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Effect Of Agricultural Wastes On Mechanical Properties Of Green Concrete

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Abstract
Concrete components are considered as one of the most essential materials in buildings. The project's cost is increasing due to the usage of these materials, hence natural resources are being employed to boost strength values while lowering construction costs. In the current study, the cement in concrete is partially replaced by rice husk ash (RHA) due to its high amorphous silica and CaO content. The agricultural by product known as rice husk is collected. Both fresh and hardened concrete properties were studied by casting specimens with different proportions up to 20% rice husk ash replacement. According to the experimental results, the rice husk ash proportion in concrete should be increased from 0% up to 20% to achieve the highest values of mechanical properties. It was found that the best replacement proportion is 10% after 28 days of curing.

KEYWORDS: Natural Material, Mechanical Properties, Rice Husk Ash, Green concrete.

1. Introduction

Due to its widespread use in construction, cement is one of the most essential building materials. Its manufacture contributes to 8–10% of global greenhouse gas emissions [1, 2]. Most of the structure's concrete is used as the main component. Cement is the main binding material that binds the components of the concrete. One metric ton of OPC consumes 4GJ of energy and releases approximately one metric ton of CO_2 into the environment [3]. Cement manufacture results in 7% of total CO_2 emissions per year [4,5]. The need for building infrastructure and structures is rapidly expanding because of both the increased development occurring around the world and the continuously growing population [5]. A significant number of construction techniques require natural raw materials, expends a large amount of energy which is expensive, and emits waste while the components and building are being processed. In some circumstances, the harmful effects of specific building materials on the environment are also getting worse. Relatedly, cement-concrete construction is the most used method for constructing buildings and infrastructure since it requires little money, is incredibly durable, has high mechanical strength, and is the most practical and straightforward to use [6,7]. However, the process of making cement is expensive since it requires adequate amount of limestone, expends a significant amount of energy, generates CO_2. [8].
It is confirmed that adding waste material in concrete as a replacement for cement not only helps resolve the issues of disposing of waste but also improves the durability of the resultant concrete. [9].

Researchers are looking for different cement alternatives made from waste and by products due to growing concern for environmental protection and energy conservation with no negative economic impact. Construction from these materials is considered environmentally friendly and sustainable. The crucial characteristics of supplementary cementitious materials (SCM) are their strong pozzolanic behaviour and suitable bonding to aggregates (same as cement) [10]. Therefore, researchers and industrialists are increasingly focusing on concrete that is environmentally friendly and its use in buildings to alleviate environmental limitations and

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save natural resources by using waste materials in concrete. [11]

So nowadays research work on supplementary and cementitious materials like rice husk. It is important to replace cement with biomass. Waste managers have a significant issue when trying to dispose of RHA, which is considered as an agricultural waste. RHA is viewed as a true super pozzolan because of its high silica content, which ranges between 85 and 90% [12]. The concrete durability is increasing due to the pozzolanic property of RHA which serves to lower the permeability of concrete at advanced age [9]. RHA can lower cement manufacturing costs because, like other agricultural wastes, it is less expensive than clinker. However, no mix design guidelines exist for RHA added composite cement to generate durable concrete. One of the key reasons for RHA's failure to have popularity as a supplemental cementitious material (SCM) to date is the lack of a specific mix technique [13, 14]. Rice husk is an agricultural product that is becoming increasingly popular in the environment, requiring a big space to be filled. To address this issue, rice husk is being used in concrete to create eco-friendly concrete. The RHA exhibits exceptional pozzolanic capabilities due to its high surface area, high porous nature, and compatibility with pozzolanic reaction of cement. Its silica content is around 90% [15]. There is no doubt that RHA is considered as a carbon-neutral green product not only contains more than 50% silica (SiO_2), 7 up to 45% carbon, but also contain multiply secondary mineral compositions. Investigating the compatibility of RHA as pozzolanic material on concrete has lately been one of the most essential topics to be studied for its potential utility and cost effectiveness [16]. It is founded that milling one kilogramme of rice, resulting 0.28 kilogrammes of rice husk. Because of this there is a lot of rice husk waste being generated every year. Several industries, such as incineration and burning units, uses the heat energy being generated from burning rice husk as a fuel. 20–25% RHA by weight is formed after complete burning of rice husk [17]. The RHA is then mostly disposed of in open landfills, with a very small percentage being employed as a fertilizer on the field. RHA may be utilized well as SCM in concrete since it contains amorphous silica and CaO. Concrete that uses RHA has better strength and durability qualities, lower material costs because less cement is used and environmental advantages as a result of the effective recycling of waste materials [18].

The amount of silicon oxide, the degree of silicon oxide crystallisation, the size and area of the ash particles all affect the pozzolanic activity of RHA. Ash should, in general, only include a small amount of unburned carbon. When rice husk is burned at a regulated temperature, RHA with high amorphous silicon oxide concentration and large specific surface areas are frequently produced; these characteristics are initially responsible for their high reactivity [19]. Because the progressive development of cement-related reactions is not fully reflected, the RHA reactivity can be roughly estimated using accelerated pozzolanic testing. This example may be used to demonstrate how intrinsic qualities like reactive silicon oxide which is impossible be valued as an absolute RHA reactivity level in blended cement [20].

The research problem is how to minimize the amount of cement without effecting on both fresh and hardened concrete properties. The primary goal of this paper is to enhance the concrete properties and decrease the cost of concrete production using natural materials such as rice husk ash by replacing cement in different proportions due to its high pozzolanic reaction. This research attempts to address many environmental issues in the cement industry, including RHA, while also preserving the natural resources. Analysis is done on fresh and hardened concrete using high proportions of replacement up to 20% to summarize the different effect on concrete properties.

2. **Materials**

2.1. Cement

For all specimens were casted an OPC (CEM I 52.5N) has been used to unitize the same type of cement. Used newly produced cement and complied the specifications of the Egyptian standards for the mechanical and physical properties of OPC (ES 4756–1/2013) [21].

2.2. Rice Husk Ash

RHA was collected, dried and burnt under a controlled temperature (less than 700 ◦C) in a closed oven not directly exposed to fire. The gathered ash was grinded till it reached a suitable degree of fineness. To remove the large particles a BS sieve with a size of 75 μm was used. The generated RHA was grey in coloration.

2.3. Fine Aggregate

According to ES 1109/2008 [22], the fine aggregate (clean and rounded) used in this experiment was natural siliceous sand with physical properties of a fineness modulus of 2.58, a bulk unit weight of 1680 kg m^3, specific gravity of 2.56 and a bulk unit weight of 1680 kg m^3.

2.4. Coarse Aggregate

According to ES 1109/2008 [22], the coarse aggregate was natural dolomite with physical properties of a maximum nominal size of 13 mm, a bulk unit weight of 1700 kg m^3 a specific gravity of 2.74. The fine-to-coarse aggregate ratio is around 1:2.

2.5. Water

Both the mixing and curing of the specimens were done with potable water which was used for mixing and curing that is devoid of salts, oils, acids, sugars, and other potentially dangerous compounds. For concrete mixing, a w/c ratio of 0.54 is employed.

2.6. Super Plasticizer

In order to produce high-quality concrete, Sikament®-163M was employed as a super plasticizer and extremely efficient water reduction agent. The experimental dosage 1% by weight of cement.

2.7. Grade and Trials Used for Study

The final trial mix for concrete (characteristic compressive strength of 35 N/mm^2) with a mix percentage of 1:3.4:1.93 was employed for this investigation.

2.8. Mix Design as Per the Materials Proportions

The ideal strength and durability parameters for this experimentation research were obtained after five trials, as demonstrated in Table 1.

Table 1. Mixture proportions.

Mix	**Aggregates**				**Super plasticizer %**	**w/c**
	Cement Kg m−3	**RHA %**	**Fine %**	**Coarse %**		
Mix 1	350	0	30	70	1	0.54
Mix 2	332.5	5	30	70	1	0.54
Mix 3	315	10	30	70	1	0.54
Mix 4	297.5	15	30	70	1	0.54
Mix 5	280	20	30	70	1	0.54

3. **Methodology**

3.1. Batching

Calculating the amount of material needed for the study is the process of batching. In general, there are two ways to measure the quantity of the material: weight batching and volume batching. Weight batching is used in the current study to measure the number of materials.

3.2. Mixing the Concrete

Mix the elements according to the trials after determining the quantity of the materials. Prior to adding cement, mix the coarse aggregates, fine aggregates, and rice husk ash for a while to obtain an even mixture. Repeat this process for a second time to obtain the same combination throughout the material. To create freshly produced concrete, now add the water in accordance with the calculations from the mix design.

3.3. Casting of Specimen

We must cast cubes, cylinders, and prisms to evaluate the strength and uniformity of the concrete. We will cast 30 cubes, 15 cylinders, and 15 prisms to evaluate mechanical qualities after 7 and 28 days of curing, as well as 2 cubes to test the water sorptivity for the 10% concrete mix, for this study.

3.4. Curing of Specimen

During all lifetime of curing, all five-trial mixes for mechanical characteristics were tested after a curing time of 7 & 28 days at potable water.

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4. **Results and Discussion**

4.1. Chemical Composition

From Table 2, when comparing chemical analysis that was obtained from XRF analysis for concrete mixtures with replacing the 0% and 10% RHA. The quantity of SO_3 oxide found in the 10% RHA replacement combination is less than 1% and is not worthy when compared to the percentage of control mixture. Broadly, the use of RHA in concrete reduces the ratios of chloride Cl, sulphate SO_3, aluminum Al_2O_3 potassium K_2O, sodium Na_2O, and iron Fe_2O_3 while increasing the ratios of silicon SiO_2 and calcium CaO. According to ECP 203-2007[23], the total concentration of sulphates in hardened concrete at final setting time in the form of SO_3 cannot be more than 4% of cement weight.

4.2. The Mineralogical Composition Decomposition

In Fig.1. when comparing XRD analysis results for concrete mixture with 10% RHA replacement with control mixture. All combinations contain the same primary minerals in the form of [Quartz, syn (SiO_2), or Quartz, Calcite of Calcite, syn (Ca CO_3) or Dolomite (Ca Mg $(CO_3)_2$)]. It was found that the Quartz, syn or quartz, the dolomite, and the calcite or calcite, syn has a direct relationship between increasing RHA. In general, increasing the RHA ratio has no substantial effect on the primary minerals of combinations.

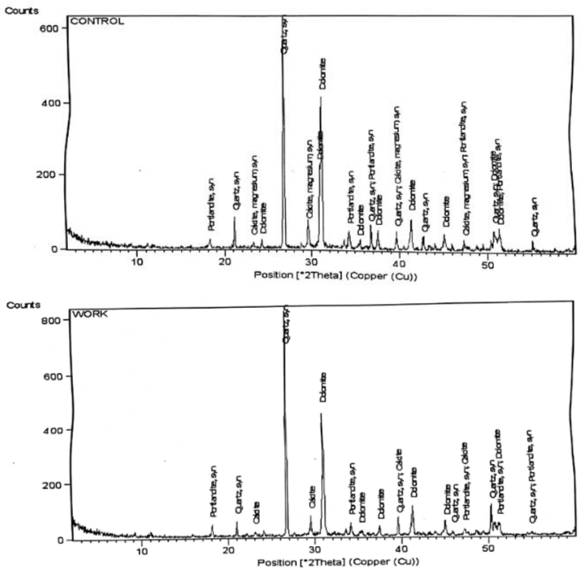

Fig. 1. The X-ray diffraction analysis for concrete mixture which cement replacement with 10% RHA and 0% RHA mixture.

4.3. Workability of Concrete

It is a feature of fresh mixed concrete. The compaction factor test and the slump cone test were used in this investigation to assess the workability of concrete. Fig.

2 displays the slump cone values for the various mix experiments. Based on the aforementioned findings, it was shown that adding more RHA to the concrete mix from 0 to 20% increases the slump cone values. The slump values of fresh concretes were measured in accordance with the Egyptian code for the design and implementation of concrete buildings, testing guide C203 [24].

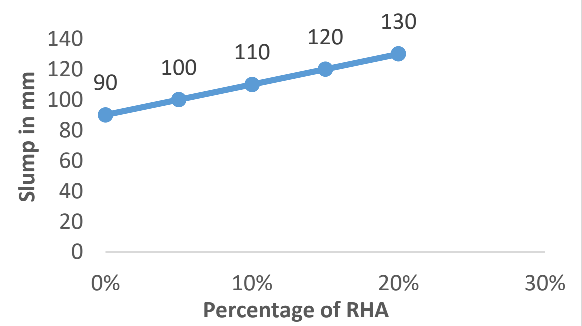

Fig. 2. Comparison between Slump cone values

Table 2. Comparison between chemical analysis for concrete mixture which cement replacement with 10% RHA and 0% RHA mixture.

Specimen / Component	10% RHA	0% RHA
SiO_2	21.35	19.00
TiO_2	0.03	0.1
Al_2O_3	4.29	5.66
Fe_2O_3	0.28	0.9
MnO	0.02	<0.01
MgO	9.88	7.5
CaO	39.80	37.28
Na_2O	<0.01	0.1
K_2O	<0.01	<0.01
P_2O_5	<0.01	<0.01
Cl	<0.01	<0.01
SO_3	<0.01	0.1
L.O. I	25.39	26.61

4.4. Compressive Strength of Concrete

According to the Egyptian code for the design and implementation of concrete buildings, tests guide C203, a compression testing machine (CTM) is used to evaluate the compression strength [23]. For trials 1 through 5. The compressive strength of concrete for specimens at 7 and 28 days is depicted in Fig. 2, as demonstrated in the fig.2 The link between the increase in rice husk ash and the 7- and 28-day compression strength is seen in Fig. 3 above. It is extremely likely that the initial increment of the compressive strength up to 10%. At the end of curing at 28 days the strength is enhanced by 11.75%, unlike the other mix proportions that reveled a lesser value compared with 10%.

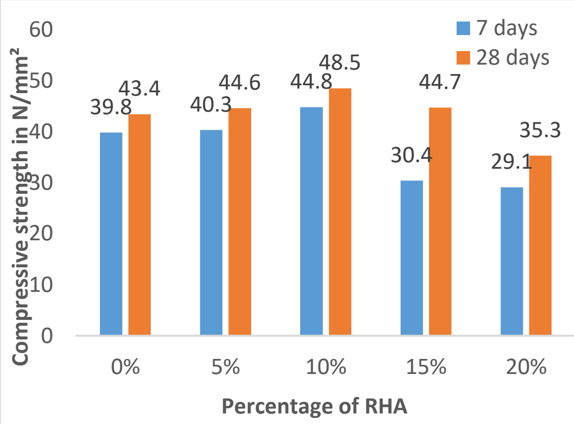

Fig. 3. Comparison of Compressive strength

4.5. Split Tensile Strength of Concrete

Using cylinder samples for concrete from trials 1 to 5, different percentages of RHA are used to estimate the split tensile strength according to Egyptian code for the design and implementation of concrete structures, tests guide C203 [23]. The cylinder is 300 mm long and has a 150 mm diameter. The split tensile strength for a 28-day curing time is depicted in the diagram below. As shown in Fig. 4, the ideal value for the concrete mix was achieved at a 10% rice husk ash concentration for 28 days of restoration. When we compared our concrete mix to a normal concrete mix, the percentage of split tensile strength improved by 4.87%. The benefits of split elasticity decreased as the RHA content increased beyond 10%.

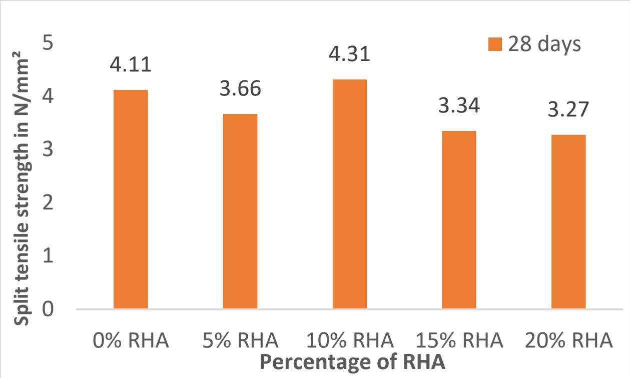

Fig. 4. Comparison of Split tensile strength

4.6. Flexural Strength of Concrete

According to Egyptian Code for the Design and Implementation of Concrete Structures, Tests Guide C203 [23], the flexural strength of concrete is measured. using prisms that are 100, 100, and 500 mm in size. The flexural strength of concrete prism samples is evaluated after 28 days during trials 1 through 5. Fig. 5 compares the flexural strength values. The greatest values of strength are reached when 10% of rice husk is added to the concrete mix. After 10%, the strength values decline. For 10% of RHA, the flexural strength increases by 9.2%.

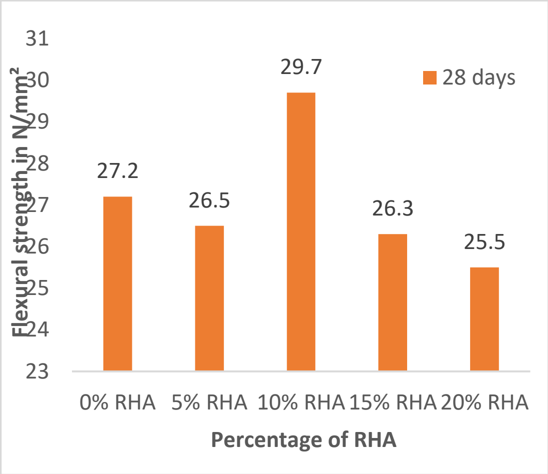

Fig. 5. Comparison of Flexural strength

4.7. Bond Strength

In reinforced concrete, a strong connection must be made between the steel bars and the concrete around it. The bond between the steel bars and concrete was strengthened as a result of the RHA ratios and it was increased by approximately 0.06 for the concrete containing 10%. RHA replacement using (TTM) with the capacity of 800kN for direct pullout test of specimens. The specimens were placed upside-down and inside the test machine's load frame. The steel bar's end is subjected to a direct tensile force until it fails by rebar cutting or concrete splitting. During testing, both failure of embedded bar and applied load are measured according to ASTM C234-91a [25]. The bond strength for the specimen with 10% RHA replacement resulted on higher bond strength than the specimen with 0% RHA replacement as shown in fig. 6.

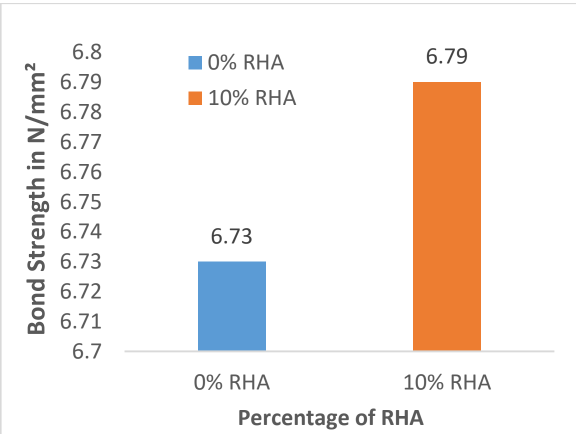

Fig. 6. Comparison of Bond Strength

4.8. The Water Sorptivity

Its a rapid test to demonstrate how quickly water absorbs through a sample of dry concrete. A capillary suction test was used to examine the impact of RHA on water sorptivity in accordance with ASTM C1585-04 on samples with 0% and 10% RHA at a 28-day age [26]. Fig. 5 shows the rate of change on the sorptivity values for mixtures where cement replacing with 10% RHA and 0% replacement at 28 days. It was observed that sorptivity value at amount of 10% RHA replacement was decreased when compared with the 0% replacement mix.

4.9. Microstructure of RHA

The control specimen's critical pore diameter was less than 0.04 m. RHA has a potent pozzolanic reaction and a filling effect because of this. At the age of 28 days, an incredibly enormous output of RHA concrete also experienced pore refinement and pore size reduction. As far as RHA has a larger pozzolanic reaction than regular cement, it was discovered that the total porosity of RHA improved concrete properties more than cement.

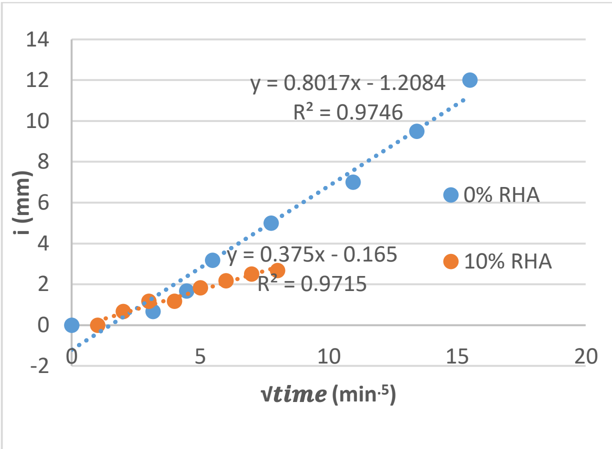

Fig. 7. Relation between (i) and ($\sqrt{time}$)

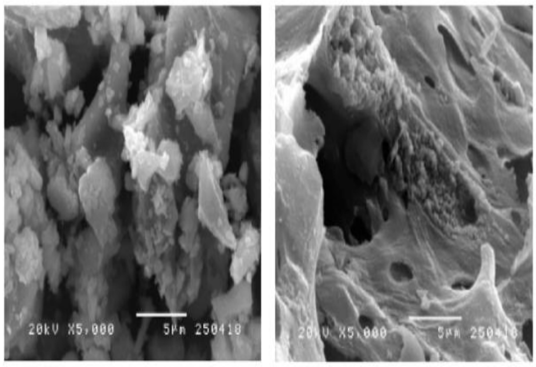

Fig. 8. SEM image (5000x) of (left) OPC, (right) RHA

5. **Conclusion**

This analysis led to the conclusion that concrete containing RHA has a number of attractive qualities that make it ecologically and structurally appropriate. Both the cost of concrete and the reduction of greenhouse gas emissions are benefits. The slump values grow as RHA concentration in the concrete mix increases from 0% up to 20%. The maximum mechanical properties including water sorptivity and bond strength for rice husk ash concrete is 10% RHA mix, which is higher than the values for the other types of concrete. In addition, that can be summed up at the following points:

- The slump test increased with the addition of cementitious materials, notably when RHA was used as a result for concrete mixtures.
- The best replacement ratio of RHA was 10%. The mixtures with RHA showed a higher compressive strength than those containing OPC. Compressive strength at 28 days increased by 11.75% in comparison to the control mix.
- The 10% replacement mixture showed higher tensile strength than those containing OPC. But also, the tensile results presented that the best replacement ratio of RHA was 10%. The ratio of tensile strength to compressive strength showed that when the RHA grew, the rate of tensile strength increment dropped.
- By applying 10% RHA replacement, the flexural strength was considerably increased. The ratio between flexural strength and compressive strength increased meaning that RHA helped on the improvement of the flexural strength and compressive strength.
- RHA's desirable replacement mix produced a strong bond strength. The bond strength ratio to compressive strength was increased. This means that RHA increased the bond strength of concrete mixtures.
- The permeability of concrete was decreased by 46.8% due to the sorptivity result of 10% replacement mix. from control mixture. Thus, was resulted because of the reduction of the air content compared with mixture contain 0% RHA. By adopting higher replacement ratios of RHA and enhancing concrete durability, this outcome met the primary objective.

Conflicts of Interest: The authors declare that none of their known financial or personal conflicts may have possibly affected the research reported in this paper.

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