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Investigation of Mechanical Properties of Concrete by Partial Replacement of Cement with Rice Husk Ash and Wheat Straw Ash

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Abstract The possibility to reuse and recycle agricultural garbage as a building material has been displayed in a diversity of applications. This research is an investigational study that was made on the influence of using Rice Husk Ash (RHA) and Wheat Straw Ash (WSA) as a partial substitution of cement in the concrete mixture. The RHA and WSA have been chosen combined for this research due to their easy availability and their cementitious properties. The objective of this research was to minimize the utilization of large quantities of cement, evaluate the compressive strength of concrete, and compare it with control concrete. RHA and WSA carried a large amount of formless silica that can be a customary partial replacement of ordinary Portland cement in concrete. The cylindrical specimens (100 mm × 200 mm) were made for this research as a partial substitution of 0%, 5%, 10%, 15%, and 20% by volume of an equal amount of RHA and WSA with constant water/cement ratio as 0.45. In this research, the unit weight of concrete, compressive, splitting tensile and flexural strength, and water absorption tests were performed at different percentages of replacement and different curing periods such as 7 and 28 days. The optimum compressive strength was given a 15% substitution of cement by RHA and WSA. After that the compressive, splitting tensile, and flexural strength of concrete was decreased with increasing ordinary Portland cement replacement with RHA and WSA. The unit weight of concrete has been decreased, and water absorption has been increased with increasing ordinary Portland cement replacement with RHA and WSA.

Keywords: *Rice Husk Ash (RHA), Wheat Straw Ash (WSA), Water-cement ratio, Unit weight, Compressive strength, Water absorption*

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1. Introduction

Concrete's high brittle characteristic and strength under compression are widely known. Because of all of its benefits, concrete is the most widely used building material in modern society [1,2]. It is the world's most consumed man-made material. Today's demand for concrete for infrastructural development is rising day by day. Concrete production is not only a valuable source of societal development but also an important source of employment. Various types of agricultural garbage are being generated in large quantities, particularly in developing countries such as Bangladesh. As a developing country, Bangladesh's economy is principally based on agriculture. The production of rice and wheat is increasing day by day according to the requirements of rapidly growing populations. Rice husk may be a rural deposit, rice paddy produces about 649.7 million tons each year around the world, responsible for the annual production of rice husk is 129.94 million tons [3]. Bangladesh produces more than 46 million tons of paddy each year and annual rice husk production is about 9.2 million tons during the rice processing [4]. The total global wheat production is 778.6 million tons in 2021 and 2022 and annual wheat straw production is 709.2 million tons [5]. By utilizing waste for large-scale production of new products, Bangladesh has to potential to profit both economy and environmentally. The present investigation focuses on the replacement of cement partially with agricultural waste like Rice Husk Ash (RHA) and Wheat Straw Ash (WSA) for example, it could be utilized as a partial replacement of ordinary Portland cement combined because of their availability and it is suitable as a substitution of Portland cement owing to their high silica content. RHA and WSA are found to be good materials that fulfill the mechanical properties of concrete like as compressive strength, tensile strength, flexural strength, modulus of elasticity, and durability decreasing manufacturing costs and defending the environment from the adverse effects of these wastes. In the slump test they followed the American Society for Testing and Materials standard ASTM-C143-05 and their result is a decrease in a slump is noted as the ash content is improved, because of the high-water absorption capacity of ash. In the compaction factor test the research ability of WSA for different percentages is evaluated, and a decrease in workability is calculated as the ash content is increased. The comparison of the density of WSA concrete showed that the WSA is a lightweight material, and its density decreases as the content of ash is increased and the water absorption is increased as the percentage of WSA is increased. In compressive strength tests, their test is carried out at the age of 7, 28, 56, and 90 days, and their results evaluated that different ash content indicates 10% replacement as an optimum percentage [6,7]. Test investigations of the behavior of a concrete mixture using wheat straw in the cement. According to their study's compressive strength test results, strength decreases as WSA ratios increase and ratios of 15% approach those of the control specimen. According to the modulus of rupture test results, flexural strength increases by 3.47% for every 10% rise in WSA. However, flexural strength decreases when WSA increases above 10%. According to the findings of the splitting tensile test, the control specimen's high tensile strength was 12.84% when 15% of WSA was used [8,9].

This research's goal is to find out the mechanical properties of concrete as a partial substitution of 0%, 5%, 10%, 15%, and 20% by equal amounts of RHA and WSA with cement and with a constant water/cement ratio of 0.45.

2. Methodology

2.1. Materials

Rice husk ash was found by combustion of the rice husk obtained from rice mills. Wheat Straw was collected from the local area in Dinajpur district. The obtained wheat straw was burned in the open air for approximately 8 hours to form ash after that it was allowed to cool down for 24 hours. In this research, crushed stones are used as coarse aggregate, and sand is utilized as fine aggregate. This crushed stone and sand is the place of origin in the Panchagarh district and was collected from our new academic building construction works site of the HSTU campus.

2.2. Sample Preparation

In this research, the RHA and WSA were sieved where further impurities were minimized. Sand and crushed stone were also sieved then we took definite proportions of materials for each replacement and mixed them to make concrete to follow ACI 211.1-91 [10]. Preparation of concrete was done by adopting ASTM C 192 [15].

2.3. Experimental Procedure

Firstly, we have done a sieve analysis for crushed stone and sand to follow ASTM C136 [11] and also determined the unit weight of sand and crushed stone. This test is performed to follow ASTM C 29/C 29M – 97 [12]. Secondly, we have also done the specific gravity of coarse aggregate as well as fine aggregate attained according to ASTM C127 [13] and ASTM C128 [14] then the Compaction of concrete is done according to ASTM C31/C31M-19 [16] also determined unit of concrete to follow ASTM C138. Finally, curing is done according to ASTM C31, and the compressive strength, splitting tensile, and flexural strength tests are conducted according to the ASTM standards. A water absorption test was done to follow ASTM D570.

2.4. Sample Size

In this research, concrete specimens (100 mm × 200 mm) were cast and cured at 7 and 28 days to define the mechanical properties of concrete according to ASTM standards.

3. Results and Discussions

3.1. Sieve Analysis of Sand

According to ASTM C136, the fineness modulus of sand was got to be 2.39. The particle size distribution curve is shown in Figure 1.

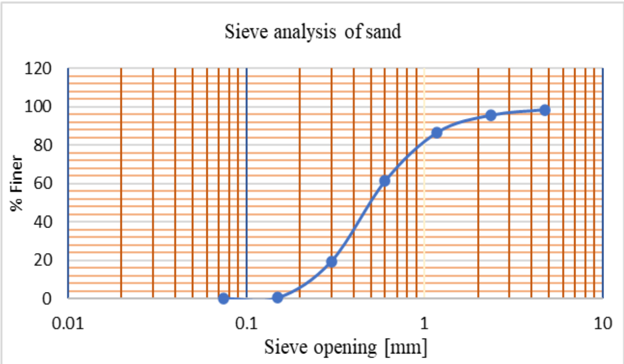

Figure 1. Sieve Analysis of Sand

3.2. Sieve analysis of Crushed Stone

According to ASTM C136, the fineness modulus of coarse aggregate was found to be 7.6. From the test results, the following graph is drawn as shown in Figure 2.

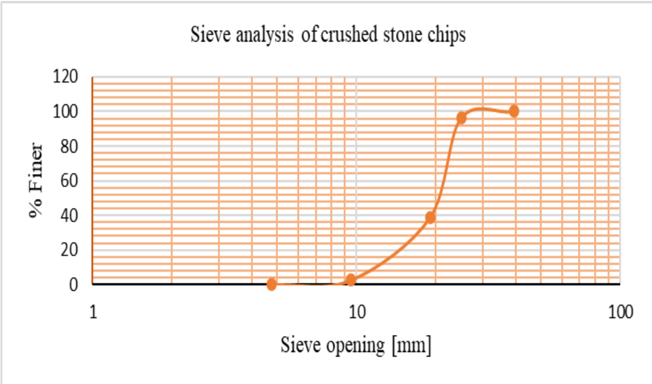

Figure 2. Gradation curve of crushed stone chips

3.3. Specific Gravity of Sand

According to ASTM C128-15, the value of specific gravity was found to be 2.62.

3.4. Specific Gravity of Crushed Stone

According to ASTM C127-15, the specific gravity of crushed stone in this research was found to be 2.66.

3.5. Unit Weight of Aggregates

Under ASTM C128-15, the unit weight of sand and crushed stones used for this research was found to be 1601.24 kg/m^3 and 1563.3 kg/m^3 respectively.

3.6. Unit Weight of Concrete

The value of the unit weight of concrete decreases with increasing percentage of cement replacement. The result is shown in Figure 3.

From Figure 3, it can be stated that the unit weight of concrete decreased by about 6.83% of equal amount by 20% of RHA and WST than the control concrete.

3.7. Compressive Strength Test Results

The concrete cylinders were cured and tested according to ASTM C39 [17] for 7 and 28 days. The test results are shown in Figures 4 and 5.

Based on Figure 4 and Figure 5, it was stated that after partially replacing cement with combined RHA and WSA, at the age of 7 and 28 days, the compressive strength of concrete of 15% replacement was more than the 5% and 10% replacement. So, the optimum cement replacement was found to be 15% and the compressive strength of this replacement was 22.05 MPa and 28.63 MPa for 7 and 28 days respectively.

3.8. Splitting Tensile Strength Test Results

In this research, the splitting tensile strength tests of concrete were carried out at 7 and 28 days for different percentages of replacement of cement with RHA and WSA. The test result is shown in Figure 6.

From Figure 6, it was stated that the splitting tensile test results decreased with the increase in the amount of RHA and WSA with the replacement of cement. The splitting tensile strength for control concrete was found to be 2.97 MPa and 3.42 MPa for 7 and 28 days respectively whereas, for 20% RHA and WSA, it was found to be 2.15 MPa and 2.59 MPa respectively at the same curing periods.

3.9. Flexural Strength Test Results

In this research, the flexural strength tests of concrete were carried out at 7 and 28 days according to ASTM C78 [18]. The test results are depicted in Figure 7.

It can be illustrated (Figure 7) that the flexural strength for control concrete was found to be 2.89 MPa and 3.28 MPa for 7 and 28 days respectively whereas for 20% RHA and WSA, it was found to be 2.12 MPa and 2.45 MPa respectively at the same curing periods.

3.10. Water Absorption Test Results

For the durability properties of concrete, the water absorption test was done. The rate of average water absorption concerning cement replacement for 7 days and 28 days was monitored. The outcomes of the water absorption test are shown in Figures 8 and 9.

From Figure 8 and Figure 9, it was found that the value of water absorption is increasing with the gradual increase of the percentage replacement of cement by RHA and WSA.

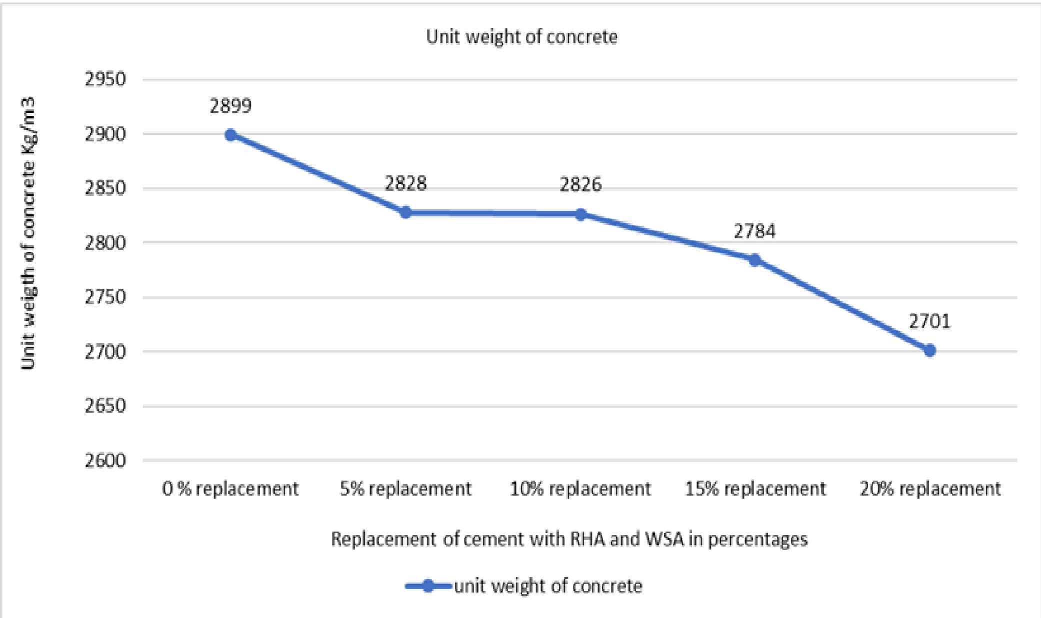

Figure 3. Variation of Unit weight of concrete with different percentages of replacement of RHA and WSA

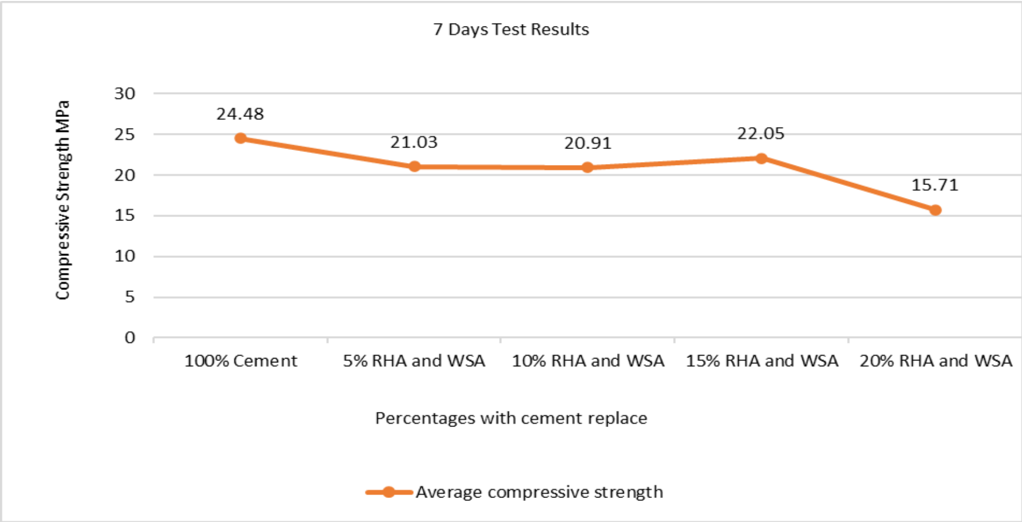

Figure 4. Change of Compressive strength of 7 days for different percentages of replacement of RHA and WSA

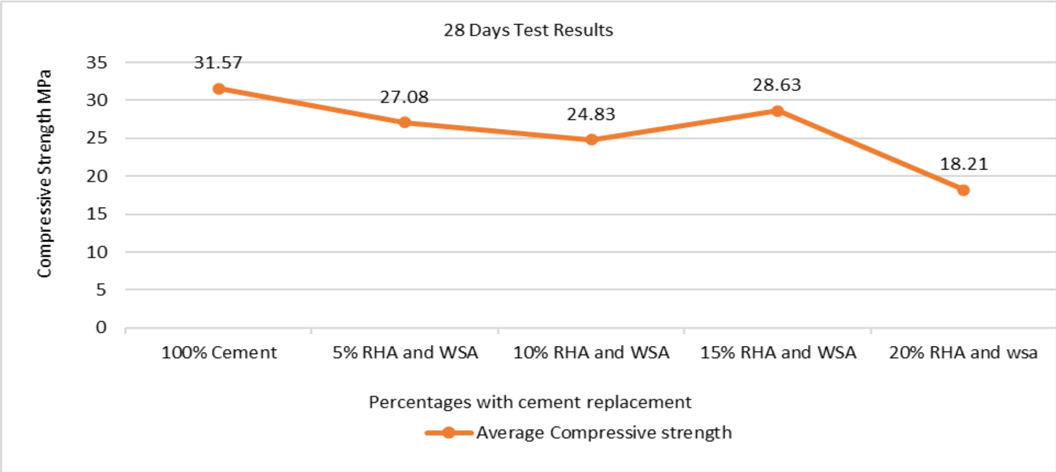

Figure 5. Change of compressive strength of 28 days for different percentages of replacement of RHA and WSA

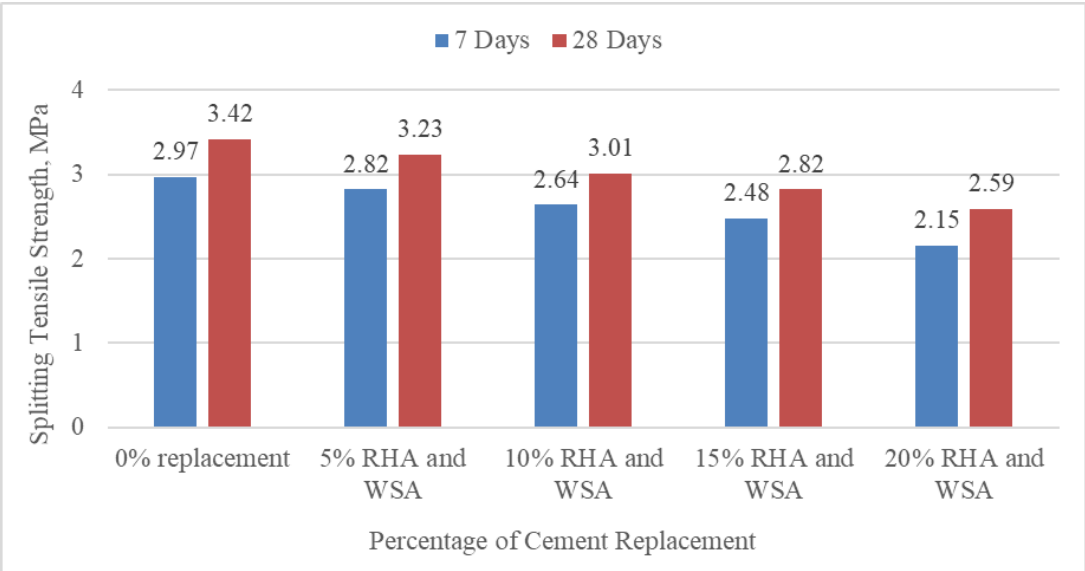

Figure 6. Variation of splitting tensile strength at different cement replacements and at different curing periods

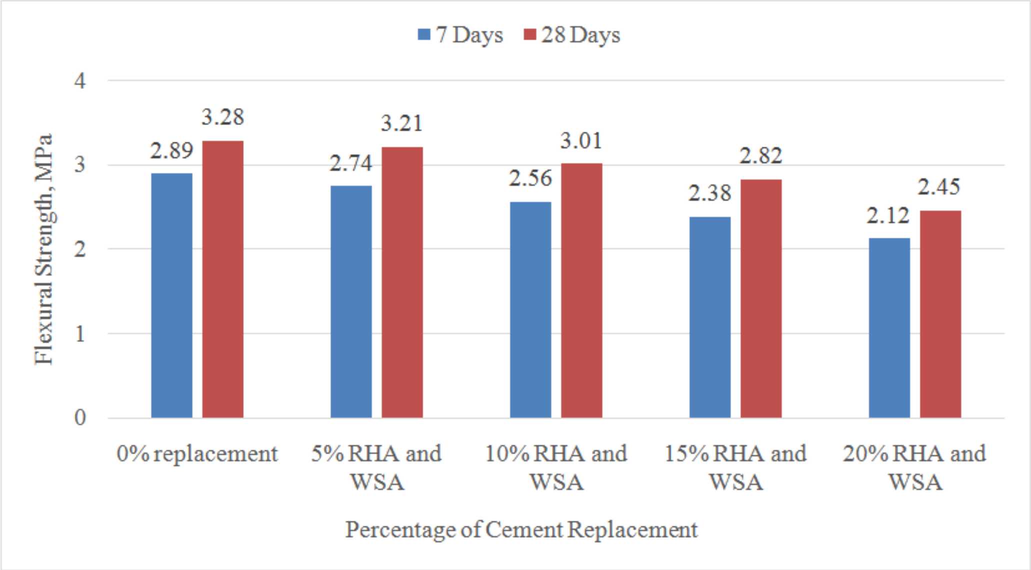

Figure 7. Variation of flexural strength at different cement replacements and at different curing periods.

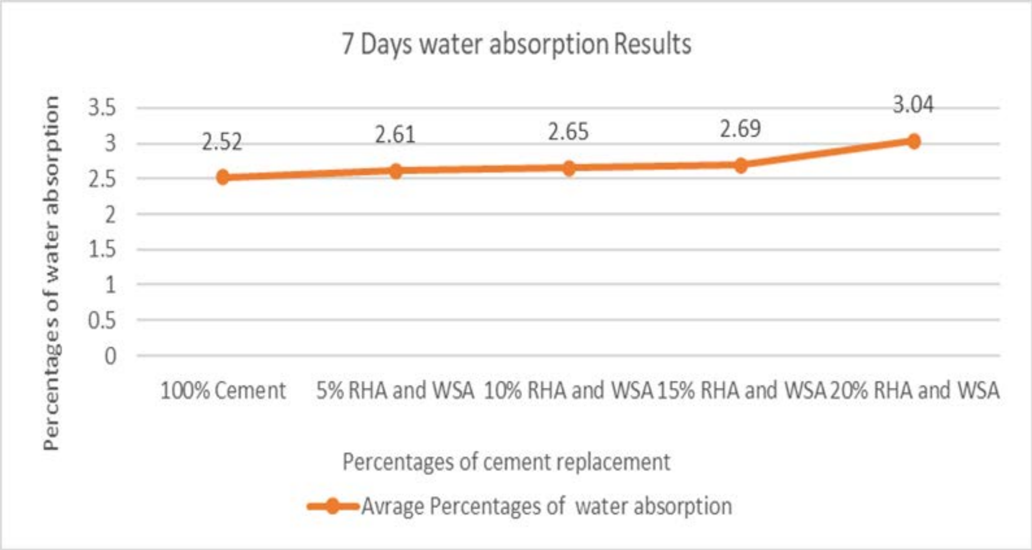

Figure 8 Variation of water absorption of 7 days for various percentages of replacement of RHA and WSA

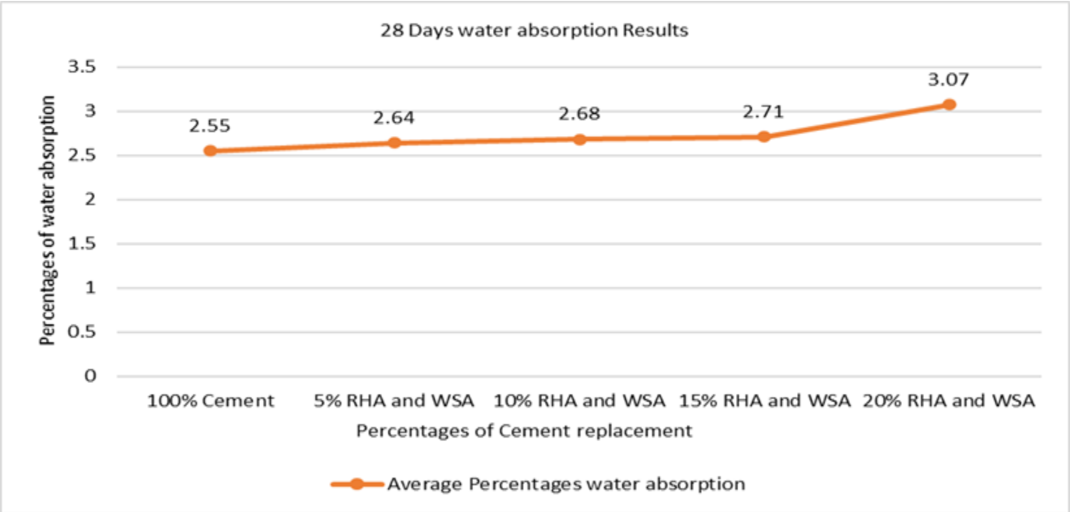

Figure 9. Variation of water absorption of 28 days for various percentages of replacement of RHA and WSA

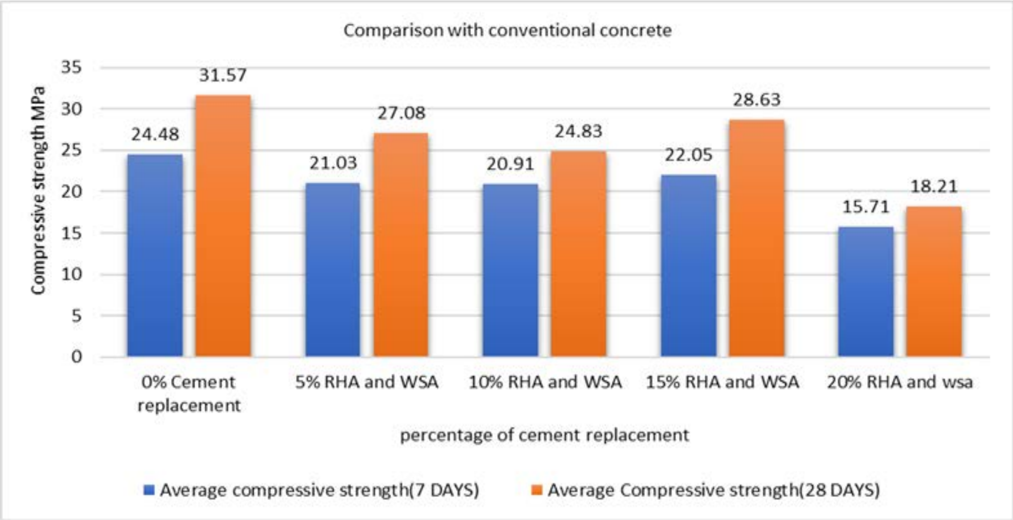

Figure 10. Comparison of Compressive Strength with Control Concrete

3.9. Comparison of Compressive Strength with Control Concrete

The compressive strength of 0% cement replacement and the optimum cement replacement was given the nearest value and fulfilled the minimum requirement of residential and commercial building compressive strength value. The comparison is given in Figure 10.

4. Conclusions

In this research, different percentages of Rice Husk Ash and Wheat Straw Ash are used combinedly with the replacement of cement (0%, 5%, 10%, 15%, and 20%) utilized to manufacture concrete. A destructive test was performed to realize the strength. The main conclusion of this research is stated below:

- The unit weight value of concrete declines with the increases in percentage substitution of cement by RHA and WSA up to a certain proportion.
- The compressive strength was gained 22.05 MPa and 28.63 MPa for 7 and 28 days respectively for 15% replacement of cement and that was optimum percentages of replacement of cement by RHA and WSA.
- Based on splitting tensile and flexural strength test results, it can be said that these strengths are decreasing a much lower amount than the control concrete at 7 and 28 days.
- The value of water absorption increases with the increases of the percentage's replacement by RHA and WSA with cement and the results that concrete containing RHA and WSA was more durable than the control concrete.

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