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Study the Effect of Fiber Length on Mechanical Properties of Rock Fiber Reinforced Concrete

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Abstract

The effects of different Rock Fiber length on some fundamental mechanical properties of concrete are studied. Rock Fiber (RF) is a non-metallic, inorganic product manufactured using stone/rock. The effect of Rock Fiber length on mechanical concrete properties is observed. The results indicated that use of Rock Fibers has a significant effects on compressive strength and flexure strength of concrete. It was observed that the concrete mechanical properties improves with the increase in fiber length. The results show that the optimum ratio of Rock Fibers for improved the mechanical properties of concrete is 3%.

Keywords: Concrete, Rock Fiber, Compression Stress, Flexural Strength

1. INTRODUCTION

The most widely used building material is concrete due to its high compressive strength, corrosion resistance, and relatively lower cost. Concrete defects starts to appear as time passes which affect engineering applications. Concrete has been used in nuclear facilities constructions due to two main properties, its structural strength and its ability to protect against radiation. Concrete is used in nuclear and radiological facilities to protect the environment and contain the radiation to insure the safe operation of the facilities. Spent Nuclear Fuel (SNF) is stored in concrete structures, barrels and cellars for planned storage during a period up to 40 years. The physical and chemical environmental conditions will deteriorate the concrete structures in very short periods of time when exposed to. Cracking is a major and frequent problem with concrete used in nuclear power applications. Cracking causes moisture to penetrate into the concrete, which in turn leads to a gradual deterioration leads to the destruction of the reinforced concrete elements.

The increase in environmental concerns of society from radiation and radioactive materials needs the search for new alternative materials that can ensure the safety of the environment, the use of mineral and organic fiber reinforcement in cement compounds is one of these solutions. Many research work has also emerged looking to replace the raw materials of traditional structures by other materials with less environmental impact [1, 2], such as those that contain additives of fibers in the concrete matrix, which improves its a variety of fracture residences such as fracture energy, fracture durability and vital crack mouth opening displacement. Propagation of cracks in concrete can be controlled through the addition of fibers to bridge the motion throughout both micro and macro-cracking of the matrix [3].

Basalt Fibers (BF) have recently been used for reinforced concrete as one of the materials that ensures the safety of the environment and have good compatibility with concrete, because of its good resistance to exposure to high temperatures, chemical decomposition, high modulus of elasticity and low price. Aathithya [4] stated that Basalt Fibers have higher tensile strength than steel and are rust free because they are chemically inert. Some researchers [5, 6] reported that there is a significant improve in the flexural properties of concrete due to the introduction of BF. Branston et al. [7] found that cracks can be prevented by reducing the magnitude of free shrinkage, and by restricting the growth of cracks through the use of BF in concrete. Ayub et al. [8, 9] observed that BF reinforced HSC significantly enhance the splitting tensile strength and the critical stress intensity factor. Investigation of High et al. [10] on BF reinforced concrete revealed that BF addition in concrete significantly enhance its flexural modulus. Kabay [11] established a quite strong relationship between abrasive wear and void content and flexural strength of concretes when adding BF. Experimental study of Jiang et al. [12] showed that adding BF in concrete significantly improves the tensile strength, flexural strength and toughness index. Pehlivanlı et al. [13] studied BF reinforced lightweight autoclaved aerated concrete, and found that the inclusion of BF in autoclaved aerated concrete increases the flexural and compressive strengths. Julita et al. [14] reported a significant effect of Basalt Fibers on the cracking resistance. The moment of first crack appearance in the fiber reinforced beams occurred later than in the beam

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without fibers and it was related to their content. The increase in the amount of dispersed reinforcement caused the increase in value of cracking moment. Gaili et al. (15) the primary mechanisms of fiber reinforcement, including fiber tensile strength, bonding strength with matrix, and frictional strength, are relatively complicated and affected by several factors, such as fiber length, distribution interval, and volume fraction. Mészöly et al. [16] studied the coupled effect of fiber content and length on the mechanical properties of concrete. Kwan and Chu [17] analyzed the effect of fiber length on the mechanical properties of thermoplastic composites and found that material strength increases minimally with the increase in fiber length. The objective of this study was to investigate the compressive, flexural and impact ductility of chopped Rock Fiber reinforced lightweight concrete. The influence of the addition of Rock Fiber on the performance of concrete and the optimum content of Rock Fiber are also studied and discussed.

2. EXPERIMENTAL

2.1 Properties of the Used Materials

The properties of the materials used in this work which are; Cement, Fine aggregate, Coarse aggregate, and Rock Fiber are given below. All materials used are locally produced.

2.1.1 Cement

Ordinary Portland cement was used. Table 1 shows the chemical composition of cement.

2.1.2. Fine aggregate

Natural sand was used as fine aggregate in the concrete specimens. Table 2 presents the grading analysis of sand.

2.1.3. Coarse aggregate

Natural gravel is used in usual ordinary concrete. It is widely used as coarse aggregate because it possesses the ability to produce required sizes, ease of handling and satisfactory results obtained. Its analysis is presented in Table 3.

2.1.4. Rock Fiber

Rock Fiber used in this work is provided from a local factory "Egyptian Rock Fiber Factory", Cairo, Egypt. The chemical and physical specifications are given in Tables 4, 5 respectively. Two types of Rock Fibers of 0.5 mm and 2.3 mm length were used.

2.2. Mix Proportions

Seven concrete mixes with different weight ratios of RF were used in the current study. The proportions of the mixtures are presented in Table 6. The specimens of standard cubes (150 mm x150 mm x150 mm), special cubes (100 mm x100 mm x100 mm) and standard cylinders of (150 mm Diameter x300mm height) were casted.

2.4. Testing procedures

The fresh concrete workability was determined using the slump test. This was carried out on the fresh concrete, prior to making samples for the compressive and flexural tests. The compressive strength was assessed using 150mm cubes.

Table 1: The chemical analyses of Portland cement

Chemical Composition	Weight (%)
SiO2	23.69
Al2O3	5.63
Fe2O3	3.28
CaO	63.68
MgO	1.38
SO3	0.19
K2O	1.18

Table 2. Grading of sand

Sieve size, mm	0.125	0.25	1	2	4	5.6
Sand passing, %	0	6.07	78.87	96.36	98.99	100

Table 3. Grading of coarse aggregate

Sieve size, mm	2	4	5.6	8	11.2	16	22.4	32
Sand passing, %	0	0.25	3.63	22.01	47.92	61.61	99.05	100

Table 4: Chemical composition of RF

Chemical composition	
Sio_2	49.79 %
AlO_3	14.02 %
Fe_2O_3	10.23 %
MgO	5.25 %
Na_2O	1.83 %
K_2O	1.01 %
TiO_2	2.66 %

Table 5: Physical Properties of RF

Physical Properties	
Tensile strength,	4840 MPa
Elastic Modulus,	(85-89) GPa
Elongation at Break	3.15 %
Diameter,	6.5 µm
Length of fiber	0.5, 2.3 mm

Table 6: Mix proportions of all specimens.

Mix No	Cement	Fine Aggregate	Coarse Aggregate	RF length mm	RF Content (wt %)
1	350	656	583	———	———
2	349.125	656	583	0.5	0.25
3	348.25	656	583	0.5	0.5
4	346.5	656	583	0.5	1
5	339.5	656	583	0.5	3
6	339.5	656	583	2.3	3
7	329	656	583	2.3	6

The flexural strength of each mix was determined for 150 × 150 × 510 mm prisms. Mix with 0.5 mm length RF was tested at both 7 and 28 days. Mix with 2.3 mm length RF was tested at 7, 28 and 90 days.

3. RESULTS AND DISCUSSION

3.1. Slump Results

The slump test results obtained from the concrete mixes prepared with different ratios of RF content are given in Figure 1(a,b). Fig. 1a shows that the slump values of concrete with RF of 0.5 mm length (0.25, 0.5, 1, 3) %. It shows a gradual decrease with an increasing RF content by 0.25%, 0.40%, 0.50%, and 0.10 % respectively. Also, the slump values for concrete samples reinforcement RF with 2.3 mm length decreases by 0.20 and 0.35. These results can be attributed mainly to the differences in the water absorption ratios of the different ratio of RF in concrete samples. The reductions in the slump test results are attributed to the large surface area of the fibers. The large surface area negatively affects the new and rheological properties of the concrete, as a result of its spreading over a large area and impeding the movement of fresh concrete (18, 19).

3.2. Effect of Rock Fiber on compressive strength

Fig. 2 shows the mean values of compressive strength. The RF reinforced concrete samples exhibited a reduction in the compressive strength compared to the reference blank sample. Fig. 2 a shows that compressive strength for different ratios of RF (0.5 mm) decreases for (0.25, 0.5, 3) % fiber weight and gradually increases for 1% at both 7 days and 28 days. In this case, it showed to be an optimum RF content at approximately 0.1%, which provided increases of 1.1% (7 days) and 1.2% (28 days) over the blank samples. The compressive strength decreased due to the Basalt Fibers that create a "defect zone" in the cement paste, due to the lower specific gravity and density of the fibers than the cement paste, so that the fibers produce higher deformations under pressure than the cement paste in the concrete matrix (20).The compressive strength results for RF 2.3 mm length at the age of 7, 28 and 90 days are shown in fig. 2b. At the age of 28 and 90 days the compressive strength of 3% RF sample increases compared to blank samples.

3.3 Effect of Rock Fiber on tensile flexural behavior

The mean values of flexural strength are presented in Fig. 3. The flexural strength depends on the addition of Rock Fibers ratio and length. Fig. 3a shows a slight decrease, for all concrete samples with Rock Fiber except for 1% RF sample which increases 1.02% compared to blank sample. Fig.3b shows slightly increase in the flexural strength results for Rock Fiber at 7, 28, and 90 days. The highest value of flexural tensile test is obtained for the concrete sample with 0.3% RF. Comparing with the control sample, the flexural tensile test results for the samples with 0.3% RF are increased by about 4% and 2.5% for 6% RF. These results are due to the Rock Fiber particles, which filled the presence voids in the concrete matrix, resulting in a dense microstructure and a relatively impermeable compound, thus enhancing the pozzolanic properties of the cement and improving the strength of the concrete (21-23). From the results the hydration and pozzolanic reaction of Rock Fiber is similar to Basalt Fibers behavior (22).

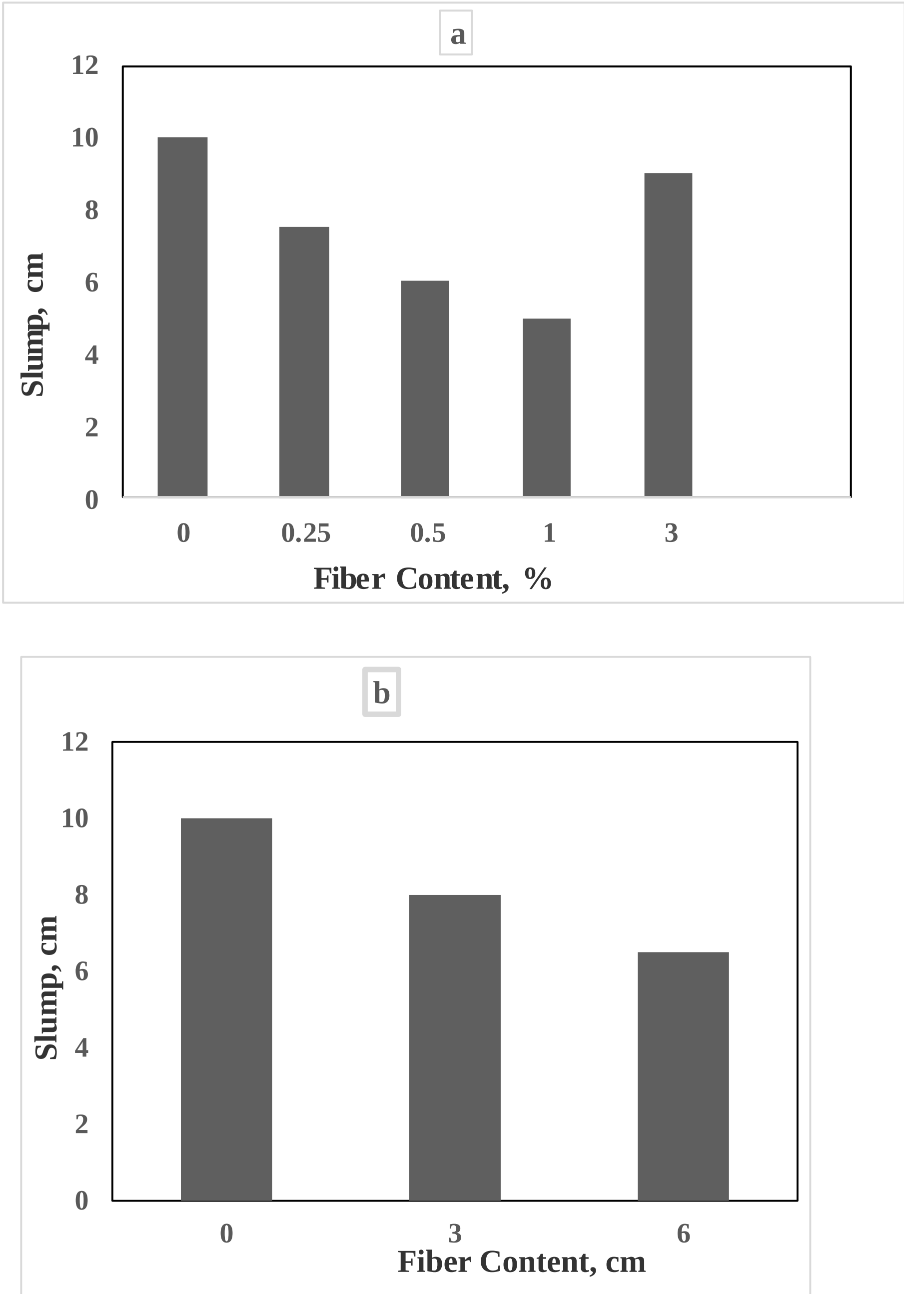
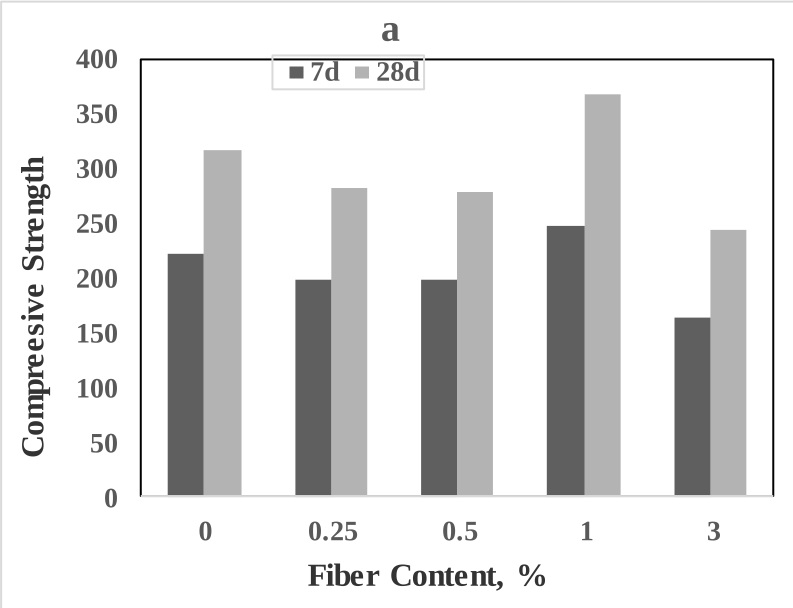


Fig. 1. Slump test of concrete samples with different RF length: (a) 0.5mm; (b) 2.3mm



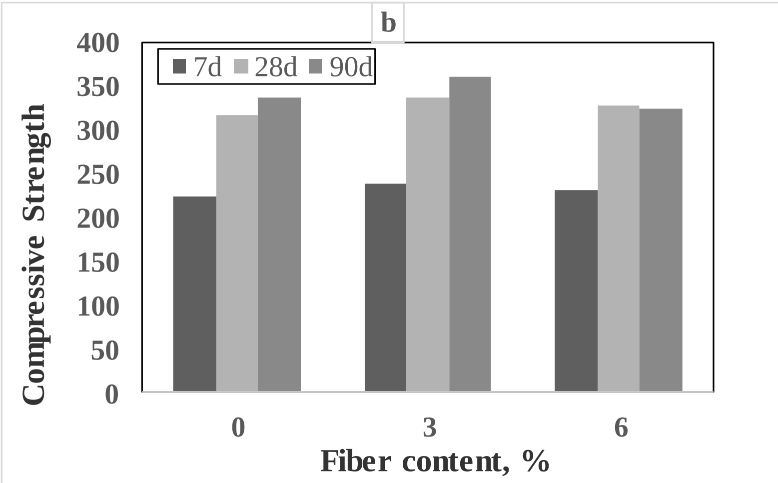
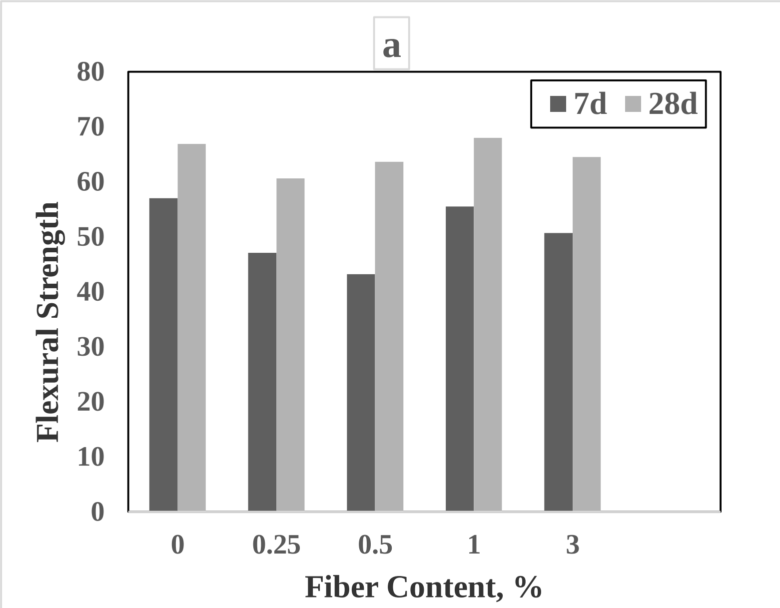


Fig. 2. Compressive strength of concrete samples with different RF length: (a) 0.5mm; (b) 2.3mm

4. CONCLUSION

The aim of this study is to investigate the effects of Rock Fiber on the mechanical properties of lightweight concrete. Two types of Rock Fiber with different lengths (0.5, 2.3) mm are used to study the variation on mechanical properties of concrete samples. The main conclusions of this study are as follows:

- The slump values of concrete mixes decreases gradually with the increase of RF content for the all samples. The concrete sample with 1% RF (0.5mm) has the lowest value, while the sample with 3% RF (2.3) has the highest value.
- The compressive strength was affected to different extents by the fiber type. The addition of RFs to the concrete slightly decreases the compressive strength up to ratio 1% of fiber. The compressive strength of samples aged for 90 days was higher than that of the other concrete mixes due to the pozzolanic activity of Rock Fiber particles.
- The flexural strength values of the concrete specimens decrease gradually with the increase in the ratio of RF from 0 to 0.5% for fiber of 0.5 mm length. The high flexural strength values was observed for samples with 2.3 mm length fiber aged for 90 days
- The fiber length are important factors that greatly affect the mechanical properties for concrete.



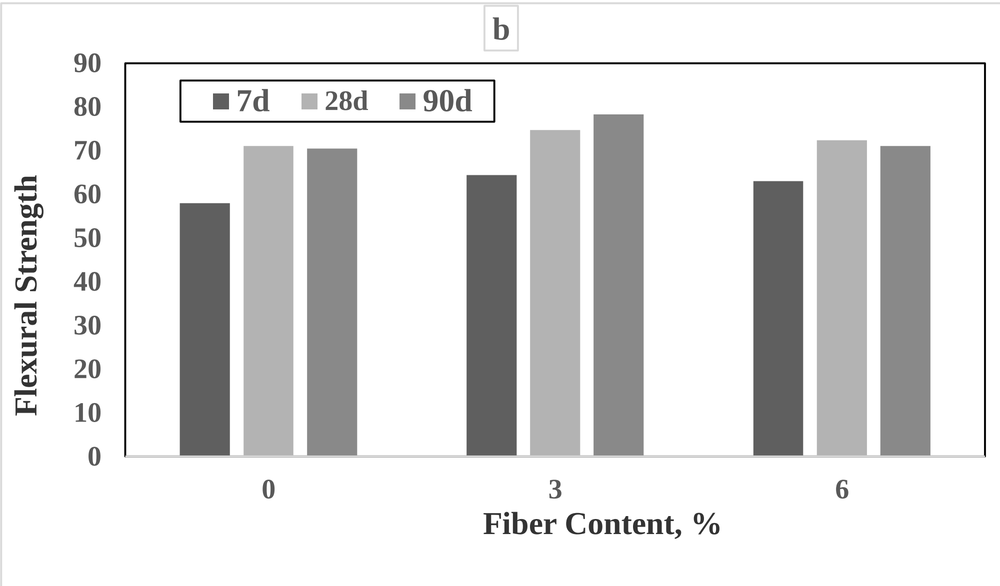


Fig. 3. Flexure strength of concrete samples with different RF length: (a) 0.5mm; (b) 2.3mm

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