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The Influence of Addition of Date Palm Leaves and Rice Husk on the Mechanical Properties of Cement Mortar

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Abstract: The technological trend towards waste utilization and cost reduction in industrial processing has attracted the use of Rice Husk (RH) and Date palm leaves (DPL) as a value added material. Both RH and DPL have been found suitable for wide range of domestic as well as industrial applications. This paper presents the finding of the investigations done to assess the effect of DPL and RH additions on the properties of cement mortar. Mix design was cement: sand = 1:3, and DPL and RH were added individually to the cement mortar as 1, 1.5, 2, and 2.5% of the total weight of the mix. Fresh density, hardened density, compressive strength, water absorption and modulus of rupture were evaluated. The results revealed that the compressive strength and modulus of rupture decreased with the addition of DPL and RH. However, the compressive strength was slightly higher with the addition of RH than the addition of DPL. Water absorption was increased with the addition of DPL and RH. Additions of RH and DPL to the cement mortar would significantly contribute to waste management and sustainability. Cement mortar produced in this study could be used for finishing.

Keywords: Date Palm Leaves, Rice Husk, Compressive Strength, the Modulus of Rupture, Water Absorption

1. Introduction

Utilization of agricultural residues as an energy resource has received in the last decades much attention. In fact, these biomasses have various economical and environmental advantages. It is may be a promising solution which does not interfere with the production of food and contribute to cover energy needs [1] Considerable research efforts have been spent on vegetable fiber reinforced cement composites. Natural fibers, either unprocessed or processed, have been used to reinforce cement based products in various applications around the world. These include materials obtained from different parts of plants. For example, fibers are obtained from the stems of jute, ramie, flax, kenaf and hemp, whereas leaf and cotton are obtained from sisal, banana and pineapple, and kapok from the seed. Natural fibers are composites with a cellular structure including different proportions of cellulose, hemicellulose and lignin which constitute different layers [2, 3].

Date palm is one of the most cultivated palms around the world. Date palms have a fibrous structure. It is used for reinforcing cement matrices as it has been reported to resist rapid propagation of micro cracking induced stress as well as to possess the ability to withstand loads even after initial cracking, thereby improving toughness. Furthermore, an increase in the flexural strength of the fiber-cement composite up to 30% had been observed. However, fiber inclusion reduces the workability of the fresh concrete [4]. Rice husk (RH) is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of rice paddy are produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tons [5]. Rice husk removal during rice refining

creates disposal problems due to less commercial interest. Besides, handling and transportation of RH is a problematic issue due to its low density. Considerable researches have been done on using rice husk ash (RHA) obtained from burning and grinding RH and using it as cement replacement [6]. However, burning RH in landfill to obtain RHA is a pollutant process since it emits greenhouse gases to atmosphere [1].

The objective of this study is to recycle RH and DPL conducted from landfill as additives to cement mortar with ratios of 1, 1.5, 2 and 2.5% of the total weight of the mix, hence the pollution problems initiated by the accumulation of RH and DPL in landfill will be reduced.

2. Materials and Mixing Method

Ordinary Portland cement (Type 1) was used for casting all specimens throughout the research program. The cement complies with Iraqi specification (IQS No.5/1984) [7]. Graded natural sand with fineness modulus of 3.02, specific gravity of 2.6, absorption of 0.77% and bulk density of 1342 kg/m^3 was used. Date palm leaves were obtained from a farm in Karbala, Iraq. They were dried in an oven at 115°C for 24 hours to absorb moisture and then shredded by a shredder to about 3 mm particle size. Rice husk was dried and shredded to about 1.18 mm particle size. Table 1 illustrates mix design adopted in this study, with the mix design fixed at cement: sand of 1:3. The reference mortar was made and symbolized as (H0). RH was added as 1, 1.5, 2 and 2.5% of the total weight of the mix represented by H1, H2, H3 and H4, respectively. Here H1 represents 1% addition of RH and H4 represents 2.5% addition of RH. DPL was then added as 1, 1.5, 2 and 2.5% of the total mix, which are represented as H5, H6, H7 and H8 where H5 represents 1% addition of DPL to the total mix and H8 indicates 2.5% addition of DPL to the mix. The percentage additions were adopted based on the past research which gives 2% as the optimum dose of fiber addition to concrete [2]. DPL and RH were added alternatively to the cement mortar in this study to investigate the individual effects of DPL and RH additions on the properties of the cement mortar. The mortar was put in the moulds to make 2 kinds of samples: 5 cm × 5 cm cubes (Please check!) and 16 cm × 16 cm × 4 cm prisms. Mortar samples were demoulded after 24 hours and then immersed in water for 28 days.

Table 1. *Mix design.*

Mix Cod	C (kg/m^3)	S (kg/m^3)	RH (kg/m^3)	DPL(kg/m^3)	F. D (kg/m^3)
H0	503	1519	0	0	2362.0
H1	503	1519	20	0	2279.5
H2	503	1519	30	0	2225.2
H3	503	1519	40	0	2157.4
H4	503	1519	50	0	2118.5
H5	503	1519	0	20	2257.1
H6	503	1519	0	30	2195.3
H7	503	1519	0	40	2157.3
H8	503	1519	0	50	2103.8

3. Test Methods

3.1. Compressive Strength

Compressive strength is the capacity of a material to endure axially directed pushing forces. The compressive strength is tested at 7, 14, and 28 days on (5×5)cm cubic specimens using a hydraulic universal digital compression testing machine (ELE-Digital Elect) of 2000 Kn capacity. The test was performed according to ASTM C67 – 07a, 2003 [8]. Three specimens were tested and the average value was recorded.

3.2. Modulus of Rupture

The modulus of rupture test was done according to the ASTM 78-02, 2003[9]. The methodology requires testing simply supported prism under two point loading and with dimensions of (16×16×4) cm. Modulus of rupture was conducted at 28 days on three samples were rested and the average value was evaluated.

3.3. Water Absorption

For the study of absorption three specimens per each curing condition was dried in oven at 105°C for 24 hours and then immersed in water for 24 hours according to ASTM C1403-15, 2003 [10]. The water absorption was computed from the weight difference after immersing samples in water and dried them in oven using eq. 1 below:

$$A = \frac{m_w - m_d}{m_d} \quad (1)$$

Where A = water absorption (%), m_w= wet mass (g), and m_d= dry mass (g)

4. Test Results and Discussion

Table 2 lists the test results of the test mechanical properties, including the fresh density, the compressive strength at 7, 14 and 28 days, the modulus of rupture and the water absorption. The fresh density ranged from 2279.5 to

2118.5 kg/m^3 and significantly decreased from H1 to H4 when rice husk was added. The fresh density dropped from 2257.1 kg/m^3 to 2103.8 kg/m^3 from H5 to H8 when date palm leaves were added. The compressive strength at 28 days varied from 24.45 MPa to 14.56 MPa from H1 to H4 after adding RH. However, it ranged from 16.54 MPa to 6.71 MPa from H5 to H8 after adding DPL. The relationships between the fresh density and the bulk compositions of rice husk and date palm leaves are illuminated in Figure. (1). It is obviously noticed that adding RH to the mix gave higher compressive strength as compared with adding DPL. However, the corresponding compressive strength generally decreased compared with the referenced mortar which had a compressive strength of 30.97 MPa. The relationships between the compressive strength and the bulk compositions of RH and DPL are illustrated in Fig. (2). This behavior is related to the increase in fiber content, leading to lower densities of samples. In fact, at high content, if the fiber is stiff, the packing of the fiber becomes difficult and voids are introduced into the composite. Thus, the decrease in the compressive strength is related to the low mechanical strength of the inclusions and the increase of the porosity in the matrix due to air entrainment [11].

The addition of date palm leaves caused an increase in the water absorption from 12.12% to 15.00% compared with the water absorption of 7.90% for the referenced mortar. However, the water absorption for the mortar incorporated with rice husk was less than that for the mortar with date palm leaves. Date palm fibers show an enormous capacity of water absorption. It can absorb amount of water up to 3 times its dry weight. This is generally due to the porous structure and their distributions. Besides, the hydrophilic character of the DPF leads to high moisture absorption of mortar composites [11]. The relationships between the water absorption and the bulk compositions of rice husk and date palm leaves are clarified in Figure. (3).

The modulus of rupture followed a similar trend to the compressive strength and showed a slight decrease for the mortar incorporated with rice husk from 3.13 MPa to 2.20 MPa. However, the modulus of rupture distinctly decreased compared with the mortar containing rice husk, showing 0.98 MPa for H5 down to 0.53 MPa for H8. The visual inspections on the broken specimens revealed that in spite of the rupture the broken specimens were not fully split as the leaves of date palm still held to the pieces together, hence protecting the samples from totally splitting. A similar trend was observed by Kriker et al [12]. The relationships between the modulus of rupture and the bulk compositions of rice husk and date palm leaves are shown in Fig. (4). It demonstrated that adding rice husk into the mortar gave better mechanical properties than incorporating date palm leaves. However, the properties of the mortar containing rice husk could be enhanced by treating rice husk in alkaline solutions like Ca $(OH)_2$ and removing hemicellulose lignin or imparting hydrophobicity. Hence, the compressive strength and the modulus of rupture could be increased and water absorption be decreased.

Table 2. *Test results for the mechanical properties of the cement mortars.*

Mix Cod	7 day	14D	28D	H. D (Kg/m^3)	WA (%)	MR (MPa)
H0	21.92	26.35	30.97	2280	7.90	5.24
H1	18.96	21.10	24.45	2236	8.89	3.13
H2	16.23	19.84	22.36	2196	9.53	3.02
H3	11.56	16.49	20.14	2138	10.03	2.99
H4	8.34	12.13	14.56	2124	11.95	2.20
H5	10.98	13.61	16.54	2288	12.12	0.98
H6	6.65	9.41	12.67	2192	13.34	0.80
H7	5.12	6.68	9.11	2152	14.29	0.92
H8	4.01	5.52	6.71	2088	15.00	0.53

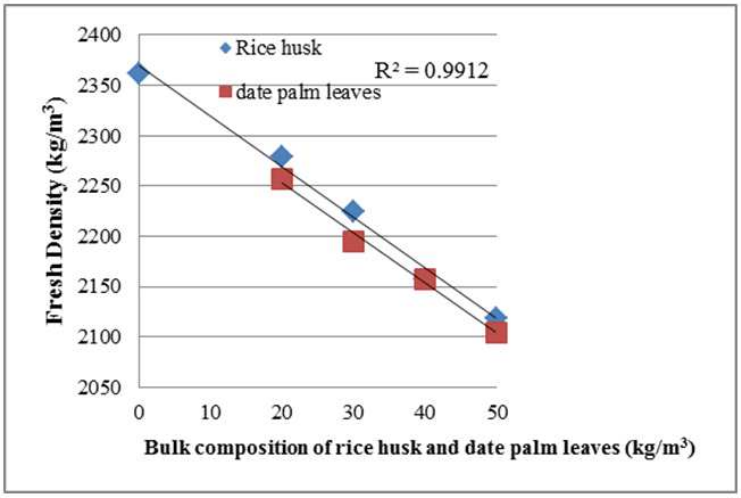

Figure 1. *Relationships between the fresh density and the bulk compositions of rice husk and date palm leaves.*

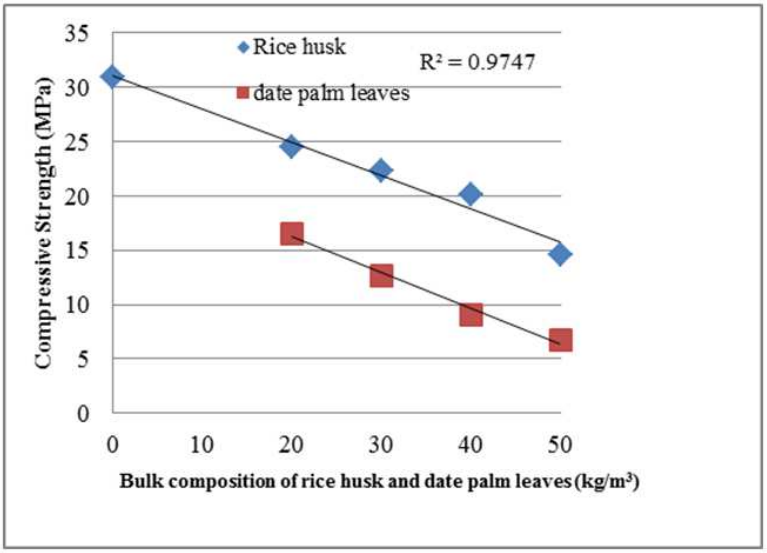

Figure 2. *Relationships between the compressive strength and the bulk compositions of rice husk and date palm leaves.*

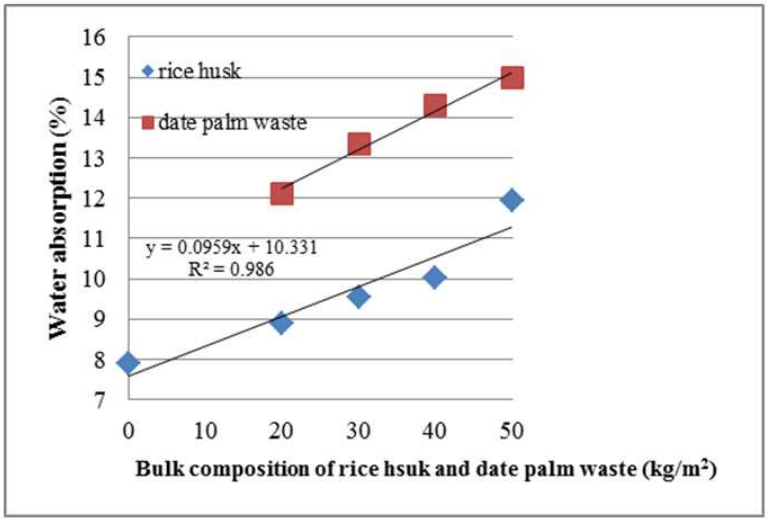

Figure 3. *Relationships between the water absorption and the bulk compositions of rice husk and date palm leaves.*

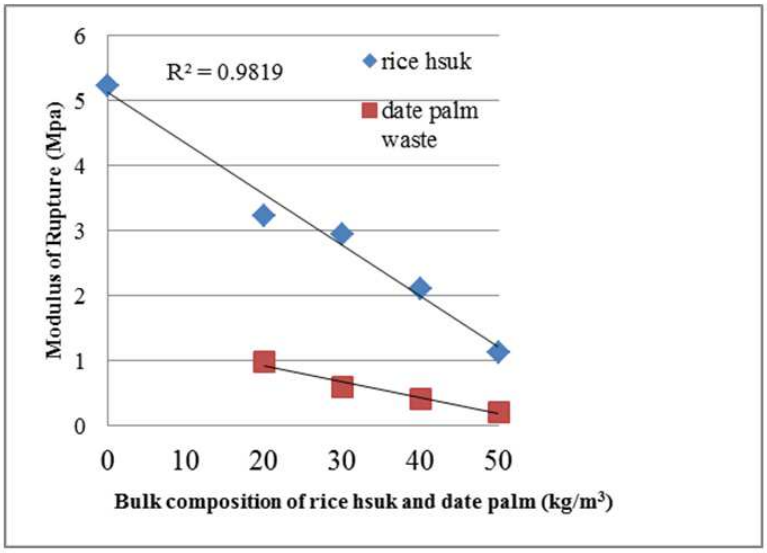

Figure 4. *Relationships between the modulus of rupture and the bulk compositions of rice husk and date palm leaves.*

5. Conclusions

(a). The compressive strength and the modulus of rupture of the cement mortars decreased with the increase of RH. Adding DPL into the cement mortars reduced the compressive strength and the modulus of rupture as well. However, the strength results for the mortar with RH were higher than those for the mortar with DPL. Besides, adding DPL into the mortar could avoid the samples from total separations when applied to flexural loading.

(b). The water absorption of the mortar increased with the increase in RH and DPW contents.

(c). The mechanical properties of mortar could be enhanced by treating RH with alkaline solutions.

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