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Experimental Study of Hybrid Concrete

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Abstract--Since ancient time, fiber reinforced concrete has been replaced with plain concrete which is brittle material. Although, the inclusion of single type fiber may improve mechanical properties of concrete, the hybridization can compensate the disadvantages of two fiber types and represent their advantages. The effect of using steel fiber and polypropylene fiber for reinforcing the concrete to quantify the mechanical properties of concrete matrix. For this purpose, specimens of fiber reinforced concrete which contains different fibers dosage were casted. All mixes were tested on 28 days of curing, compressive strength, and flexural strength. According to the test results, the regression analysis was carried out to predict the value of compressive strength and flexural strength. The experimental results show that the hybrid form of fiber has slight effect on compressive values, while it causes increase in modulus of rupture, toughness and impact resistance values.
Keywords--Fibers, hybrid fiber reinforced concrete, compressive strength, flexural test and polypropylene fiber.

I. INTRODUCTION

Concrete is the most widely used construction material which is characterized by its low tensile strength and strain capacity. Historically, reinforcement in the form of iron rods were used initially, while continuous steel reinforcing bars and stirrups which improve one or more properties of concrete for a number of structural systems are used at present time.

Generally, "FRC can be regarded as a composite material with two or more phases in which concrete represents the matrix phase and the fiber constitutes the inclusion phase." Composite material consist of two or more components with different molecular level, mixed purposefully result in new material with new properties in comparison with 2 single component. Moreover, reinforcement of concrete with two or more types of fiber referred to the concept of hybridization. Therefore, the presence of one fiber provide a suitable condition for other fiber to use its potential properties.

Generally, fibers have different classification based on elastic modulus and origin of the material. Some of them have low modulus and some others have high modulus in comparison with cement matrix. Polypropylene, nylon, and cellulose are in first category, while steel, glass, carbon and asbestos belong to the second one. These days, the applications of FRC are as varied as the types of fibers which are produced in various forms, bars, cables and different cross section, stirrups, sheets, channels and angles. Since concrete is a complex material, a single type of fiber may affect properties to a limited level of fiber reinforced concrete. In order to overcome most weaknesses of concrete, the concept of hybridization which implies using two or more different types of fibers can eliminate concrete deficiency and present a synergetic response.

II. OBJECTIVES

The objective of this research is to evaluate and compare the mechanical properties of FRC with the use of hybrid fibers compared to single type fiber composites. The compressive strength and flexural strength were examined of various FRCs. Research results provide recommendation for fiber volume fraction to achieve a highly workable fiber reinforced concrete having high performance in compressive and flexural strength as well as impact resistance.

III. MATERIAL AND METHODOLOGY

A. Materials

The properties of materials used in this research were obtained from local sources and are as follows.

1) Cement: The cement used in all concrete mix was a Portland Cement Type II. The type of cement is important for the water requirement and workability of concrete mix.

2) Aggregate: Since, aggregates occupy the volume of concrete, their size, shape and surface have significant impact on fresh and hardened properties of concrete.

In present research, the crushed limestone was used as aggregates which were extracted from Beşparmak Mountains (Cyprus). The aggregates were carefully sieved and meet ASTM C33 grading requirements. The maximum sizes of aggregates were 20 mm, 14 mm, 10 mm, and 5 mm.

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a) Fine Aggregate: Fine aggregate shall consist of natural or other inert materials with similar characteristics which combines the hard, strong and durable particles. In this research, fine sand passing through sieve 5 mm and retained on sieve 0.075 mm was used as fine aggregate.

b) Coarse Aggregate: The coarse aggregate used for concrete mix passing through sieve 20 mm and retained over sieve 5 mm. The maximum size is 20 mm with irregular shape and saturated surface dry condition.

3) Silica Fume: The silica fume used in this study was produced from silicon metal and ferrosilicon alloys which increased the concrete properties, both in the fresh and hardened state.

4) Water: In concrete mix, the water has significant impact on development of cement hydration. As Na jin indicated, the addition of too much water causes higher prosperity and lower strength result from the increased distance between particles. As Wanielista et al claimed, "The correct amount of water will maximize the strength without compromising the permeability characteristics of the pervious concrete."

In present research, the water used in all mixes was local tap drinking water of Northern Cyprus. The determined required water-cement ratio used for this study was 0.5.

5) Reinforcement: As Bentur et.al. claimed, "the efficiency of fiber reinforcement can be judged on the basis of two criteria: the enhancement in strength, and the enhancement in toughness of the composite, compared with the brittle matrix."

In order to investigate the influence of various fibers and their volume fractions in concrete matrix, two types of fiber "steel fiber" and "polypropylene fiber", were used. According to the purpose of present research, the optimum mix design achieved by Eren et al which was taken as reference for concrete mixes.

B. Casting and Curing

According to the goal of this study and related tests, the following specimens were cast from each mix:

For compression test three moulds were made of size 150 X 150 X 150 mm cubes.

For evaluation of flexural test: one 150 × 150 × 600 mm beam.

IV. RESULTS AND ANALYSIS

A. Analysis of Compressive Strength

According to the test results, it is obvious that the addition of polypropylene fiber at very low volume percentage, has slight effect on compressive strength. The inclusion of polypropylene fiber, if it is clustered, will caused low workability and initial defect in concrete resulting in reduction of compressive strength. Also, this reduction attributed to air voids, compaction and consolidation problems. At the end, the HyFRC has lower compressive strength value than single type fiber reinforced concrete resulting from reduction in volume fraction of effective fiber which is steel one. So by increasing polypropylene fiber and decreasing steel fiber volume fraction, compressive strength decrease as well. The maximum compressive strength obtained is 50.23 MPa for 1.5% steel fiber while a decrease in strength value was observed in hybrid composite

Table 1. Compressive Strength values at 28 days of age.

Mix designation	Volume fraction %	CONPRESSIVE STRENGTH ON 28 days age (MPa)			AVE (MPa)
Steel fiber reinforced concrete (SFRC)	1.500	49.90	50.80	50.00	50.23
PP fiber reinforced concrete (PPFRC)	0.150	38.80	37.70	35.80	36.95
(50% of 1.5 Steel fiber + 50% of 0.15 PP) FRC	0.825	28.90	32.30	30.10	30.43
(30% of 1.5 Steel fiber + 70%of 0.15PP) FRC	0.555	23.80	26.60	25.60	25.38
(20% of 1.5 Steel fiber+ 80% of 0.15 PP) FRC	0.420	22.00	20.70	21.30	21.33
(10% of 1.5 Steel fiber+ 90% of 0.15 PP) FRC	0.285	19.20	20.80	21.30	20.43

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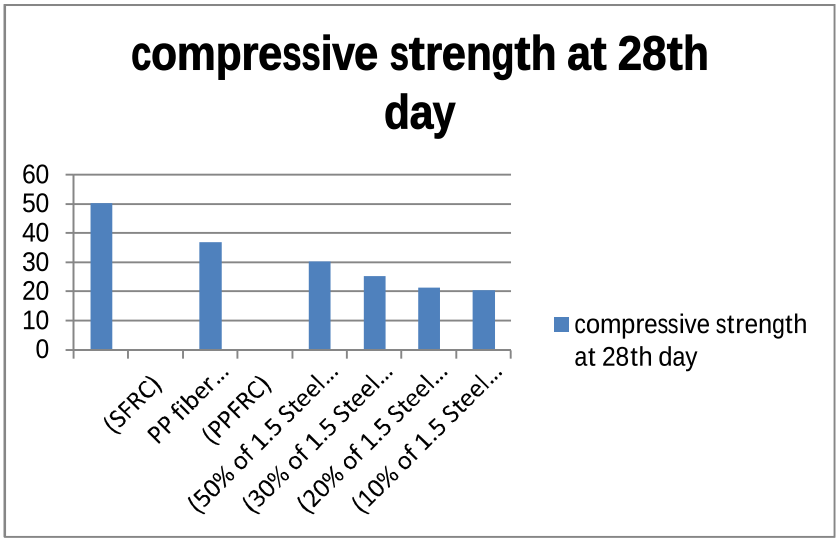
Graph 1. Compressive Strength on 28th day of curing



B. Analysis of Flexural Strength

The results reported in Table. 5 are showing the flexural strength values. In a broad view from Figure. 14, the highest flexural strength was obtained in HyFRC with 0.825% volume fraction of both steel and polypropylene fiber and the lowest value was obtained in SFRC with 1.5% steel fiber volume fraction. However, the fiber volume fraction of SFRC is 10 times greater than fiber volume fraction in PPFRC composite. This is a result from the ability of polypropylene to enhance the load bearing capacity in the post-cracking zone. In case of hybridization, the presence of steel fiber which is stronger and stiffer improves the first crack stress and presence of polypropylene which is smaller can bridge the stress and control the crack growth leading to better function in concrete composite compared to presence of single type fiber.

Table2. Flexural strength test results.

Mix designation	Volume Fraction (%)	*CONPRESSIVE STRENGTH ON 28 days age (MPa)*			Flexural Strength (MOR) MPa
Steel fiber reinforced concrete (SFRC)	1.500	2.583	3.23	2.65	2.82
PP fiber reinforced concrete (PPFRC)	0.150	3.67	4.21	4.34	4.07
(50% of 1.5 Steel fiber + 50% of 0.15 PP) FRC	0.340	3.23	2.30	3.10	2.876
(30% of 1.5 Steel fiber + 70%of 0.15PP) FRC	0.825	4.96	5.75	5.34	5.35
(20% of 1.5 Steel fiber+ 80% of 0.15 PP) FRC	0.555	3.65	3.58	4.35	3.85
(10% of 1.5 Steel fiber+ 90% of 0.15 PP) FRC	0.420	4.86	4.12	4.02	4.33

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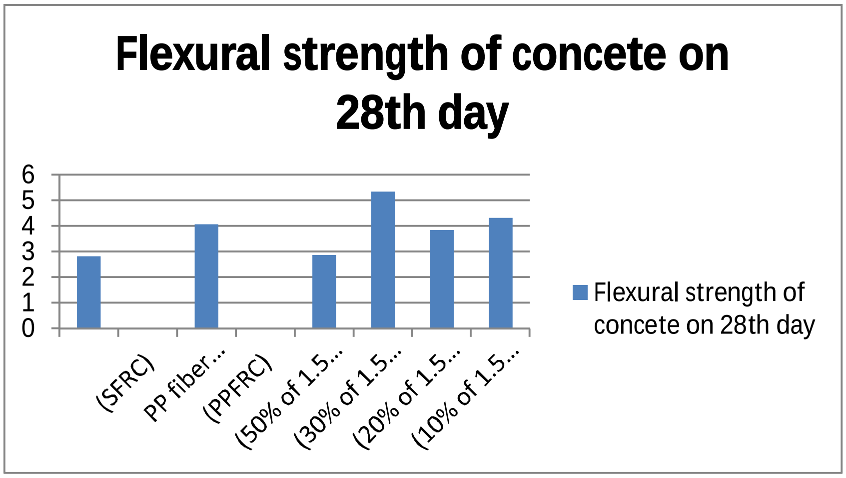
Graph 2. Flexural Strength of concrete on 28th day of curing



V. CONCLUSION

Based upon the obtained results, the following conclusion and recommendation are derived.

In general, the addition of fibers with different types and various amounts are achieved the desired improvements in mechanical behavior of reinforced concrete. For the compressive strength, the better result was taken form single type fiber which is cased sufficient bond to material resulting in sufficient transfer of stress. So, the high volume percentage fibers has significant effect on compressive strength compered to low volume percentage. Therefore, in this case, the HyFRC with lower volume fraction of fibers than volume fraction steel fiber in SFRC has less compressive strength. From the flexural test results, it has been concluded that the type and volume percentage of fiber have direct effect on MOR. Because in presence of fiber which is stronger result in improving the first crack strength. On the other hand, fibers with small size has better function in controlling the crack growth. Therefore, the HyFRC include 0.825% fiber volume fraction has highest MOR which is because of inclusion of steel fiber which is strong and inclusion of polypropylene which is 43 small. Therefore, in case of hybrid matrix, it can be concluded that the obtained results are sensitive, not only to amount of fiber, but also types of fiber used for reinforcing the composites.

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