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A study of durable and reliable reactive powder concrete containing rice husk fibers

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ABSTRACT

Natural fibers have seen a surge in popularity over the past decade as a direct response to the growing number of people who are concerned about the environment. The use of natural fibers has many advantages, including their low cost and their little impact on the environment. Rice husk is a byproduct of milling rice and is frequently regarded as a waste product by many people. However, it has a number of possible applications, one of which is the use of its natural fibers in the production of bio-composites. In this paper, experimental work was carried out to study the effect of Rice Husk Fibers with a volume fraction of one percent on the properties of Reactive Powder Concrete (RPC), utilizing various temperatures curing for four hours due two days after hardening the sample directly, and the optimal temperature that will give the highest strength will be adopted to study the effect on some mechanical properties. Rice Husk Fibers were added to the RPC mixture at a volume fraction of one percent. These characteristics include the compressive strength, dry density, and slump of the material. According to the findings, the compressive strength of the RPC grew by 7.4%, while the dry density reduced by 0.69 % after being heated to 60 °C for 28 days. On the other hand, the RPC's workability decreased by 5.62 % when compared to the reference mixture.

Keywords: Reactive Powder Concrete, Rice Husk Fiber, compressive strength, flow test and dry density.

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1. Introduction

One of the primary benefits of constructing with locally sourced materials and waste products is that it lowers overall construction costs. This is because locally sourced resources and waste products are frequently less expensive than conventional construction components that need to be imported. In general, the use of locally accessible resources and waste products in the construction sector has the potential to provide a long-term solution to the economic and environmental problems that developing countries are currently experiencing. [1]. It is noted for its excellent strength, durability, and resistance to cracking, and it goes by the acronym RPC (which stands for reactive powder concrete). RPC is an extremely dense and ultra-high performance cement-based composite material. In most cases, RPC is made up of a combination of fine powders, such as silica fume, Portland cement, and quartz powder, in addition to other components such as super plasticizers, steel fibers, and mineral additives. [2]. In place of coarse aggregate, reactive powder concrete (RPC) typically makes use of very fine quartz sand (with a particle size ranging from 0.15-0.40 mm) to achieve its distinctive properties. The absence of coarse aggregate is one of the most distinguishing characteristics of reactive powder concrete (RPC). This absence makes it possible for RPC to have a highly dense microstructure that is free from the heterogeneity that can be caused by the use of coarse aggregates. This sand is mixed with a mixture of silica fume, Portland cement, super plasticizers, and other additives to produce a cement-based composite material that is both extremely dense and capable of delivering extremely high levels of performance. [3]. Researchers have carried out a great number of investigations to examine the mechanical and fresh properties of the material known as Reactive Powder Concrete (RPC). This material is famous for its extraordinary strength. In one of these types of studies, researchers created RPC with a compressive strength of 130 MPa at the age of 28 days under typical processing settings. They discovered that the strength attained after curing for 28 days was similar to approximately 70% of the strength attained after curing for 7 days. This indicates that RPC reaches its strength rather soon. When compared to concrete that does not contain fibers, it has been demonstrated that the addition of fibers to the RPC mixture results in a significant improvement in the material's compressive strength as well as its bending qualities. This is due to the fibers' capacity to assist reinforce the material and prevent cracking, both of which can contribute to a reduction in the material's strength and durability [4]. Rice husk, also known as RH, has traditionally been regarded as an agricultural byproduct that is left over from the milling of rice. It refers to the covering that can be found on a seed or a grain of rice. RH is constructed from abrasive components, such as lignin and silica, in order to provide the seed with protection during the growth season. It has been discovered that rice husk, which is a type of agricultural waste, can improve the mechanical qualities as well as the durability of concrete. Rice husks are accessible in a variety of nations, and their chemical make-up can vary greatly from one to the next due to the fact that they contain up to 72% organic content among its individual components. These components include pentosan, cellulose, unripe fiber, lignin, free nitrogen juice, protein, and fat, along with 12–24% ash. And (3.5-12)% moisture [5]. Rice husk can be utilized in a variety of forms, including the husk itself as well as the silica that is obtained from the husk. Rice husk can be processed in a variety of ways, each of which results in the product possessing a unique set of physical and mechanical properties. These properties, in turn, influence the range of uses to which rice husk is suited. In general, the utilization of rice husk in a variety of various forms and through a variety of different processing procedures offers a wide range of possibilities for the development of novel materials that possess features that are unmatched in their own right. [6] The purpose of this study is to investigate the impacts that are imposed by RHF mixing on the properties of RPC. This has the potential to lead to new and sustainable solutions in industries such as building, agriculture, and manufacturing. We looked at both the slump and the compressive strength of the RHF-containing material. These characteristics were evaluated for the mixture that served as the reference.

2. Materials

OPC (Cem I 42.5R) has been employed in this investigation, the chemical and physical requirements are compatible with the Iraqi specification (IQS No. 5/2019) [7]. Fine aggregate has been employed in this study passed from 0.6 mm sieve, and comply with the Iraqi standard specification (IQS 45, 1984) [8]. The physical parameters and the strength activity index of the RPC mixtures created using silica fume as a mineral additive conform with the specification (ASTM C1240,2015) [9]. Silica fume was utilized as a mineral additive that was added to the RPC mixtures by replacing 10% by weight of cement. The water used in this investigation comply with the standard specification (IQS.No.1703/1992) [10]. Super plasticizer was added to the mixture to improve the workability while adding the fibers, the type of superplasticizer used were (Sika ViscoCrete 180 GS) with the dose (0.5 -1 %) liters per 100 Kg of cement which conform to (ASTM C494, 2005) [11]. Rice husk fibers from Al-Najaf in Iraq for reinforcement was used in this study as shown in Figure 1. The physical properties and chemical composition of the fibers used in this work are illustrated in Table 1 and Table 2.

Table 1. Physical features of RH [12]

Constituent	Specification
Colour	Straw or gold
Length	4 -5 mm
Hardness	6 (Mohs scale)
Bulk Density	700 kg/m³

Table 2. Chemical composition of RH [12]

Constituents	Percent by weight
H2O	2 - 11.5
Crude protein	7 – 11.5
Crude fat	0.5 – 3
Nitrogen	24.5 – 38.8
Crude fiber	31.5 - 50

Constituents	Percent by weight
Cellulose	34 – 45
Ash	15 – 30
Lignin	20 – 47.5
Silica in the ash	85 - 95

Figure 1. Rice Husk fibers used in this work

2. Experimental methods

2.1. Reactive powder concrete design

Rice husk fibers were used with a vol. fraction of 1% by volume of the concrete mixture, the dosage of super plasticizer used was 1 lit/100 kg of cement, and all of the mixtures contained 10% replacement of silica fume by weight of cement. These steps were taken in order to obtain RPC that had good properties. The design strength for RHRPC was set at 85 MPa, and rice husk fibers were used with a vol. fraction of 1% by volume of the mixture. The RPC for the mix design is summarized in Table 3.

Table 3. Particulars of RHRPC mix proportions in units of (kg/m³)

Mix type	OPC	FA	SF	Water weight	W/Cm	Fiber percentage
M0	720	950	80	185	0.23	-
M1	720	950	80	185	0.23	1%

2.2. Mixing process

The process of preparing concrete mixtures includes the following steps:

- All the dry material were mixed for (3 min).
- Water and super plasticizer were mixed separately then poured into the properly mixed dry materials and mixed for (5 min).
- For (2 min) while the concrete was revolving, fibers were sprinkled on top, and then it was mixed for another (5 min) to ensure the fiber is uniform distribution. So the total time for mixing is 15 min.

2.3. Curing of samples

After 24 hours of removing the samples from the molds, they are placed in ovens with different temperatures (60-120-200) C̊ for four hours within two days, after that the samples are placed in another oven to keep the temperature until the day of the test, and the optimum temperature that will give the highest strength is the one that will be adopted in the other tests as shown in Fig. 2.

Figure 2. RPC cubes while curin

3. Results and discussion

3.1. Flow test

Regarding the flow for RHRPC samples, the workability of the reactive powder concrete is carried out in accordance with (ASTM C-1437, 2015) [12]. The flow ability in the presence of rice husk fibers decreased from the reference mixture due to water absorbent property because it has high specific surface area and due to the pore structure of RH as shown in figure3, and the reasons for decrease complied with ref. [13,14].

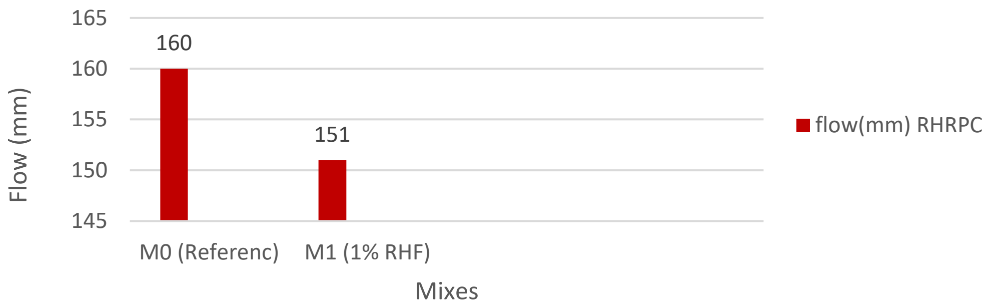

Figure 3.   Relationship between flow and Rice husk percentage for RHRPC

3.2. Compressive strength

Reactive powder concrete testing was carried out in accordance with (ASTM C 109/C 109M, 2016) [15]. The samples were tested after 7, 28 and 90 days at different temperatures (60, 120 and 200) C̊. When adding RHF at 1% by vol. to the concrete mixture compressive strength increased and more than the reference mixture as shown in figure 4 and 5, and when RH amount increased the compressive strength began to decrease this is due to the porosity and low density of RH and due to the presence of air gaps that reduce the density while reducing the compressive strength also the highest value of compressive strength was obtained when the temperature was 60 C̊.The results agree with the results of [16, 17,18].

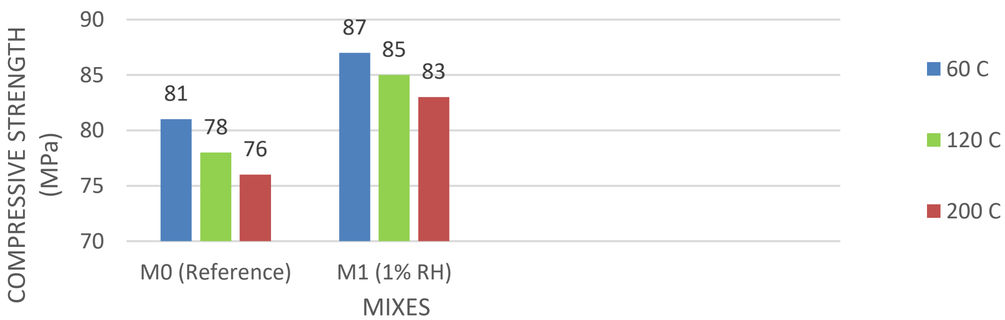

Figure 5. Compressive Strength of RPC at 28 days with curing temperatures

Figure 6. Testing of concrete sample

4.3. Dry bulk density

This test was carried out in accordance with (Iraqi Reference Guide 274, 192) [19], and the findings reveal that the dry density of the hardened test specimen, when 1% by vol. of RHF was added, was lower than that of the reference mixture at all three ages (7, 28, and 90 days), as depicted in Figure 7. Rice husk contains organic matter, which creates pores in the material; these pores increase the porosity of the material, reducing its bulk density; these reasons are in agreement with [20, 21]. This is as a result of the low specific gravity of RH, which led to the reduction in mass per unit volume of the mixtures; this was also caused by the pore structure of RH; and because rice husk contains organic matter, which created pores in the material.

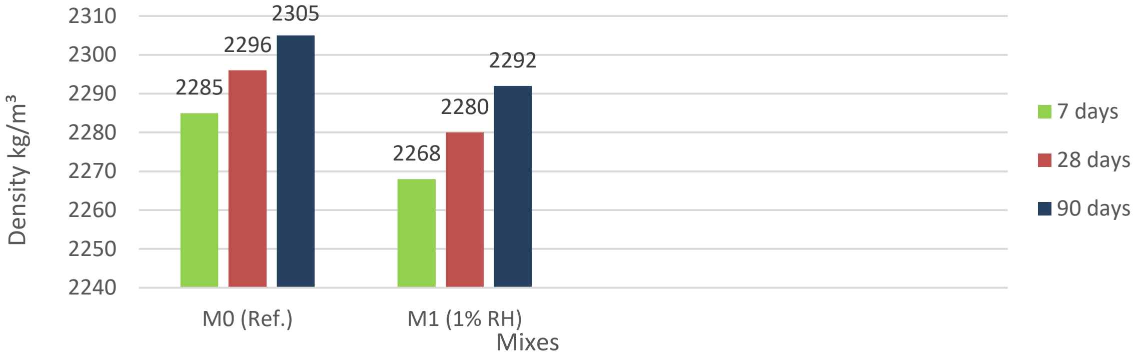

Figure 7. Relationship between the bulk densities with age for (RHRPC)

4. Conclusions

After carrying out the experiments in the laboratory and contrasting the outcomes of the reference RPC combination with those of the mixtures that contained 1% by volume of concrete Rice Husk fibers, it has been determined that the following is true:

- The workability of RPC had been found to be decreased when adding Rice Husk Fibers.
- The compressive strength of RPC increase when adding RHF by about (11.4%, 7.4% and 8.1%) for 7, 28 and 90 day respectively at curing temperature 60 C̊.
- • In comparison to the reference mixture and the values, the dry density of RPC has been shown to decrease with increasing age was (2268 kg/m³, 2280 kg/m³ and 2292 kg/m³) and the percent of decreased was (0.74%, 0.69% and 0.56%) for 7, 28 and 90 day.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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