# PARTIAL REPLACEMENT OF EGGSHELL AND RICE HUSK POWDER AS CEMENT IN CONCRETE

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## ABSTRACT

The demand for construction materials has increased with the rapid growth of infrastructure development. Cement is one of the materials that is widely used throughout the world. Cement production, which uses nonrenewable resources and emits carbon dioxide, has significantly impacted the environment. One practical option is utilizing solid waste as a substitute for cement. However, one of the biggest challenges that emerging nations encounter is solid waste management. Restaurants, bakeries, and households all produce eggshells, a waste product. On the other hand, rice husk is also an agricultural waste, and rice husk ash (RHA) is a promising alternative pozzolanic material that can be used to improve the durability and strength of concrete. To overcome these challenges, eggshells and rice husks could be effectively employed as partial replacements for cement during concrete manufacturing. This study investigates the mechanical properties of concrete by using concrete-grade G30 cylinders and beams. The samples were mixed with eggshell powder and RHA in different proportions. A constant mixing ratio of 1:1.5:3 was chosen for the mix design, and a w/c ratio of 0.45 was selected for the water-cement balance. RHA was collected from a local market in the Rajshahi district, and eggshell powder (ESP) was collected from neighbourhood eateries. The chemical composition of ESP was determined. A calcination process was required to produce cementitious material from eggshells and rice husks. The results show that concrete strength increases relatively at 6% and 9% replacement, while at 12% replacement, compressive strength and flexural strength decrease. Higher strength was achieved in the compressive, split tensile, and flexural tests with the 9% replacement. So, a combination of ESP and RHA can be an energy- and cost-effective solution to the problem of sustainable construction materials.

***Keywords:*** *Cement, Eggshell powder, Rice husk ash, Mechanical properties*

## 1. INTRODUCTION

Cement is one of the most vital components used to produce concrete. Cement production, which generates more carbon dioxide ($CO_2$), has led to environmental and social issues such as global warming. The construction industry is one of the economic sectors' propelling forces. According to sources, about 8% of the world's carbon dioxide emissions that warm the planet come from the cement business. The building industry promotes the adoption of sustainable concrete production methods by utilizing waste resources as a substitute for traditional concrete components.

This study examined the practical benefits of using alternative materials in the concrete industry to reduce $CO_2$ emissions. These emissions primarily occur during the process of burning Portland cement clinker. To mitigate its adverse effects on the environment, the manufacture of concrete can benefit from using waste products from agriculture and industry. Previous studies have been done on using agricultural wastes instead of cement. For example, eggshells, rice husk, oyster shells, sugar cane bagasse, and sawdust have been utilized in replacement of cement. Among this organic waste, the chemical composition of eggshells has a remarkable amount of limestone, a mineral rich in calcium oxide (Nandhini & Karthikeyan, 2022). The use of powdered eggshell as an alternative cement component has the potential to reduce cement consumption in the production of concrete significantly. This approach helps conserve natural lime resources and facilitates the recycling of solid waste materials (Basit et al., 2019). On the other hand, rice husks are another type of waste product that decomposes naturally. Rice is grown in more than 75 countries worldwide (Wang et al., 2021). Hu et al. (Hu et al., 2020) reported that using residual ashes from rice husks (RH) as an additive in building materials leads to a considerable enhancement of the overall value.

According to Nandhini et al. (Nandhini & Karthikeyan, 2022), 10% pulverized eggshell powder (ESP) provides the best compressive strength when used in mortar. In this paper, it only shows the change in the compressive strength. On the other hand, according to Xiaofeng Li et al. (Li et al., 2021), 5% cement replacement with eggshell powder is the ideal proportion for both compressive strength and flexural strength. It does not indicate a difference in split tensile strength after utilizing cement as a partial substitute in concrete. Meikandaan et al. (Meikandaan, 2016) used Rice husk as a partial cement replacement. According to them, as the percentage increased, the slump progressively decreased. The compressive strength of concrete is also investigated in this study. When RHA was replaced by up to 30%, compressive strength increased. This paper only presents the results of the compressive strength test and slump value change when rice husk is partially replaced with cement. However, it doesn't demonstrate how the partial cement replacement affects split tensile and flexural strength. According to most previous studies, rice husk may not be used as a pozzolanic material with eggshell.

This paper deals with a compelling solution by investigating using two waste materials, eggshells, and rice husks, as viable substitutes for traditional cement in concrete mixtures.

## 2. METHODOLOGY

### 2.1 Materials

Among the materials used in this study were cement, water, fine aggregate, coarse aggregate, eggshell, and rice husk. The cement used in this investigation was ordinary Portland cement (OPC). Cement was found to have a specific gravity of 3.12. The cement sample had a standard consistency of 26%. The cement sample's initial and final setting times were examined and reported at 110 min and 150 min. Clean, impurity-free water is utilized for the design mix. Domar sand was used as a fine aggregate in this research, with a specific gravity of 2.8. Crushed coarse aggregates of 20 mm, obtained from local crushing plants, were used for this study. The bulk specific gravity of coarse aggregate is 2.8.

Four types of eggshells were collected: brown eggshells, white eggshells, local hen eggshells, and duck eggshells. These particular eggshells were collected from a variety of local restaurants in

Rajshahi. Figure 1 shows four types of eggshells. The chemical composition of four types of eggshells was determined by atomic absorption spectroscopy (AAS). A solution was prepared with 2g of ESP, 65% $HNO_3$ and 70% $HClO_4$. The process called digestion is used for this test. A $25\ ml$ sample was prepared for each type of eggshell after digestion. The results of this test were obtained in $ppm$ and the formation of $Ca$ and $Fe$ are not oxide composition. Table 1 represents the chemical composition of four types of eggshells and Figure 2 shows the total process of AAS. The white eggshell contains the maximum percentage of calcium, and the duck eggshell has the highest rate of iron. Calcium is the leading property of cement. So, white eggshells were selected for this experiment. As pozzolanic filler material, rice husk was collected from the local market. White eggshells were collected and washed correctly. Then, those are dried with the help of sunlight. The sun-dried eggshells were ground to decrease the particle size. The white membrane of the eggshell was removed during this process. Then ESP and RHP (rice husk powder) were used for calcination in the furnace—the furnace at temperatures ranging from $700$ to $800°C$. The calcinated samples were collected carefully because the samples could be oxidized in the presence of air. Then, a hand grinder was used to decrease the particle size (less than 75 microns). Lastly, the grinding samples were passed by the No. 200 sieve. Figure 3 shows the total process from collecting eggshells and rice husks to preparing the sample used for the mix design.


Figure 1: Different Types of Eggshells

Table 1 Chemical composition percentage of different samples

| **Name of content** | $Ca$**(Calcium)(%)** | $Fe$**(Iron)(%)** |
|---|---|---|
| Red Egg Shell | 53.62 | 11.62 |
| White Egg Shell | 57.93 | 11.99 |
| Egg Shell from Local Hen | 51.70 | 12.64 |
| Duck Egg Shell | 52.23 | 14.92 |

Figure 2: Chemical Composition Determination by Atomic Absorption Spectroscopy (AAS)

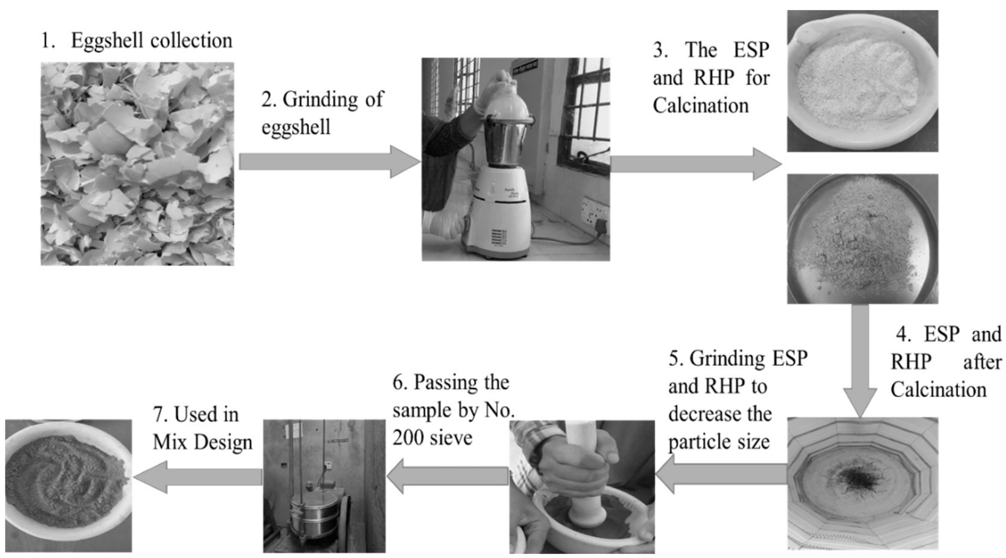


Figure 3: ESP and RHP are being processed

## 2.2 Experimental program

For Mix Design, ACI 211.1-91 Code was followed. The design was done according to the M30 mix design. A mix design was done to fix the ratio of ordinary Portland cement, fine aggregate, and coarse aggregate to 1:1.5:3. Table 2 shows the constant parameters of this study. The mix labels for all these experimental studies were Mix 1, Mix 2, Mix 3, and Mix 4, denoting the 0%, 6%, 9%, and 12% replacement of ESP and RHA as cement replacement. Table 3 shows the types of mix and the percentage of replacement. Three types of tests were conducted in this program. They are compressive, splitting, tensile, and flexural strength tests. Compressive, splitting tensile, and flexural strength tests were performed according to ASTM C 39/C39M, ASTM C496/C496M-11, and ASTM C 293-02, respectively. Three specimens were cast for each test condition. Cylinders (4inch x 8inch) for compressive strength, cylinders (6inch x 12inch) for spitting tensile strength, and Beams (4inch x 4inch x 20inch) for flexural strength were cast. After casting, all the test specimens were stored for 24 hours. They were then put into a curing tank for 7 and 28 days. After 7 and 28 days, the above three mechanical properties were determined.

Table 2 Constant Parameter

| **Type of cement** | **Ordinary Portland Cement (OPC)** |
|---|---|
| Water cement ratio | 0.45 |
| Cement sand coarse aggregate | 1:1.5:3 |
| Sample type (cylinder) | (4inch x 8inch), ( 6inch x 12inch) |
| Sample type (Beam) | (4inch x 4inch x 20inch) |
| Curing days | 7 and 28 days |

Table 3 Cement replacement

| **Mix Name** | **Percentage of cement** | **Percentage of Eggshell** | **Percentage of Rice Husk** |
|---|---|---|---|
| Mix 1 | 100 | 0 | 0 |
| Mix 2 | 94 | 4 | 2 |
| Mix 3 | 91 | 6 | 3 |
| Mix 4 | 88 | 8 | 4 |

## 3. RESULTS AND DISCUSSIONS

### 3.1 Compressive Strength

Figure 4 shows the comparison bar chart at 28 and 7 days of curing strength. A comparison of the data for 28 days of curing time shows that the compressive strength increases with the increase of replacement up to 9 percent, and the compressive strength of concrete attains its maximum value at this replacement percentage. The maximum increasing value is 4.22% for 9 percent replacement at 28 days. After that, compressive strength decreases with the increase of ESP and RHA. 7-day curing results show a similar trend. According to Code BNBC 2020, the minimum compressive strength for 7 days is 20 MPa and 30 MPa for 28 days for M30.

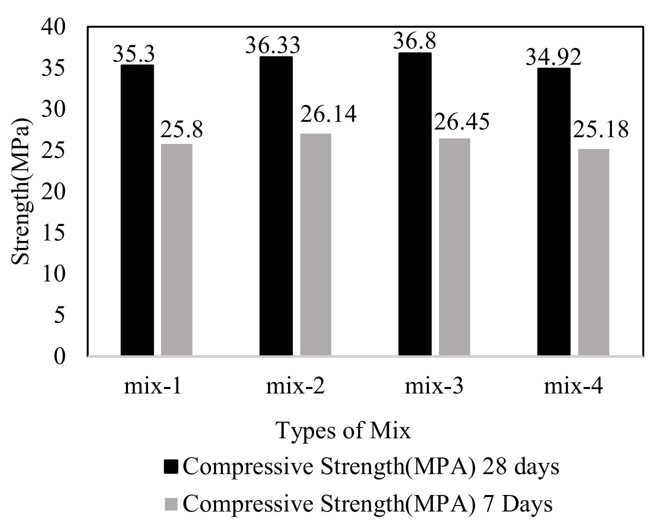


Figure 4: Compressive Strength of cylindrical specimens

### 3.2 Splitting Tensile Strength

Figure 5 shows the comparison of splitting tensile strength at 28 and 7 days. The Spitting Tensile Strength is maximum at 9% and 12% replacement and minimum at 0% replacement for 28 days. The highest possible increasing percentage is 22.77 for this replacement portion. For 7 days, the strengths are found same for 0,6 and 9% replacement. However, 12% replacement shows the maximum strength for 7 days of replacement.

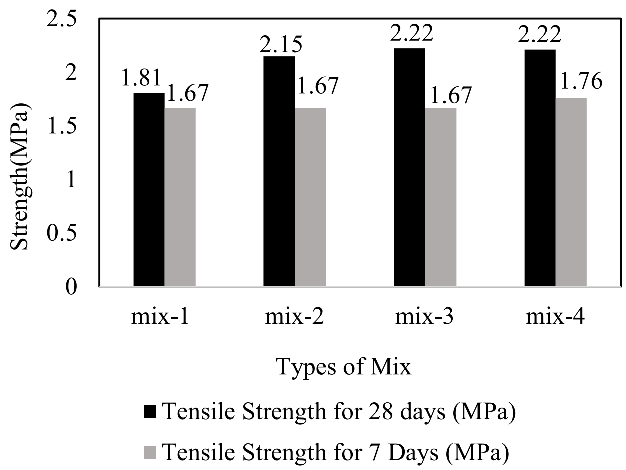


Figure 5: Splitting Tensile Strength of cylindrical specimens

### 3.3 Flexural Strength

A comparison of the data for a curing time of 28 days shows the Flexural Strength of the concrete in Figure 6. The Flexural Strength improves by up to 9% with replacement. The highest possible increase is 2.67% for a replacement portion. After that, the strength decreases with an increasing proportion of ESP and RHA.

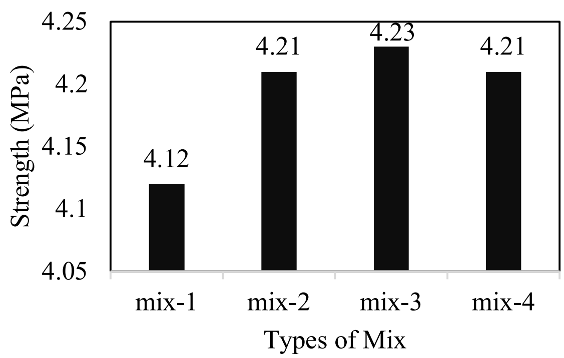


Figure 6: Flexural Strength

The calcium hydroxide and the particle size of ESP affect the strength of ESP mixed concrete. The calcium hydroxide $(C-H)$ reacts with the silica, which was released during the hydration of the cement, leading to the formation of calcium silicates, which are responsible for the strength of the cement mixture. The ESP acts as a filler, filling the existing voids, resulting in a more compact mortar mix and the development of higher compressive Strength (Tan et al., 2018). When ESP is used instead of high cement content, the amount of calcium hydroxide and silica in the mixture is reduced due to the lower cement content. Because of this, there is not enough silica to react with $C-H$ and form gel $C-S-H$, resulting in a lack of compressive strength. The splitting tensile and flexural strength drops beyond the threshold of ideal ESP replacement, as does the compressive Strength (Sathiparan, 2021). With the increasing of ESP, the RHA may also increase because of the silicious properties of RHA that react with $C-H$ and improve the strength.

## 4. CONCLUSION

This paper investigates utilizing eggshells and rice husks as sustainable cement alternatives in concrete. The experiment results show that adding more ESP and RHA increases the compressive and flexural strength values over time up to 9% replacement. On the other hand, the maximum increasing strength for tensile strength is found for 9% and 12% replacement. The strength increasing percentage at 7 days is less than 28 days. This is because Calcium hydroxide ($C-H$) and $silica$ accelerate the reaction by increasing the strength which is gained by the concrete. The main chemical composition of cement is $Ca$, $Al$, $Mg$, $Si$, and $Fe$. However, ESP and RHA mainly contain $Ca$, $Fe$, and $Silica$. So, this is also the reason for decreasing the strength with increasing the percentage of replacement. The highest strength is obtained at 9% replacement for compressive, tensile, and flexural strength. Rice husk is used as a pozzolanic material; however, other pozzolanic materials such as siliceous and calcareous fly ash, natural and industrial pozzolanas, and silica fume can also mix with eggshell as pozzolanic properties.

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