Recycling Waste Biomaterials as Low-Cost Mortar for Cement Replacement

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Abstract: This study was carried out to investigate the physical and mechanical properties of mortar cement produced from biomaterials like rice husk ash (RHA) and carrot powder (CP). To do this, 8 mortar cement specimens were formed by changing the weight of RHA and CP with cement. Increasing ratio of RHA and CP weight ratio affected the compressive strength, impact, hardness. As for the bending ,water absorption and fracture toughness decreased and were affected positively. It was concluded that RHA and CP might be used in mortar cement production replaced the cement in certain ratio to make them profitable and lessen their adverse effects on the environment.

Keywords: Mechanical; materials technology; recycling and reuse of materials

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1. Introduction

The first biomaterials is Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide[1]. The produced partially burnt husk from the milling plants when used as a fuel also contributes to pollution and efforts are being made to overcome this environmental issue by utilizing this material as a supplementary cementing material[2] . The chemical composition of rice husk is found to vary from one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions [3-5].Burning the husk under controlled temperature below 800 °C can produce ash with silica mainly in amorphous form. Recently, [6] reported an investigation on the pozzolanic activity of RHA by using various techniques in order to verify the effect of incineration temperature and burning duration. He stated that the samples burnt at 500 or 700 °C and burned for more than 12 hours produced ashes with high reactivity with no significant amount of crystalline material. The short burning durations (15 – 360 minutes) resulted in high carbon content for the produced RHA even with high incinerating temperatures of 500 to 700 °C. A state-of-the-art report on rice husk ash (RHA) was published by[7] , and contains a review of physical and chemical properties of RHA, the effect of incineration conditions on the pozzolanic characteristics of the ash, and a summary of the research findings from several countries on the use of RHA as a supplementary cementing pozzolanic material.

Rice husk contains 75-90 % organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements[8] . Rice husk is unusually high in ash compared to other biomass fuels in the range 10-20%. The ash is 87-97% silica[9] , highly porous and light weight, with a very high external surface area. Presence of high amount of silica makes it a valuable material for use in industrial application. Other constituents of RHA, such as K_2O, Al_2O_3., CaO, MgO, Na_2O, Fe_2O_3 are available in less than 1 % ref. Various factors which influence ash properties are incinerating conditions (temperature and duration), rate of heating, burning technique, crop variety and fertilizer used. [10] the silica in the ash undergoes structural transformations depending on the conditions of combustion such as time and temperature .

The second biomaterials is carrot seeds, The carrot is one of the most commonly used vegetables for human nutrition. It gets its characteristic and bright orange colour from β - carotene, which is metabolized into vitamin A in humans when bile salts are present in the intestines. Massive over consumption of carrot can cause carotenosis, a benign condition in which the skin turns orange . carrot are also rich in dietary fiber, antioxidants and minerals. Carrot fiber provides high strength, stiffness, toughness and a very smooth finish. The composite made from carrot fibers has a lower density than carbon fiber. It can also be molded which makes it valuable for many applications. The carrot fibers have stiffness of 130 GPa, strength of up to 5 GPa and density 1.5 g/cm^3 [11-12]. James et al. [13] found that carrots grown at Perkins, Oklahoma, that harvested at two times during the year once in midsummer and in the late fall contented 25.8-51.2 % fibers. Mehmet et al. found carrot seeds cultivated in Turkey contented about 31.99+2.21 % fibers [14]. Blanching et al. found carrot's pulp contained 37- 48 % from the total fibers [15]. Carrot fibers composites were used in: Sports equipment The carrot fibers material can also be utilized in a range of other sports equipment such as snowboards, road cycling (bike), and boat [16].Automotive industry In the early 1930's, Henry Ford examined a variety of natural materials including carrots, cantaloupes, cornstalks, cabbages and onions in a search for potential candidate materials from which he could build an organic car body. He developed a prototype based on Hemp but due to economic limitations at that time the vehicle was not mass produced. The steering wheel in a race car is made from carrot fibers paste which injected into the mould to form the part. The steering wheel in a race car is made from composite composed of carrot fibers [17].

2. Experimental Work

Ordinary Portland Cement (OPC) was used for this study. The fine cement used was 53µm, The average particle size distribution was determined by laser particle analysis. The fine sand used was 53 µm .for making cement mortar. Ordinary tap water has been used. The husk was collected from Al-Batar field in Al- kut ,Iraq, it was then burned in the laboratory by using a melting furnace with 1200 degree, Chamber size:250mm x 250mm x 300 mm,Heated by resistance wire and Max Temp :1200C̊ ,This furnace can hold up to 1 kg of rice husks; it has one small openings through which allow ventilation. A electrical source was maintained around the furnace for around 10 minutes, after which the husks slowly burned for more than one hour .To produce the best pozzolanic, the burning of the husk must be carefully controlled to keep the temperature below 700°C and to ensure that the creation of carbon is kept to a minimum by supplying an adequate quantity of air. At burning temperatures below 700°C an ash rich in amorphous silica is formed which is highly reactive. Temperatures above 700°C produce crystalline silica which is far less reactive. The presence of large quantities of carbon in the ash will adversely affect the strength of any mortar produced using RHA cements. Where possible, the carbon content of the ash should be limited to a maximum of 10%. The burin husk was left inside the furnace to cool down before it was collected .The husk was milling for 15 minutes . The rice husk ash (RHA) was only tested for particle size analysis and surface area to show the effect of milling time on the average particle size and specific surface area. Ball milling model 9,power source 230 v ,dimension 400mm high,(360 mm guard open) ,250mm deep (450 mm guard open)for milling the ash. The mill can hold up to 13 kg of ash and this amount was kept constant each time the mill was used. The milling time was adjustable in the range of (15–20 minutes) according to the required fineness. The X-ray Diffraction (XRD) analysis was performed to determine the silica phase of the produced RHA powder samples, they were scanned by an X-ray diffractometer -6000 using CuKα radiation at 60 kV/80 mA, CPS = 1k, width 2.5, speed 2°/min and scanning with angle of 2θ from 3 – 70°, shimadzu. To study the effect of milling time on the average particle size (APS), the particle size analyses were carried out by using the laser diffraction particle size analyzer sald -2101 ,shimadzu and beam length of 680 nm. RHA samples were also measured The chemical composition of the RHA is determined using the ICP-OES chemical analysis machine.

Carrot seeds were purchased locally from vegetable supplier. They were cleaned to remove all foreign matter such as dust, dirt, and stones. The juice was removed from carrot seeds the solid waste from carrot juice is rich in fiber which regarded as a functional fiber source. The carrot fiber was milling for 15 minutes. The carrot powder (CP) was only tested for particle size analysis and surface area to show the effect of milling time on the average particle size and specific surface area. Ball milling for milling the powder .the X-ray Diffraction was analyzed. To study the effect of milling time on the average particle size. the particle size analyses were carried out by using the laser diffraction particle size analyzer. samples were also measured The chemical composition of the CP is determined

A mortar specimen of approximately 3cm*3cm for compression test and 1.5cm*1.5 cm For bending and impact test was cast for each mix considering a control mix, four mixes corresponding to 5%,10% and 15% rice husk ash cement replacement. Mixing proportion are given in table 1. The specimens were left for setting for three different time (7,14 and 28)days.

Table 1. Mortar Cement Mixture Proportioning of CP & RHA

No.	RHA&CP (g)	Replacement Of Cement%	Sand (g)	Cement (g)	Water (ml)
5	0	0%	30	10	10
6	2	5%	28	10	10
7	4	10%	26	10	10
8	6	15%	24	10	10

3. Results

The particle size distribution of the RHA powder exhibiting sizes in the range (15 –120)µm. Figure 3-a shows that the number of particles in the small size region of the distribution is higher than that in the large size region. The average size of the particles is found equal to 61.667µm. Therefore, the grinding has produced a RHA powder. This powder is expected to mix homogeneously with the mortar cement providing reinforcement centers in the mortar cement at macro scale dimension .while The particle size distribution of the CP exhibiting sizes in the range (20–400)µm. Figure 3-b shows that the number of particles in the small size region of the distribution is higher than that in the large size region. The average size of the particles is found equal to 95.580µm.

3.2. X-Ray diffraction.

Sharp XRD peaks of RHA at 2θ values of 20.9, 21.9, 26.6, 31.4 and 36.0˚ indicate presence of silica in crystalline form Figure 5.These reflections would give corresponding d-values of 4.06, 3.35, 2.85, and 2.49 as estimated from Bragg's law in agreement with the values from ICDD of tridymite (4.06, 3.33, and 10.9) and cristobalite (4.04, 2.49, and 2.84) phases.[18-19] These XRD peaks, therefore, suggest that the RHA has mixed phases of both forms of crystalline silica. At calcinations temperatures above 900℃, the SiO_2 in RHA would consist of cristobalite and some tridymite phases due to melting of the surfaces of ash silica particles and bonding of particles together.[18] .It is observed that at temperature around 1000℃ the RH turns into ash with predominant crystalline silica. At 1350℃ 83% of the RH turns into crystalline silica. It is worth mentioning that in the temperature range 450 – 700℃, the contained silica exhibits an amorphous nature in the RH with less than 5% of crystallinity. As Shown In Figure 1-a.The x-ray diffraction of carrot powder shows no diffraction peak was observed in the (2ϴ) range(20-60) , it shows that the Carrot powder is amorphous in nature [19]. As Shown In figure 1-b.

I(cps)

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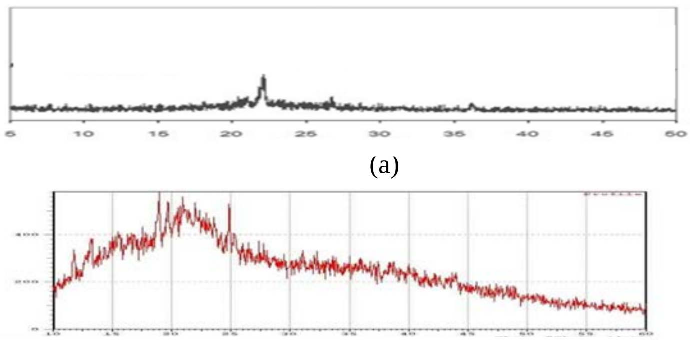

Figure1.(a) X-Ray Diffraction of RHA,(b) X-Ray Diffraction of CP

3.3. Chemical Analysis .

Typical chemical composition of the RHA is shown in Table 2-a.the higher range of RHA is silica 94.41%.while the typical chemical composition of the CP is shown in Table 2-b the higher range of CP is potassium and calcium**.**

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Table 2-a. The Chemical Composition of the RHA**, b -** the chemical Composition of CP.

(a)

Compound formula	RHA Content %
SiO_2	94.41%
Al_2O_3	0.15%
Fe_2O_3	0.99%
CaO	0.52%
MgO	0.70%
K_2O	2.27%
Na_2O	0.26%
P_2O_5	0.62%
TiO2	<0.01%
MnO	0.08%

(b)

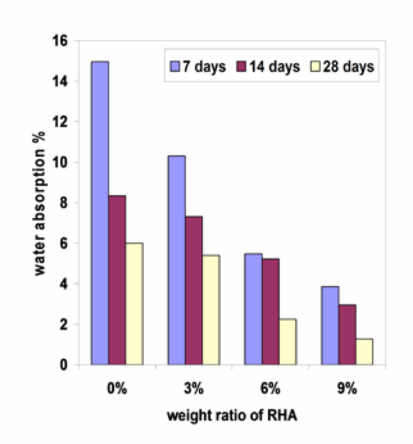
Compound formula	Carrot powder%
K	35.55%
Ca	31.27%
P	12.85%
Na	6.08%
Fe	6.05%
Mg	3.87%
Al	3.82%
Mn	0.463%
Zn	0.281%
V	0.184%
Ni	0.059%
Cr	0.086%

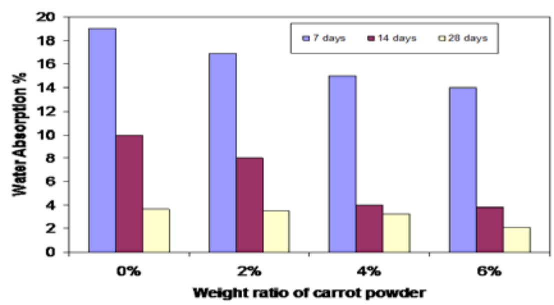
3.4. Water absorption

Water absorption is used to determine the amount of water absorbed under specified conditions. See equation 1, For the water absorption test, the dried specimens are weighed. The material is then emerged in water at room Temperature for 24 hours, specimens are removed, patted dry with a lint free cloth, and weighed. Water absorption is expressed as increase in weight percent. As shown in figure 2(a)and(b).

$$\text{Water Absorption\%} = \left(\frac{(\text{Wet Weight} - \text{Dry Weight})}{\text{Dry Weight}}\right) * 100 \text{----------(1)}$$

Figure 5 (a)and (b) shows that increasing the RHA and CP to the cement ratio in the cement mortar resulted into a decrease of water absorption by the specimen. This behavior is found reproducible in all reinforced mortars regardless the time interval after which measurements were taken. This behavior is attributed to the fact that the RHA and CP might have filled the micro-cracks and the pores in the mortar leading to decrease of voids being otherwise occupied with water**.**





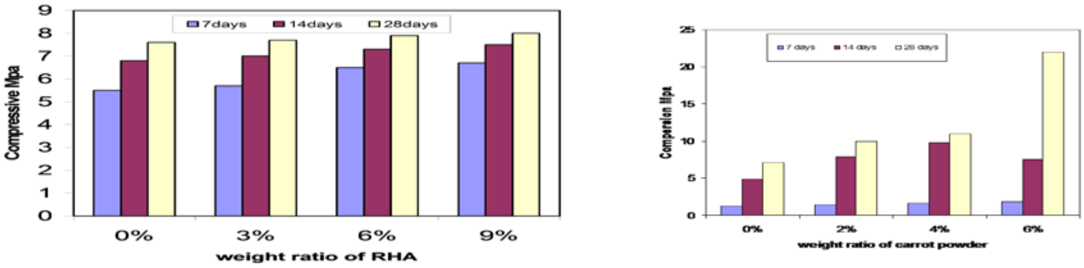
(a) **(b)**

Figure2.(a) Water Absorption of RHA**,(b)**Water Absorption of CP

3.5. Compression

A compression test is a method for determining the behavior of materials under a compressive load. Compression tests are conducted by loading the test specimen between two plates and then applying a force to the specimen by moving the crossheads together. The compression test is used to determine elastic limit, proportionality limit, yield point, yield strength and compressive strength. The

Dimensions Of the specimen that used in this test is 3cm*3cm. In general, the RHA mortar had higher compressive strengths at various ages and up to 28 days when compared with the pure mortar . The results show that it was possible to obtain a compressive strength of as high as 7.5 MPa after 28 days. In addition, strengths up to 8 MPa were obtained at 28 days .as shown in figure.3 (a).while the CP mortar had higher compressive strengths at various ages and up to 28 days when compared with the pure mortar . The results show that it was possible to obtain a compressive strength of as high as 7.5 MPa after 28 days. In addition, strengths up to 22 MPa were obtained at 28 days. As shown in figure 3(b).



(a) **(b)**

Figure3.(a).Compression of RHA,(b)Compression of CP

4. Conclusions

The RHA used in this study is efficient as a pozzolanic material; it is rich in crystalline silica (94.41%). The loss on ignition was relatively high (4.71%). Increasing RHA fineness increases its reactivity. The process of extraction of carrot fibers is simple. The lower density of carrot fibers is an interesting parameter in designing lightweight material made from carrot fiber. Increasing ratio of RHA and CP weight ratio affected the compressive strength, impact, hardness. As for the bending ,water absorption and fracture toughness decreased and were affected positively. It was concluded that RHA and CP might be used in mortar cement production replaced the cement in certain ratio to make them profitable and lessen their adverse effects on the environment**.**

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