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Mechanical Behavior of Concrete Containing One Type and Hybrid Fibers

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ABSTRACT

This research work studies the effect of the addition glass and Polypropylene hybrid fibers on concrete properties. Straight glass fibers (GF) with 14 mm length 0.013mm diameter, and Polypropylene fibers (PF) with 12mm length and 0.018mm diameter were used. Each type was used separate by 0.2, 0.4 and 0.6% form cement content to produce six mixes. Three mixes were produced with the combination of glass and polypropylene fibers by (0.1%+0.1%), (0.2%+0.2%), and (0.3%+0.3%) form cement content. The last one is control mix without fibers. Beams ware used for flexural test. The depth of fibers mix in beams were taken one-third, two-third. and full from the total beams depth. The experimental program was carried out to cover the various properties of fresh and hardened concrete. Ten design mixes with different content of fibers were needed for the parametric study. Finally, the experimental results show that using hybrid fibers with concrete are increased the properties of concrete (Compressive strength, split tensile strength, and flexural strength) and depending on the fibers ratio used compared to control mix. The increasing of fibers content is improved the properties of concrete. The difference between flexural strength for the three fibers depth is small, so the one-third fibers content mix is the economic. The improvement on the properties of concrete due to polypropylene fibers is greater than glass fibers.

1. Introduction

Although concrete is the most utilized building material on earth, this material has a large short coming. It has a good resistance against compressive stresses. The steel reinforcement in concrete structures is solved the low resistance of concrete tensile strength . Other possibility is the application of different types of fibers in the concrete which mean getting reinforced concrete with different types of reinforcement by adding glass or polypropylene or carbon or steel fibers to concrete then, this new material is called “Hybrid Concrete”. Hybrid concrete has increased attention by researchers in recent years due to their unique properties and superior performance compared to plain concrete. The expression “Hybrid” refers to the “hybridization” of glass and polypropylene fibers in plain concrete [1-8].

Funke, Gelbrich, and Ehrlich [9] studied the combination of textile reinforced concrete (TRC) and glass-fiber reinforced plastic (GFRP) to develop a new high-performance hybrid material. The new hybrid material which contained with the both materials had high strength, durability, surface

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quality and cost-efficient production. For the composite of GFRP and TRC the integration of an interlayer for the mechanical and thermal decoupling was indispensable. The new GFRP-TRC-hybrid material has a tensile strength of 165 MPa and a density of 1.65 g/cm. Fu, Lauke, and others studied the tensile properties of short-glass-fiber- and short-carbon-fiber-reinforced polypropylene composites and observed that the tensile failure strain of the composites decreased with the increase of fiber volume fraction [10].

2. Materials and Methods

2.1. Materials

In this experimental research glass fibers and polypropylene fibers were used with concrete content. Properties of materials used are shown in table 1,2, and 3. Figure 1 is shown the shape of fibers.

Table 1: Properties of Coarse Aggregate (Basalt) and Sand

Property	Basalt	Sand
Specific Gravity	2.55	2.5
Bulk Density (t/m^3)	1.53	1.73
Max Aggregate Size (mm)	9.5	
Absorption %	0.2	-

Table 2: Properties of Glass and Polypropylene Fibers

Type of Fiber	Shape of Fiber	Length l (mm)	Diameter d (mm)	Aspect Ratio l/d	Density (Kg/m^3)
Glass	Straight	14	0.013	1077	2700
Polypropylene	Straight	12	0.018	666	910

Table 3: Technical Data (at 25°C) for Super plasticizer ADDICRETE BVS 100

Base	Qualified poly Carboxylate
Appearance	Brown liquid
Specific Gravity	1.175 ± 0.02
Percentage of Solid Materials	42.5% ± 2%
Compatibility	All types of Portland cement

2.2. Concrete Mix Proportions, Samples, and Experimental Program

Ten mixes of concrete were produced to cast a series of test specimens divided from mix M1 to mix M10 as shown in Table 4. M1 plain concrete, M2 contain 0.2% glass fibers, M3 contain 0.4% glass fibers, M4 mix contain 0.6% glass fibers, M5 contain 0.2% polypropylene fibers, M6 contain 0.4% polypropylene fibers, M7 contain 0.6% polypropylene fibers, M8 contain 0.1% glass fibers and 0.1% polypropylene fibers, M9 contain 0.2% glass fibers and 0.2% polypropylene fibers, and M10 contain 0.3% glass fibers and 0.3% polypropylene fibers. For each mix, 6 cubes of 100*100*100 mm dimensions and 3 cylinders of 100*200 mm dimensions were cast. 9 beams of 150*150*750 mm dimensions were, also, cast. Three of them contain a complete fibers mix with height 150mm, another three contain 100 mm fibers mix plus 50 mm plain concrete, and another three contain 50 mm fibers mix plus 100 mm plain concrete as shown figure 2.

Figure 1: Glass and Polypropylene Fibers

Table 4: Mix Proportions of Concrete Mixes

Mix	Water	Cement	Fine Agg.	Coarse Agg.	Super plasticizer	Fiber/ Cement (%)	
	(kg/m^3)					GF	PF
M1	202.5	450	722	903	4.50	0	0
M2	202.5	450	722	903	4.50	0.2	0
M3	202.5	450	722	903	4.50	0.4	0
M4	202.5	450	722	903	4.50	0.6	0
M5	202.5	450	722	903	4.50	0	0.2
M6	202.5	450	722	903	4.50	0	0.4
M7	202.5	450	722	903	4.50	0	0.6
M8	202.5	450	722	903	4.50	0.1	0.1
M9	202.5	450	722	903	4.50	0.2	0.2
M10	202.5	450	722	903	4.50	0.3	0.3

2.3. Experimental Tests

The slump test is used to measure fresh concrete consistency. The loading rates for the machine applied in the compression and splitting tensile tests were 0.6 and 0.03 $N/mm^2/sec$ respectively. Compressive strength was measured at the ages of 7 and 28 days while the splitting tensile and flexural strengths were measured only at 28 days. The loading rate applied for flexural test was 0.06 N/mm2/sec, as shown in figure 2 (according to Egyptian Code, Tests Guide for Concrete Materials 2003). The average results of three specimens were calculated

3. Results and Discussion

Results of slump test, density, compressive strength, splitting tensile strength, and flexural strength for ten mixes of concrete were shown in table 5.

3.1. Slump

Slump for all mixes are presented in table 5 and

figure 3. It observed that increasing the fiber volume percentage d

minimum slump value reaches 50 mm in M7 and M10. The workability of mixes with glass fibers is better than others fibers mix.

3.2. Density

The density of concrete for ten mixes is presented in table 5. It observed that density values rang is between 2430 and 2500 t\m^3.

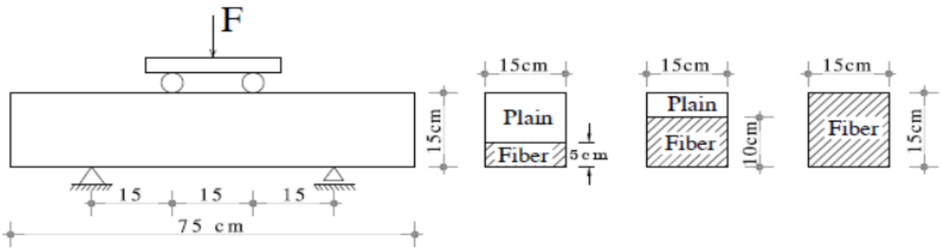

Figure 2: Shape of Beam for Flexural Strength Test

Table 5: Results of Slump, Density, Compressive Strength, Split Tensile Strength and Flexural Strength Tests

Mix No.	% Fibers		Slump (mm)	Density (Kg/m3)	Compressive Strength at 7 days (kg/cm2)	Compressive Strength at 28 days (kg/cm2)	Splitting Tensile Strength at 28 days (kg/cm2)	Flexural Strength at 28 days (kg/cm^2) Fibers Height (mm)		
	GF	PF						150	100	50
M1	0	0	210	2460	270	367	35	57.4		
M2	0.2	0	180	2470	279	391	43	78.5	75.6	68.5
M3	0.4	0	110	2500	295	415	44	82.7	77.6	70.0
M4	0.6	0	60	2500	356	436	45	86.4	79.6	73.0
M5	0	0.2	110	2480	324	464	44	77.0	72.0	68.5
M6	0	0.4	90	2500	366	481	45	81.5	77.0	69.0
M7	0	0.6	50	2550	373	499	51	84.0	80.0	74.0
M8	0.1	0.1	130	2500	367	466	42	87.0	78.5	77.0
M9	0.2	0.2	80	2470	275	402	43	82.7	75.6	74.0
M10	0.3	0.3	50	2430	271	382	45	78.5	74.6	73.0

3.3. Compressive Strength

The compressive strength test results for ten mixes at 7 days with different types of fibers are presented in table 5 and figure 4. It observed that compressive strength at 7 days for all mixes are higher than plain concrete mix. The maximum compressive strength is reached 373 kg/cm^2 in the mix M7 of 0.6% polypropylene fibers.

The results of compressive strength test for ten mixes at 28 days with different types of fibers are presented in table 5 and figure 5. It observed that compressive strength for all mixes at 28 days are higher than plain concrete mix. The maximum compressive strength is reached 464, 481, 499 kg/cm^2 for mixes M5, M6, and M7 of 0.2, 0.4, and 0.6% polypropylene fibers because of the elastic modulus of polypropylene fiber is higher than elastic modulus of glass fiber. It was observed that the compressive strength of the composites (PF and GF) decreased with the increase of fiber volume fraction due to decrease the fiber efficiency factors [10].

Relation between compressive strength at 28 days and compressive strength at 7 days for ten mixes with different types of fibers is shown in Figure 6. It observed that:

f_{cu} at7 days ≈ 0.7397 f_{cu} at 28 day

Where f_{cu} is compressive strength

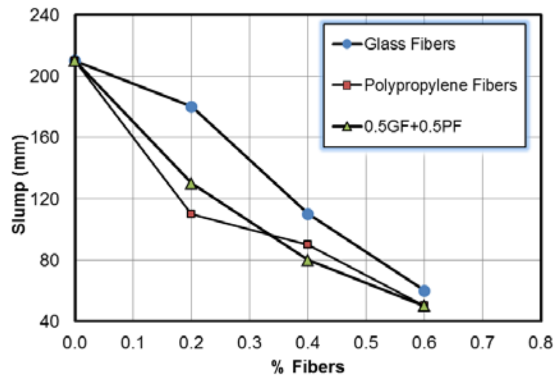

Figure 3: Relation between Fibers Content and Slump for Different Types Fibers

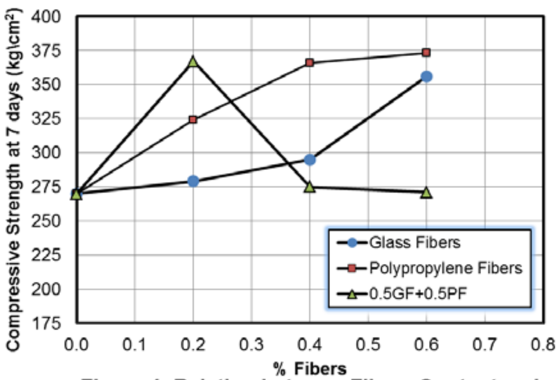

Figure 4: Relation between Fibers Content and Compressive Strength at 7 days for Different Types Fibers

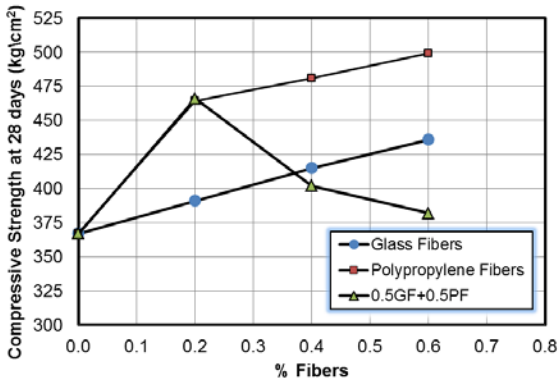

Figure 5: Relation between Fibers Content and Compressive Strength at 28 days for Different Types Fibers

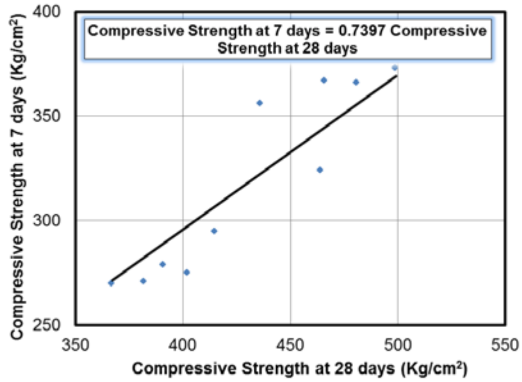

Figure 6: Relation between Compressive Strength at 7 days and 28 days for Fibers Concrete

3.4. Splitting Tensile Strength

The splitting tensile strength test results for ten mixes at 28 days with different types of fibers are presented in table 5 and figure 8. It observed that splitting tensile strength for all mixes are higher than plain concrete mix because of the higher number of fibres bridging the cracks and restraining the extension of cracks. The maximum splitting tensile strength is reached 44, 45, 51 kg/cm^2 for mixes M5, M6, and M7 of 0.2, 0.4, and 0.6% polypropylene fibers due to the elastic modulus of polypropylene fiber is higher than elastic modulus of glass fiber. Relation between splitting tensile strength and compressive strength for ten mixes is shown in Figure 8. It observed that:

f_t at 28 day ≈ 0.1011 f_{cu} at 28 day

Where f_t is splitting tensile strength

3.5. Flexural Strength

The results of flexural strength test for ten mixes at 28 days are presented in table 5 Figure 9 to 11. It observed that flexural strength for all mixes are higher than plain concrete mix due to restrain the extension of cracks by fibers. The maximum flexural strength for full fibers mix is reached 87.0 kg/cm^2 for mix M8 with 0.1% polypropylene and 0.1% glass fibers. The maximum flexural strength for two-third fibers mix is reached 80.0 kg/cm^2 for mix M7 with 0.6% polypropylene fibers. The maximum flexural strength for one-third fibers mix is reached 77.0 kg/cm^2 for mix M8 with 0.1% polypropylene and 0.1% glass fibers. It was found that the flexural strength of the composites (PF and GF) decreased with the increase of fiber volume fraction due to decrease the fiber efficiency factors [10]. Relation between flexural strength and compressive strength for ten mixes with different types of fibers is shown in Figure 12. It observed that:

-f_{fl} (Full Fibers Mix) ≈ 0.1841 f_{cu} at 28 day

-f_{fl} (Tow-Third Fibers Mix) ≈ 0.1729 f_{cu} at 28 day

-f_{fl} (One-Third Fibers Mix) ≈ 0.1626 f_{cu} at 28 day

Where f_{fl} is flexural strength

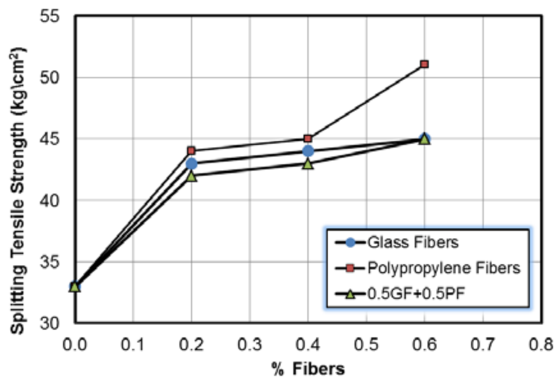

Figure 7: Relation between Fibers Content and Splitting Tensile Strength at 28 days for Different Types Fibers

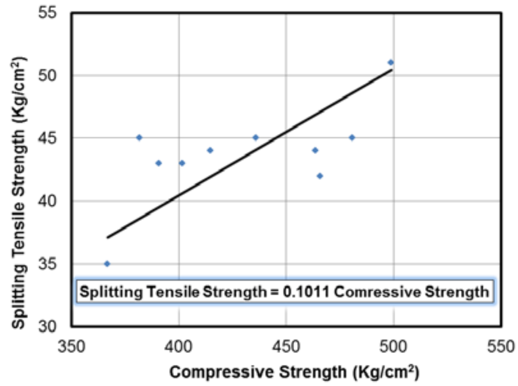

Figure 8: Relation between Compressive Strength and Splitting Tensile Strength for Fibers Concrete

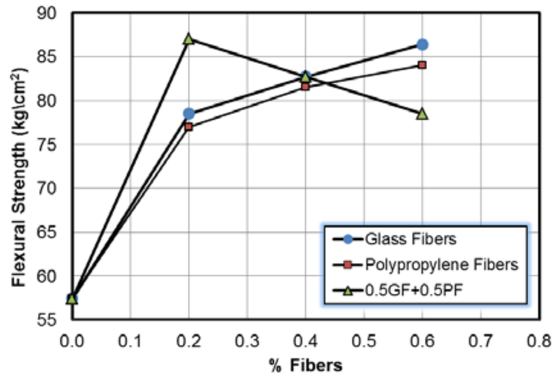

Figure 9: Relation between Fibers Content and Flexural Strength (Full Fibers Mix) at 28 days for Different Types Fibers

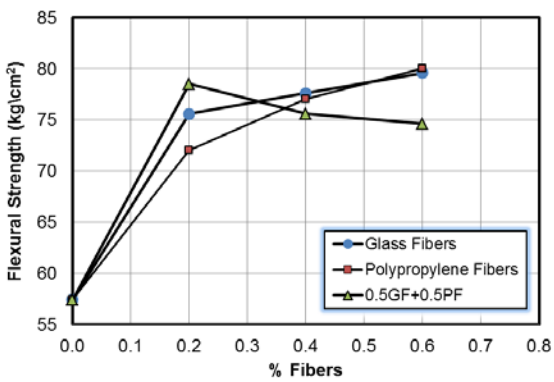

Figure 10: Relation between Fibers Content and Flexural Strength (Tow-Third Fibers Mix) at 28 days for Different Types Fibers

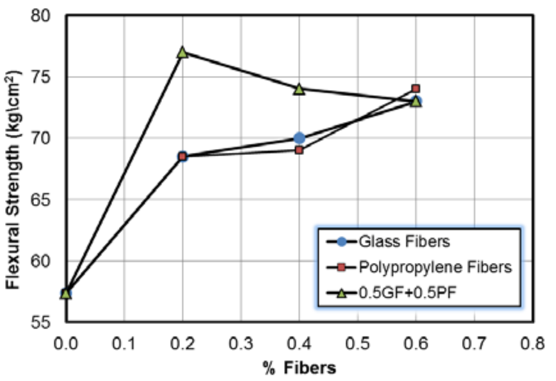

Figure 11: Relation between Fibers Content and Flexural Strength (One-Third Fibers Mix) at 28 days for Different Types Fibers

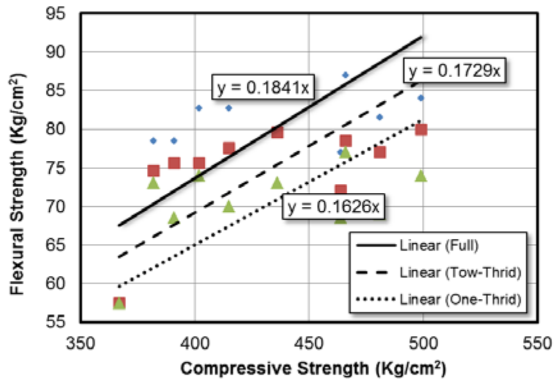

Figure 12: Relation between Compressive Strength and Flexural Strength for Fibers Concrete

4. Conclusions

Based on the experimental results presented in this paper, the main conclusions are as the follows:

1- The increasing the fiber volume percentage decreases the workability of concrete. The slump value was decreasing in all fibers mixes than plain concrete.

2- The compressive strength was increasing in all fibers mixes than plain concrete. The maximum compressive strength at 7 days is increasing by 38% for 0.6% polypropylene fibers than plain concrete. The maximum compressive strength at 28 days is increasing by 36% for 0.6% polypropylene fibers than plain concrete. Relationship between compressive strength at 7 and 28 days is linearly related by the equation:

f_{cu} at7 days $\approx$ 0.7397 f_{cu} at 28 day

3- The splitting tensile strength was increasing in all fibers mixes than plain concrete. The maximum splitting tensile strength is increasing by 46% for 0.6% polypropylene fibers than plain concrete. Relation between splitting tensile strength and compressive strength for ten mixes with different types of fibers is linearly related by the equation:

f_t at 28 day $\approx$ 0.1011 f_{cu} at 28 day

4- The flexural strength was increasing in all fibers mixes than plain concrete. The maximum flexural strength for full fibers mix is increasing by 51% for 0.1% polypropylene and 0.1% glass fibers than plain concrete. The maximum flexural strength for two-third fibers mix is increasing by 39% for 0.6% polypropylene fibers than plain concrete. The maximum flexural strength for one-third fibers mix is increasing by 34% for 0.1% polypropylene and 0.1% glass fibers than plain concrete. Relation between flexural strength and compressive strength for ten mixes with different types of fibers is linearly related by the equation:

-f_{fl} (Full Fibers Mix) $\approx$ 0.1841 f_{cu} at 28 day

-f_{fl} (Tow-Third Fibers Mix) $\approx$ 0.1729 f_{cu} at 28 day

-f_{fl} (One-Third Fibers Mix) $\approx$ 0.1626 f_{cu} at 28 day

5- The difference between flexural strength for full fibers content mixture, tow-third fibers content mixture, and one-third fibers content mixture isn't large. So the one-third fibers content mix is the economic mixture.

6- Polypropylene fibers are improved concrete properties greater than glass fibers because of the elastic modulus of polypropylene fiber is higher than elastic modulus of glass fiber.

7- The strength of the composites (PF and GF) decreased with the increase of fiber volume fraction due to decrease the fiber efficiency factors.

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