The Manufacture of Fiber Cement Blocks Using Chemical and Thermomechanical Pulps and Rice Husk Ash

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Abstract. In this work, We made fiber cement blocks by using the raw materials of Cement, Rice husk ash, Fine aggregate, Fibers of Chemical pulps (CP) and Thermomechanical pulps (TMP). The replacement amount were zero (control), 5, 10, 15, 20 and 25%. In total 36 cement blocks with dimensions of 15 * 15 * 15 cm were made. The properties of blocks which were measured include compressive strength, water absorption, density of before and after soaking. The data Statistically analysed by Spss software. Statistical analysis showed that the type of fibers had significant effect on both mechanical and physical properties at confidence level of 0.05. Based on the findings of this work, The CP fibers had better effects on the compressive strength of specimens than The TMP fibers approximately twofold. Increasing the replacement level of TMP fibers tends to reduce the compressive strength due to the low binding ability. The water absorption and density values of specimens contain fibers were lower than control. The fibers cause lighter weight, resistance to cracking and a degree of flexibility.

Keywords: Chemical pulp · Ash · Block · Compressive strength · Water absorption

1 Introduction

Since many years ago, natural fibers have been used as reinforced inorganic materials and after finding hazardous effects of asbestos fibers on human health. New fibers with both economic and environmental benefits are being considered for applications in the most of industries [1]. The aims of fibers applications are to achieve desired properties and to reduce the cost of the products [2]. The use of lingocellulosic fibers have both advantages (Low density, Low cost, Low energy consumption, non-hazardous) and disadvantages (High moisture absorption and the low compatibility between fibre and cement) [1, 3]. In thermo mechanical pulping (TMP), Pressurized steam is applied before and during refining to raise the wood temperature to soften the lignin. The bonds between fibers to break gradually and fiber bundles, single fibers and fiber fragments to be released. But in the chemical pulping (CP) processes, the fibers are liberated from the wood matrix as the lignin is removed by dissolving it into the cooking chemical solution at a high temperature. However there are many differences both in quality and

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the cost between them. In general, chemical pulps are not only longer but they are much more flexible and have a nearly pure cellulose surface that forms strong bonds. The CP yield is low (40–70%) whereas TMP yield is high (90–98%). Also there has been a strong desire to use of recycled paper and agricultural residues such as rice husk as ash. Rice husk during milling process obtained from the outer covering of rice grains [4, 5]. When rice husk is burned between 500 and 700 °C amorphous silica is soluble and reactive in an alkaline solution [6, 7]. Two types of ashes (white and black) are produced during burning process [6]. The rice husk ash is a pozzolanic material which can to replace cement by up to 30% [4, 7]. Addition of fibers to concrete blocks imparts a number of attributes include resistance to cracking and a lighter weight [6] to reduce the cost of the final product [8]. The type of fibers that can be used as reinforcing agent in cement composites must be technically and economically acceptable [1, 2]. Moslemi (2008) has reported that due to a particular fibre's specific gravity, tensile strength and cost per unit weight Kraft pulp fibers are favour fibers in place of asbestos [2]. We demonstrated before 25 wt% replacement of wood fibre waste (WFW) and rice husk ash (RHA) have good physic-mechanical properties [3]. In this work has focused the effects of the type and amount of pulps on the concrete blocks properties.

2 Experimental Procedures

2.1 Materials

The fibrous raw materials for this study were thermomechanical pulp (TMP) and chemical pulp (CP) which were collected from fiberboard and paper companies called Royal and Latif. The ash of rice husk (RHA) was used as cement replacement and plays a pozzolanic role. Also calcium chloride (Ca cl2) was used as cement setting accelerator. Ordinary Portland Cement (OPC) a product of Khazar Cement Co. Iran that was employed as binder agent. Graded River Sand (GRS) was used as fine aggregate.

2.2 Mixing and Fabrication of Blocks

Mixture proportion of the raw materials are summarized in Table 1 for using each pulp seven different types of mixtures were prepared in the laboratory trails.

The amount of water was calculated for each block using the following Eq. (1) [9].

$$\text{Water amount(ml)} = 0.25 \times \text{cement weight(gr)} + 2.7 \times \text{fiber weight(gr)} \quad (1)$$

According to flow chart (Fig. 1) raw materials were placed in a concrete mixer and mixed for 3 min and then the dilute aqueous solution of $Cacl_2$ and water were added.

In order to obtain more homogeneous mixes, the paste was mixed for another 2 min. Consequently, the blended mortars were immediately fed into the steel moulds ($150 \times 150 \times 150$ mm^3). The cast moulds were vibrated for 1 min to achieve adequate compaction afterward, the cast specimens were covered with plastic to prevent water

Table 1. Mixture proportion of raw materials

Treatment code	TMP or CP (Wt %)	GRS (Wt %)	OPC (Wt %)	RHA (Wt %)
Control	0	50	25	25
A	5	45	25	25
B	10	40	25	25
C	15	35	25	25
D	20	30	25	25
E	25	25	25	25

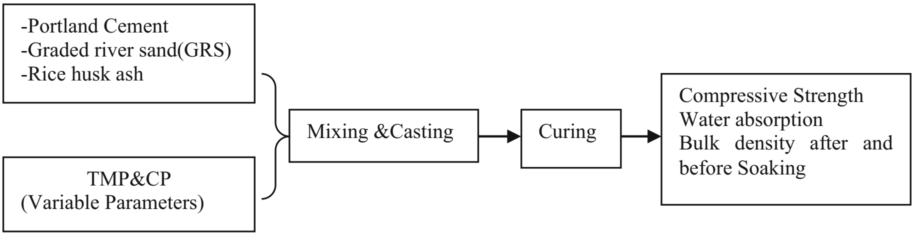

Fig. 1. Flow chart of concrete black fabrication and characterization

loss. After 24 h the blocks were decamped and conditioned for 28 days at 25 ± 1 °C and 65 ± 5%RH to allow the cement to cure and gain strength.

2.3 Tests Methods

The series of tests were carried out according to ASTM.C67 [10] to determine the compressive strength, water absorption and bulk density of the block samples.

2.3.1 Compressive Strength

The composite specimens were prepared in accordance with ASTM C109 [11]. Each compressive strength value reported is the average of three samples. The dry compression strength was determined using an Instron Universal Testing Machine (Model 4486) with a loading speed of 10 mm/min.

2.3.2 Water Absorption

Water absorption was carried out using ASTM.C642 [12]. The cube specimens for water absorption were completely submerged horizontally under distilled water maintained at 25 °C for 24 h. After soaking, the samples were drained on paper towels for 10 min to remove excess water. The water absorption was calculated from the increase in weight of the specimen during submersion. At least four specimens of every treatment were tested to obtain a reliable average and standard deviations.

2.3.3 Bulk Density

Specimens were tested following ASTM C642 for bulk density. The densities of the composites were determined by measuring the mass and volume of each sample. The air-dried samples were oven-dried up to 103 ± 2 °C until they reached constant weights. Then, the samples were cooled in a desiccators containing calcium chloride and weighed in an analytic balance with ±0.001 g sensitivity. The mass of each sample was obtained by calculating the arithmetic mean of the mass of all of the test samples. Afterward, the dimensions of the specimens were measured using a digital caliper with ±0.001 mm sensitivity and the volumes were determined by the stereo metric method. The density (D) was then calculated using the following Eq. (2).

$$D = \frac{Mo}{Vo} \tag{2}$$

Where Mo is the oven dry weight (g) and VO is the dry volume (cm^3) of the sample.

2.3.4 Data Analysis

Measured data on mechanical and physical properties of the composites were analysed with analysis of variance (ANOVA) procedure using Spss software (version13). Duncan's Multiple Range tests were used to compare the difference among the mean values for the groups properties at the level of 0.05.

3 Results and Discussion

The results of the mechanical and physical testes, with statistical analysis, are shown in Tables 2 and 3. All blocks made with different amount of the CP fibers had the highest values of the compressive strength than TMP fibers reinforcement. The unsatisfactory results in compressive behaviour were obtained in TMP fiber-cement blocks. Mostly depends on the formation of fiber-matrix, matrix-matrix and fiber-fiber bonds. The bonding can be affected by quantity and quality of fibers in given volume of materials [1, 13, 14]. In addition, pulping process can influence the mechanical and physical properties of the fiber-cement blocks. The TMP fibers creates a lack of homogenous mixture in the blocks than the CP fibers. There is not significant difference between the compressive strength of control and CP fiber blocks (P-value = 0.526, α = 0.05). The CP fibers are shown to be superior to the TMP fibers in increasing the compressive strength. The compressive strength of blocks content 5% of CP fibers were showed more strength (7.15 MPa) than control specimens (6.5 MPa). Statistical analysis showed that the compressive strength and Physical properties in terms of water absorption and density of the samples were influenced by the type of fibers (Fig. 2 and 3).

The experiment was arranged in a completely randomized design. Average values were compared by Tukey test at 5%. According to Analysis of Variance (Table 3) between three groups of the control, CP and TMP fibers there were significant difference at level of 0.05 on the mechanical and physical properties.

Table 2. Mechanical and physical properties of concrete blocks

Treatment Code	Compressive Strength (MPa)		Water Uptake (%)		Density before Soaking (gr/cm3)		Density after Soaking(gr/cm3)	
	TMP	CP	TMP	CP	TMP	CP	TMP	CP
Control	6.5 ±0.20	6.5±0.20	8.66±0.50	8.66±0.50	1.925±0.25	1.925±0.25	2.23±0.22	2.23±0.22
A	3.5 ±0.10	7.15±0.13	1.46±0.32	0.58±0.02	1.91±0.35	1.74 ±0.31	1.98 ±0.35	1.90±0.31
B	3.3 ±0.15	6.6±0.23	1.40±0.51	2.01±0.01	1.82±0.26	1.94 ±0.42	1.85±0.25	2.03±0.12
C	3.2±0.18	6.5±0.45	1.32±0.23	0.48±0.05	1.83±0.21	1.95 ±0.25	1.85±0.32	1.95 ±0.15
D	3.1±0.12	5.9±0.24	2.25±0.21	2.06±0.04	1.76 ±0.32	1.86 ±0.36	1.79±0.34	1.91±0.23
E	2.9±0.25	5.6 ±0.36	4.74±0.24	0.55±0.05	1.6 ±0.27	1.72 ±0.24	1.67±0.26	1.73±0.14

Table 3. Analysis of variance on some mechanical and physical properties

Properties		**SS**	**DF**	**MS**	**F value**	**P value**
Compressive Strength	Among groups	9301.949	2	4650.974	254.44	0.001
	Without groups	650.385	36	18.066		
	Total	9952.334	38			
Water Absorption	Among groups	410.588	2	205.294	64.155	0.001
	Without groups	115.198	36	3.200		
	Total	525.786		38		
Density before Soaking	Among groups	0.754	2	0.077	7.832	0.001
	Without groups	0.354	36	0.010		
	Total	0.508	38			
Density after Soaking	Among groups	0.508	2	0.254	24.439	0.001
	Without groups	0.374	36	0.010		
	Total	0.882	38			

SS= Sum of Squares DF= Degree of Freedom MS= Mean of Squares

All Samples made with CP and TMP fibers had the lowest values of water absorption among the other specimens (Fig. 2). Because two types of fibers to absorb water and to reach to fiber saturation point (FSP) in mixing process. Consequently after Soaking don't tend extra water. In relation to the density measurements before and after

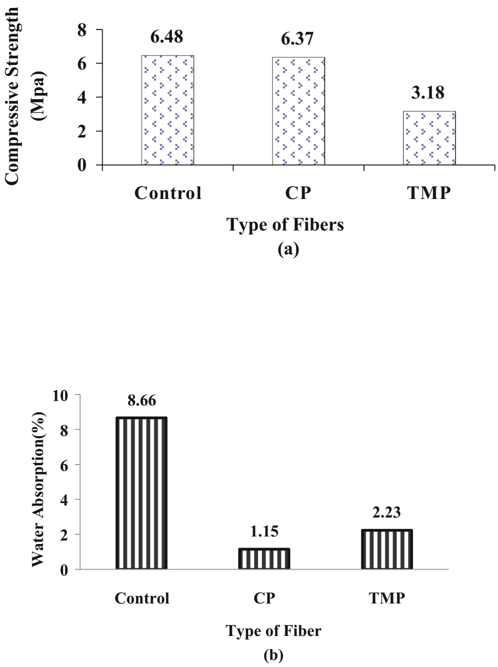

Fig. 2. Effect of Type of fibers on the (a) Compressive Strength and (b) Water Absorption

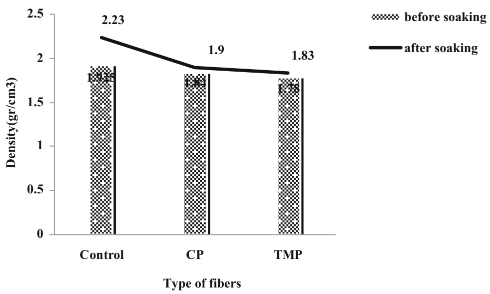

Fig. 3. Effect of Type of fibers on the bulk density before and after Soaking

soaking by replacing fibers the density of fiber-cement blocks were decreased gradually, similar results were reported by Torkaman et al. (2014). By replacing 15% CP fibers to made of fiber-cement blocks the best properties of the compressive strength and water absorption were obtained.

4 Conclusion

Based on the results of this research the following conclusion can be drown:

1. The CP fibers had best results in compare of control samples and TMP fibers on the mechanical and physical properties of the blocks.
2. There wasn't significant difference between different levels of both types of fibers on the compressive strength.
3. The optimum condition was obtained the CP fiber contents were 15% by weight.

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