Rheological, thermal and morphological properties of polyethylene terephthalate/polyamide 6/rice husk ash composites J. Appl. Polym. Sci. 138

[12] Lertwattanaruk P and Makul N 2021 Influence of ground calcium carbonate waste on the properties of green self-consolidating concrete prepared by low-quality bagasse ash and rice husk ash Materials (Basel).

[13] Zayed M A, Zawrah M F and Ali M R K 2021 Liquid phase sintering of nano silicon carbide prepared from egyptian rice husk ash waste Egypt. J. Chem. 64 4091–7

[14] Kumari U, Banerjee T and Singh N 2021 Evaluating ash and biochar mixed biomixtures for atrazine and fipronil degradation Environ. Technol. Innov. 23

[15] Siddika A, Mamun M A A, Alyousef R and Mohammadhosseini H 2021 State-of-the-art-review on rice husk ash: A supplementary cementitious material in concrete J. King Saud Univ. - Eng. Sci. 33 294–307

[16] Usman K R, Hainin M R, Mohd Satar M K I, Mohd Warid M N, Kamarudin S N N and Abdulrahman S 2021 Palm oil fuel ash application in cold mix dense-graded bituminous mixture Constr. Build. Mater. 287

[17] Zhang T, Fang G, Chen H and Cui W 2021 Experimental study on mix proportion of green environmental protection type three-doped fair-faced concrete IOP Conference Series: Earth and Environmental Science vol 787 (IOP Publishing Ltd)

[18] Singh G, Prunca C I, Gupta M K, Mia M, Khan A M, Jamil M, Pimenov D Y, Sen B
and Sharma V S 2019 Investigations of machining characteristics in the upgraded MQL-assisted turning of pure titanium alloys using evolutionary algorithms Materials (Basel). 12

[19] Abbas A T, Gupta M K, Soliman M S, Mia M, Hegab H, Luqman M and Pimenov D Y 2019 Sustainability assessment associated with surface roughness and power consumption characteristics in nanofluid MQL-assisted turning of AISI 1045 steel Int. J. Adv. Manuf. Technol. 105 1311–27

[20] Kumar S, Kumar M and Handa A 2018 Combating hot corrosion of boiler tubes – A study Eng. Fail. Anal. 94 379–95

[21] Kaur M and Wasson V 2015 ROI Based Medical Image Compression for Telemedicine Application Procedia Computer Science vol 70 pp 579–85