Experimental Study on Influence of Iraqi Rice Husk Ash as Supplementary Material on the Performance of Concrete

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Abstract. Concrete is most widely utilized construction material. Cement, sand & gravel are the ingredients of the concrete where cement is costly. In this research an experimental study was conducted to find the suitability of the replacement materials that less cost than cement such as, rice husk ash. Rice husk is considered as a waste material and has a harmful effect on the environment, hence disposed from it by burning at a controlled temperature between (500 to 600) °C to produce RHA. RHA was found that contain 86.76% of silica, which indicates that it is a substance with pozzolanic properties. Cement replaced with RHA at percentage (5,10,15,20) % by weight at mix design (1: 1.89: 2.64) with W/C is 0.53 and (1: 1.43: 2.19) with W/C is 0.44 . Sixty cube were casted for test compressive strength and thirty cylinder to test split strength, also thirty prism to test flexural strength then casted ten beams to test behaviour of beam where found that added RHA will improve properties of concrete for compressive, tension, flexural strength and behaviour of beams.

Keywords. Iraqi Rice Husk Ash, physical and chemical properties,pozzolanic material, furnace, strength, behaviour of beam.

1. Introduction
Concrete is very important in the construction industry and other purposes related to other civil works so, the most of works related to civil engineering are part of the concrete ,as it is a compound composed of different proportions of cement, sand, gravel, and water. The using cement in concrete will lead emission the greenhouse gases[1-4], therefor it causes many environmental problems. There as a many researches are being performed for utilization cementitious materials in concrete as a partial replacement material with cement, hence Cement replaced with rice husk ash (RHA). RHA used as fuel for cooking purposes In the middle 20th century because lack of knowledge[5]. Rice husk that represents 20%of the 649.7 million of rice created every year about the world[6]. Iraq produces 366151.66 tons as average from (2012 to 2017) years[7]. The weight of the resulting rice husk( RH) is 20 % of the weight of rice , which means 73230.33 tons of RH are readily available for disposal from the rice mills, which consider as a waste material. The weight of the output RHA is 25 % of weight husk , hence ash production average from (2012-2017) years is 18307.5 tons. If the value of ton of cement is about 80$, meaning the provision as a range about 1464600$. RHA is produced by burning the husk at a temperature ranging from (500 to 600) °C, in temperature-controlled furnace to
produce high silica (SiO$_2$) and get rid of unburned carbon. It is found that RHA in concrete leads to the amelioration in various properties. V. Saraswathy et al [8] 2006 was replaced cement by RHA at percentage (5, 10, 15, 20, 25, 30) % where noted that the porosity decrease when RHA increase. Tanvir Hossain et al 2011 [9] replaced cement with RHA at percentage (5, 10, 15) %, they observed normal consistency, initial setting time, final setting time increase as a RHA ratio increase while 5% of RHA give higher compressive strength. S. D. Nagrale et al [10] 2012, burned RH in electric furnace at temperature below 700°C, compressive strength increase as RHA added. Jinan [11] 2013 RHA added to mortar cement at percentage (5, 10, 15, 20) % where observed the samples having 5%, 10% and 15% RHA show better results than the OPC mortar at age (90 days). Leong tuck lun et al [12] 2015 was burn RH at temperature (600-700) °C and observed that when RHA increase workability will decrease and observed compressive strength reaches highest strength at addition 5% RHA. W.-H. Wang et al [13] 2017 convert rice husk to RHA at temperature 600°C for period 60 min, the tested were performed for (compressive strength) at different temperature (20, 200, 400, 600, 800) °C where observed the optimum percentage of RHA at all temperature is 20%. Akhil V Nair et al [14] 2017, replaced cement with RHA at percentage (5, 10, 15) % where observed The force caused failure share with RHA and marble powder beam is more than control beam and width crack for RHA - marble powder beam is less than control beam. The fact that the rice husk in Iraq are disposed of randomly is harmful to the environment. And as a result of the lack of researches that studies the husks of Iraqi rice, this was study that includes an experimental investigation on the influence of Iraqi rice husk ash on mechanical properties of concrete and behavior of beam concrete.

2. Experimental Program
The experimental program includes the manufacture of furnace to burn rice husk in order to produce RHA and then added the ash to concrete by replaced cement with different percentages.

3. Manufacture of furnace
The production of RHA requires a furnace made at controlled temperature controlled. The furnace is (640*640) mm in plan and 1000 mm in high. The furnace is made of different materials, steel with a thickness of 1.5 mm, thermal insulation (glass wool), galvanized iron with a thickness of 2 mm, thermal bricks with a thickness of 40 mm to keep the heat inside the furnace and chimney at the top with diameter of 140 mm as well as there a Mercury thermometer to know the temperature. A fire was lit at the side of the furnace using fuel (natural gas) with valve to control furnace temperature where temperature of furnace used is (500 to 600) °C to produce RHA contain high percentage silica (SiO$_2$). The furnace include two parts, the first part is burning chamber to burn RH, the second part is storage place to store RHA produced after cooling, where all these details are mentioned are shown in Figure 1, 2.
4. Materials

4.1 Cement

Ordinary Portland cement (Type 1) originated by Lafarge company (Kresta Trade name) is utilised in this research. The chemical and physical properties of the cement were successfully according to Iraqi Specification No.5/1984[15]
4.2 Fine Aggregate
Natural sand utilised in this research from the Basra region near sanam mountain in the south of Iraq. The result grading of the sand was successfully according to Iraqi Specification No.5/1984[15].

4.3 coarse aggregate
The coarse aggregates used in this research are naturally available in Maysan region. Gravel utilised with a maximum size of 20 mm. The test of grading applied according to the Iraqi Specification No. 45/1984[15] and the result was successfully.

4.4 Iraqi rice husk ash(IRHA)
The type of rice was used is (Amber) Which is found in many areas of Iraq. The rice husk(RH) was collected from rice mills in misan province then the husk burned for period (2 to 3) hours to product RHA with colour is grey as shown in Figure 3, finally RHA were taken out for grinding for 5 min by crusher with rotation speed 25000 rpm to obtain RHA with fineness. RHA analyzes by an X-Ray fluorescence device (XRF) as shown in Figure 4 to know its chemical properties as shown in table 1.

![Figure 3. Rice husk ash(RHA)](image)

![Figure 4. X-Ray fluorescence device (XRF)](image)

| Table 1. The chemical properties of RHA |
|----------------------------------------|
| constituent | % composition |
| SiO₂        | 86.76         |
| K₂O         | 6.119         |
| Fe₂O₃       | 0.09835       |
| Al₂O₃       | 0.0038        |
| CaO         | 2.468         |
| MgO         | 0.887         |
| others constituent | 3.0087       |
5. Mixture proportion
Two mix proportions were designed (1: 1.89: 2.64) with W/C is 0.53 and (1: 1.43: 2.19) with W/C is 0.44. Cement replaced with RHA at different percentage (5, 10, 15, 20)% by weight in dry condition, table 2 summarizing the mix proportions of all the concrete mixes.

Table 2. Mix proportions of concrete mixes

| Symbol | Rice Husk Ash Present (%) | Cement (Kg/m³) | Sand (Kg/m³) | Coarse Aggregate (Kg/m³) |
|--------|---------------------------|-----------------|--------------|-------------------------|
| A1     | 0                         | 386.76          | 733          | 1024                    |
| A2     | 5                         | 367.42          | 733          | 1024                    |
| A3     | 10                        | 348             | 733          | 1024                    |
| A4     | 15                        | 328.76          | 733          | 1024                    |
| A5     | 20                        | 309             | 733          | 1024                    |
| B1     | 0                         | 466             | 668          | 1024                    |
| B2     | 5                         | 442.7           | 668          | 1024                    |
| B3     | 10                        | 419.4           | 668          | 1024                    |
| B4     | 15                        | 396.1           | 668          | 1024                    |
| B5     | 20                        | 372.8           | 668          | 1024                    |

6. Testing method

6.1 Compressive strength
Sixty cube with dimensions (150*150*150) mm were casted to test Compressive strength of concrete for period (7, 28) days of each percentage according to BS1881_83[16], Figure (5, 6) summarizing result of compressive strength.

Figure 5. Compressive strength variation at 28 days for mix proportion (A1 to A5)
Figure 6. compressive strength variation at 28 days for mix proportion (B1 to B5)

6.2 Split Tensile Strength
Thirty cylinders (150*300) mm were casted to test the tensile strength of concrete (3 cylinder for 28 days) of each percentage according to ASTM C496-04[17], Figure 7,8 summarizing result of tensile strength.

Figure 7. Tensile strength at 28 days for mix proportion (A1 to A5)
6.3. Flexural strength
Thirty prisms (150*150*500) mm were casted to measure the flexural strength was performed (3 prisms for 28 days) of each percentage according to ASTM-C78[18]. The results are shown in Figure 9,10.
6.4. Beam molds

Wooden molds are used to casting concrete beams. The dimension of beam is (1200) mm length and the cross section is rectangular (b*h=140*180) mm. Details of beam include three bars of 10 mm diameter at tension reinforcement, stirrups reinforcement of 10 mm at 80 mm c/c as well as two bars of 10 mm as anchorage bar. Details of beam as shown in Figure 11. Ten beams were casting to test beam for flexural strength where result the test shown in Table 3, Figure 12,13

| Symbol | Max Load | Max Deflection |
|--------|----------|----------------|
| A1     | 101.3    | 11.3           |
| A2     | 104.5    | 9.8            |
| A3     | 105.4    | 10.1           |
| A4     | 102.0    | 11.51          |
| A5     | 102.7    | 11.7           |
| B1     | 108.0    | 10.9           |
| B2     | 107      | 10.1           |
| B3     | 111.6    | 9.8            |
| B4     | 103.2    | 8.9            |
| B5     | 111.3    | 11.7           |

Figure 10. Flexural strength at 28 days mix proportion (B1 to B5)
Figure 11. Details of beam

Figure 12. Load-deflection curve (A1 to A5)
7. Result and discussion
The results obtained with the optimum mix are compared with the normal mix.

7.1 Mechanical properties

7.1.1 Compressive strength. The results showed that compressive strength up to higher strength at replacement of 10% percent cement with RHA for mix proportions (A1), while when (15,20)% RHA, lead to that compressive strength decreasing. Since mix proportions (B1) observed that compressive strength increase at 5% RHA ,but at (15,20) % RHA , compressive strength slightly decreasing compared with normal mix.

7.1.2 Tensile strength. The results showed that tensile strength increase at 5% RHA and up to higher strength at 10% RHA, while at (15,20)% RHA up to approximate value with normal mix for mix proportions (A1). Since (B1) noted that tensile strength increase at 5% RHA, while at (10,15,20)% RHA up to approximate value to normal mix.

7.1.3 Flexural strength. The results showed that flexural strength increase at all percentage added of RHA and up to high strength at 15 % RHA for mix proportions (A1,B1).

7.2 Behavior of beam
The results showed that load which cause failure of beam is increase at all percentage added of RHA compared with normal mix (A1),while deflection decrease at (5,10)% RHA, while increase at (15, 20)% RHA. Result are varying for mix proportion (B1), where the max load that caused failure at 10% RHA with decrease in deflection compared with normal mix, while at 15% RHA, noted that max load decreasing , as well as The results of the present investigation indicate that the percentage of RHA contributing to the mechanical properties and behavior of beam are more significant than that of control concrete due to the pozzolanic property and filling ability of RHA which have finer particle size when compared with cement[19] where RHA contain high percentage of reactive silica(Sio2) that reaction with calcium hydroxide Ca(OH)2 to formed CSH (gel) which lead to obtain higher strength than normal concrete[5].

8. Conclusions
1- RHA classify as apozzolanic material due to contain high percentage of silica(SiO₂) up to 86.76%.
1. The compressive strength up to higher strength at 5% RHA and all percentage added of RHA give strength nearly to normal concrete.
2. The tensile strength increase as added RHA and up to higher strength at 10% RHA and all percentage added of RHA give strength higher normal concrete.
3. The flexural strength increase as increase RHA and up to higher strength at 15% RHA
4. The effect of RHA added to mix proportion for test behavior of beam is positive where the load that cause fail beam RHA is more or nearly than beam normal, which indicates that the investment of RHA has a great benefit in concrete.

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