University of Thi -Qar Journal for Engineering Sciences
http://www.doi.org/10.31663/tqujes13.1.439(2023)
Vol.13.1(January2023)

ISSN :2664- 5572 (online)
ISSN:2664-5564 (print)
Available at http://jeng.utq.edu.iq
utjeng@ utq.edu.iq

Influence of Hybrid Steel –Polypropylene Fibers on the Mechanical Properties of Normal Concrete

shahzinan Jawad Zaezue[†], Waleed Khalid Hadi [‡]
[†] Civil Engineering Department ,University of Thi-Qar , Iraq, shazanan.j.z@utq.edu.iq.
[‡] Civil Engineering Department , Mazaya University College, Iraq.

Abstract

This paper purposes is to study the influence of hybrid Steel-Polypropylene fibers on workability , compressive strength, splitting strength , and modulus of elasticity of ordinary concrete. For this purpose four mixes in addition to a control normal concrete mixture were prepared. The volume of steel fiber was (0.75% and 1.5%) and the volume of polypropylene fiber was (0.15% and 0.3 %) . Results show that all concrete mixes including hybrid fiber had lower slump flow than the control mix (0%) .In comparison to other forms of concrete without fibers, hybrid concrete with steel and polypropylene fibers shown an increase in compressive, splitting, and elasticity modulus. According to the test results, the hybridization ratio (1.5% steel and 0.3% polypropylene) led to a maximum increase ratio in compressive and splitting tensile strengths of 32% and 69%, respectively, above the reference mix.

Keywords: hybrid fiber ,splitting tensile strength ,modulus of elasticity, polypropylene fiber

1. Introduction

The most popular man-made construction material is concrete. The tensile strength, ductility, and crack resistance of plain concrete are all quite low. Many functional needs, like impermeability and frost resistance, are not properly met by conventional concrete. The inherent fragility of plain concrete is caused by the existence of microcracks at the mortar-aggregate Due to the low tensile strength, cracks propagate when a force is applied, causing brittle fracture of the concrete.
concrete develops microcracks as it is hardening. Previous research **[1][2][3]**demonstrated that adding both steel and polypropylene fibers to concrete enhanced strength of flexural and toughness while decreasing crack propagation when compared to adding only one kind of fiber Wang et al. **[4]** determined that the increase in the splitting tensile strength and flexural of concrete may range between 45% and 50% with a significant (nearly seven times) improved impact resistance of hybrid fiber reinforced concrete relative to ordinary concrete.
The main objective of this paper is to determine systematically the basic characteristics of the four mixes of hybrid fiber-reinforced concretes with different volume fraction of steel–Polypropylene fiber combinations in terms of slump , compressive strength, splitting tensile strength and stress –strain tests.

2. Material Used

Portland cement, fine aggregate (sand), coarse aggregate, steel fiber, polypropylene fiber, and superplasticizer are the materials employed in this study.

2.1.Cement

Portland Cement was the type of cement that was employed in this study. Cement was present in all mixtures at a rate of 410 kg/m3.The cement's chemical properties are given in Table 1 in accordance with I.Q.S No.5/1984**[5],** while Table 2 lists the cement's physical properties according to ASTM C150/C150M-21 **[6].**

Table 1 Chemical characteristics of cement

Chemical characteristic	Tested cement %	Limits of IQ No.5/1984
SiO2	21.67	------
CaO	57.3	------
MgO	2.83	≤ 5%
Fe2O3	3.8	-----
Al2O3	3.5	-----
SO3	2.25	≤ 2.8%
Loss on ignition(L.O.I)	3.9	≤ 4%
Insoluble residue(I.R)	1.42	≤ 1.5%
Lime Saturated Factor(L.S.F)	0.8274	0.66-1.02
C3A	2.9	≤5

Table 2 Cement physical characteristics

Physical characteristic	Tested cement	specification limits (ASTM C150)
Vicat initial time of setting (min)	156	Not less than 45 min
Vicat final time of setting (min)	226	Not more than 375 min
Average compressive strength, age (3	18.9	≥8

days), MPa		
Average compressive strength, age (7 days), MPa	23.8	≥15

2.2 Sand

For concrete mixes, The highest particle size of the natural sand used was 4.75 mm. Table 3 shows the sieve analysis of the used sand . It satisfies the Iraqi standard specification requirements I.Q.S. No.45/ 1984 [7].

Table 3 Sand sieve analysis and sulphate content

No.	Sieve number	Sieve size (mm)	Passing %	Limit of IQS NO.45-1984 Zone No.3
1	3/8"	9.5	100	100
2	No. 4	4.75	97	90-100
3	No. 8	2.36	83	75-100
4	No. 16	1.18	69	55-90
5	No. 30	0.6	48	35-59
6	No. 50	0.3	12	8-30
7	No. 100	0.15	8	0-10
8	No. 200	0.075	2	≤ 5%
9	Pan	0	-----	< 3 %
SO3 content				
10	SO3 content	0.313	Not more than 0.5%	

2.3 Coarse aggregate

For concrete mixtures, the maximum size of the coarse aggregate utilized was limited to 14 mm . The sieve analysis of the used aggregate is presented in Table (4). It complies with ASTM C33/C33M-13 [8].

Table 4 coarse aggregate sieve analysis

No.	Sieve Size (mm)	Passing %	Limit of ASTM C33/C33M-13
1	14	100	100
2	12.5	92	90-100
3	9.5	55	40-70
4	4.75	3	0-10
5	2.36	1	0-5
6	pan	-------	-----

2.4 Fibers

In this work , two different types of fibers were used. Steel fiber with a hooked end was the first type , polypropylene was the second type. The characteristics of the fibres used are shown in Table (5). The two types of fibers employed in this research are depicted in Figure 1.

Table 5 Fibers properties

Material	Property	Value
Steel fiber	Length (mm)	30
	Diameter(mm)	0.5
	Aspect ratio L/D	60
	Geometry	Hooked-Ends
	Tensile strength (MPa)	1300
Polypropylene (PPF)	Length (mm)	12
	Diameter(mm)	0.032
	Aspect ratio L/D	375
	Geometry	Straight
	Tensile strength (MPa)	(600-700)

Steel fiber	Polyproplene fiber

Figure. 1 fiber used in the present work

2.5. Superplasticizer

Throughout the investigation, superplasticizer (Sika Visco Crete 5930 IQ), a high range water reducing admixture and viscosity altering agent, was used. The amount of cement utilized was 0.5% by weight. The manufacturer's description of Sika Visco Crete 5930 IQ's characteristics is given in Table (6), and it conforms with the requirements outlined in ASTM C494/C494M-19 [9].

Table 6 Physical properties of superplasticizer

Composition	Aqueous solution of modified polycarboxylates
Appearance /color	Turbid liquid
Specific gravity	1.085 ± (0.005) g/cm3
pH-Value	4 - 6
Total chloride ion content	Nil
Recommended dosage	(0.2 - 0.8 %) by weight of Binder.

2.6. Water

Throughout the experimental study required to create the concrete mixtures, potable water was used, while tap water from the site of university was used to cure all samples.

3.Mix designed

Trial mixes were made in order to find the best concrete mixture with the desired strength for use in this research. Control concrete mixture intended to have a compressive strength of approximately (35) MPa after 28 days. The cement content in all mixes was 410 kg/m3. The aggregate used had a maximum size of 14mm. Table 7 contains information on all of the mixes used in this work.

4. Concrete mixing procedure

The fiber reinforced concrete mixing procedure begins with placing the coarse aggregate and sand in a mixer of concrete and dry mixing for 1 minute, followed by placing the cement in the concrete mixer and dry mixing for 1 minute as well. Following the addition of one-half of the mixing water and complete incorporation of the superplasticizer, the mixture is stirred for a period of two minutes.The fibres are then distributed and mixed for 3 minutes. The remaining water is then added, and the mixture is mixed until it is homogeneous (as visually observed).

Table 7 Details of mix proportions

No.Of Mix	Material Content (Kg/m^3)						
	Cement	Sand	Coarse aggregate	Water	Super Plasticizer% (by weight of cement)	Steel Fiber %	Polypropylene Fiber %
M1	410	750	1100	184.5	0.5	0	0
M2	410	750	1100	184.5	0.5	0.75	0.15
M3	410	750	1100	184.5	0.5	0.75	0.3
M4	410	750	1100	184.5	0.5	1.5	0.15
M5	410	750	1100	184.5	0.5	1.5	0.3

5.Casting and curing of samples

In the current investigation, concrete cube samples for determining the concrete compressive strength of the HFC samples were cast using cubes with standard dimensions of 150mm on all sides and 150 mm on the bottom. Also, cylinders with measurements of 150 mm by 300 mm (diameter by height) were utilized in the process of casting and testing concrete cylinders for strength of indirect splitting tensile, as well as in the process of drawing a stress-strain relationship.

Before they were used, the molds were given a light coating of mineral oil, and then concrete casting was done in 50 mm layers according to ASTM C 192-88 [10]. Each layer was compacted for (15-30) seconds with a Vibrating Table until there were no more air bubbles rising to the surface and the concrete was smooth all the way to the top of the molds. After then, the samples sat in the laboratory for around 24 hours., covered with a polyethylene sheet. Following that, the samples were carefully remolded, marked, and submerged in water until the date of test.For control tests, samples were 28 days old.

6.Testing methods

6.1.Compressive strength test

The compressive strength of 150x150x150 mm cube sample was determined using BS 1881: Part 5 [11]. These samples were tested under compression testing machine, with capacity 2000 kNThe strength of compressive was calculated using the three specimens' average values. The failure form of the compressive strength test is shown in Figure 2.

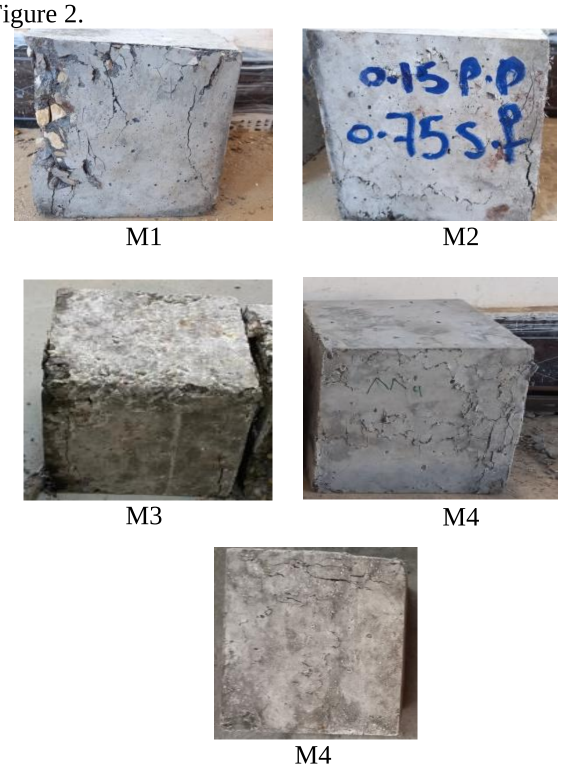

Figure. 2cubes after failure

6.2.Test of splitting tensile strength

Tests of splitting tensile strength were performed on cylinders of (150 x 300 mm).About three test samples were taken on average. The experiment was conducted in agreement with ASTM C 496-86 [12].These specimens were tested under compression testing with capacity 2000kN.Figure 3 demonstrates the stages of the test as well as the failure mode for M1,M2 and M3 samples.

Figure. 3 Splitting tensile test

Figure. 4 Test of modulus of elasticity and failure modes for samples

6.3 Modulus of elasticity

For standard hardened concrete cylindrical samples, this test technique provides a stress-to-strain ratio value. Modulus of elasticity is the material's resistance to deformation. The modulus of elasticity was determined using three cylindrical samples with dimensions of 150×300 mm and tested in the research laboratory under a uniaxial compression load in accordance with ASTM C469/C469M-10 [13]. An average of three cylinders was used. Formula according to ACI 318M-2014 [14] Code used to determine the elastic modulus

$E_C = 4700\sqrt{f_c'}$ (Eq. 1)

Figure 4 displays the steps of test and failure mode for HFC specimens.

7. Results and discussion

7.1. Workability and dry density

When compared to the control mix, which contains no fiber at all, all concrete combinations that contain hybrid fibers show a decrease in slump flow, as shown in Table 8. This is due to the statement that the incorporation fibers increase the internal resistance to flow. In comparison to the normal concrete, the increase of percentage in dry density for the hybrid concrete was 1.12 %, 0.83%, 1.24 and 0.99 % for M2, M3, M4, and M5, respectively. Increasing the use and content of steel fibre in hybrid fibre concretes increase the dry densities of the material because steel fiber has a higher density than concrete. Concrete, on the other hand, has a higher density than polypropylene fiber.

Table 8 Slump and dry density test result for mixes

Mix Symbol	PPF(%)	SF (%)	Slump (mm)	Dry Density (kg/m3)
M1	0	0	180	2405
M2	0.15	0.75	100	2432
M3	0.3	0.75	60	2425
M4	0.15	1.5	40	2435
M5	0.3	1.5	25	2429

7.2.Compressive strength and splitting tensile strength

Hybrid fibers in concrete often result in a significant increase in strength of compressive .The fibers added to the concrete mixes increase the compressive strength by 3.89 %, 20.48 %, 25.86%, and 32.12 % for hybrid fiber ratio 0.9 ,1.05 ,1.65 ,and 1.8, respectively, compared with control specimen. Fibers increased the absorption of energy or enhanced ductility and the steel fiber produced higher compressive strength ,due to the stiffness and strong bonding of steel fiber, Compared to polypropylene fiber, it may better avoid the emergence of microcracks in samples. The splitting tensile strength of mixes was significantly impacted by the adding of fibers There is a noticeable benefit from the adding fibers.When fibers were introduced, the enhancement in strength of splitting tensile over the control mix ranged from 27 to 69%. It is interesting to note that, the compressive strength and the splitting tensile strength are more sensitive to the addition of fiber and exhibits greater increases at the same fiber volume fraction.

Table 9 Compressive strength and splitting tensile strength

Mix Symbol	PPF (%)	SF (%)	Average compressive strength (MPa) fcu	Splitting tensile stress (MPa) f_{sp}
M1	0	0	41.6	3.449
M2	0.15	0.75	47.38	4.413
M3	0.3	0.75	50.12	5.065
M4	0.15	1.5	52.36	5.205
M5	0.3	1.5	54.98	5.863

7.3 Curves of stress–strain and elastic modulus

Figure 5 displays the stress-strain curves of NC and HFRC mixes with various volume fraction ratios of hybrid fiber (0.9 ,1.05 ,1.65 , and 1.8). It is clear from Figure 5 that the hybrid fibers addition has improved the stress-strain curves. Also, when compared to the normal concrete, the elastic behavior of HFRC was slightly different high strain capacity in hybrid fiber concrete translates to high ductility .

The results revealed that the modulus of elasticity of the hybrid fiber mixes was greater than that of the normal concrete mix (NC) for all volume fractions used in this study. This is because the bond strength, compressive strength, and ductility of concrete have all gone up. modulus of elasticity of concrete was evaluated in agreement with ASTM C469-02, Table 9 presents the different modulus of elasticity.

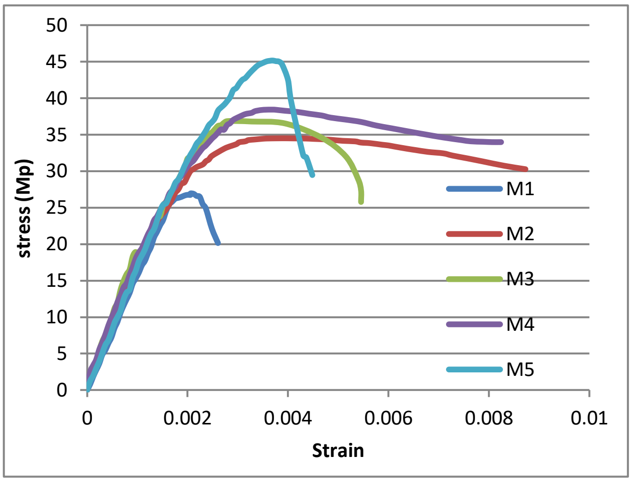

Figure. 5 Stress-Strain curves

Table 10 Compressive strength of cylinders and modulus of elasticity

Mix Symbol	PPF (%)	SF (%)	Average compressive strength f̀c (MPa)	Modulus of elasticity (MPa)
M1	0	0	26.94	24394.76
M2	0.15	0.75	34.49	27602.24
M3	0.3	0.75	36.85	28530.97
M4	0.15	1.5	38.42	29132.41
M5	0.3	1.5	45.11	31567.06

Conclusions

Various conclusions can be drawn from this experimental Study:

1-The existence of fibers reduces concrete workability. The increasing in the hybrid fiber content increases the loss of workability.
2-All concrete mixes showed improvement in compressive strength and splitting strength results for (28 days) due to the influence of hybrid fiber on the final strength characteristics . However, adding fibers increased the compressive strength by 13.89%,20.48% ,25.86%, and 32.16% , respectively. The highest splitting strength was increased by 69.9% compared to the control mixing.
3- All hybrid fiber concrete mixes showed improvement in ductility compared to plain concrete.

References

[1] Alhozaimy, A. M., Soroushian, P., and Mirza, F. (1996). “Mechanical properties of reinforced concrete and materials polypropylene fiber and the effects of pozzolanic.” Cem. Concr. Compos., 18, 85.
[2]Sivakumar, A., and Santhanam, M. (2007). “Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres.”Cem. Concr. Res., 29, 603
[3] Hsie, M., Tu, C., and Song, P. S. (2008). “Mechanical properties of polypropylene hybrid fiber reinforced concrete.” Mater. Sci. Eng. A, 494(1–2), 153.
[4] Wang, P., Huang, Z., Jiang, J., and Wu, Y. (2012). “Performance of hybrid fiber reinforced concrete with steel fibers and polypropylene fibers.” Proc., Int. Conf. Civil Engineering and Urban Planning (CEUP 2012)Yan Tai Univ., Chinese Culture Univ., Communication Univ. of China, and Construction Institute of ASCE, Yantai, China.
[5] I. S. N. 5, ―Portland Cement. Baghdad,1984.
[6]ASTM International [ASTM] (2021). Standard Specification for Portland Cement (ASTM C150/C150M-21). West Conshohocken, PA: ASTM International.
[7] I. S. No, "45, Natural Sources for Gravel that is Used in Concrete and Construction," Baghdad, 1984.

[8]ASTM International [ASTM] (2013a). Standard Specification for Concrete Aggregates (ASTM C33/C33M-13). West Conshohock-en, PA: ASTM International.

[9]ASTM International [ASTM] (2019). Standard Specification for Chemical Admixtures for Concrete (ASTM C494/C494M-19). West Conshohocken, PA: ASTM International.

[10]ASTM International [ASTM] (1989) .Standard Practice for Making and Curing Test Specimens in the Laboratory (ASTM C192-88) . Animal Book of ASTM Standard, Philadelphia.04-02,112, 1989.

[11]British Standards Institution [BSI] (1991). Testing Concrete. Part 116: Method for Determina-tion of Compressive Strength of Concrete Cubes (BS 1881-116). London: British Standards Institution.

[12] ASTM International [ASTM] (2011). Standard test method for splitting tensile strength of cylindrical concrete specimens (ASTM C496/C496M-11). West Conshohocken, PA: ASTM International.

[13] ASTM International [ASTM] (2010). Standard test method for static modulus of elasticity and Poisson's ratio of concrete in compres-sion (ASTM C469/C469M-10). West Con-shohocken, PA: ASTM International.

[14] ACI Commitee 318, ―Building Code Requirements for Structural Concrete, (ACI 318M-14) and commentary (318R-14), American Concrete Institute, Farmington Hills, Michigan, USA, 2014, 546.