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Mechanical Properties of Mortar Using Polypropylene Fibers

Eethar Thanon Dawood[1]* and Tamara Waleed Ghanim[2]

[1]Associate Prof. in Building and Construction Dept., Technical College of Mosul, Iraq

[2]Master candidate, Building and Construction Dept., Technical College of Mosul, Iraq

ABSTRACT

In the present paper the behavior of mortar reinforced with polypropylene fibers was studied. Different percentages of polypropylene fibers such as 0, 0.2, 0.4, 0.6 and 0.8% as volumetric fractions were used. Different properties which are flowability, density, compressive strength, flexural strength and splitting tensile strength were evaluated for all mix combinations. The experimental results indicated that a reduction in flowability was obtained with increased polypropylene fibers content. Besides, it can be concluded that the incorporation of polypropylene fiber may significantly reduce the density of mortar. The use of low volume fraction of polypropylene fiber improves the mechanical properties of HPM. Thus, the use of 0.2% of such fiber increases compressive strength by about (4-10%), at various ages.

***Corresponding author**

Eethar Thanon Dawood, Associate Prof in Building and Construction Dept., Technical College of Mosul, Iraq, E-Mail: eethar2005@yahoo.com

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Introduction

Mortar is one of the most materials used in construction, despite its low behavior in tension. This handicap is the most main cause of cracking which can damage its durability and its appearance; one of the solutions proposed to possess these cracking is to use of fibers reinforced cementitious material. Adding fibers to a matrix increases the energy absorbing capability of hardened concrete, makes it more suitable for use in structures subjected to impacts loads [1].

The strengthening effect of fibers in the cementitious materials is attributed to the bridge effect among the crack propagating. The three main mechanisms of failure of fibers are fiber pullout, fiber rupture and fiber/matrix debonding. The properties of the fibers play an important role in determining the dominant mechanism of failure, and subsequently on the macroscopic behaviour of the cracked fiber reinforced mortar [2-4].

Synthetic fibers have recently become more valuable as reinforcements for cementitious materials. Recently, most attention has been dedicated to the adoption of polymeric fibers, due to their advantages over the metallic ones with special regard to chemical stability, lightness and workability. Several authors have studied the efficiency of polymeric fibers as reinforcing materials for concrete as polyethylene (PE), polypropylene (PP), acrylics (PAN), poly(vinyl alcohol) (PVA), polyamides (PA) and polyester (PES). Showed that among different fibers, PP fibers were the most efficient. Polypropylene (PP) fibers have numerous properties that make them suitable for incorporation to concrete: low cost, ductility, ease of dispersal and good anchoring capacity. Polypropylene fibers do not corrode, are thermally stable (high melting point), chemically inert and very stable in the alkaline environment of concrete [5-10].

The objective of this study is to determine the basic characteristics of mortar reinforced with polypropylene fiber in terms of flowability, compressive strength, flexural strength and split tensile strength. The effect polypropylene fiber was studied in different volumes fraction at 0%, 0.2%, 0.4%, 0.6% and 0.8%.

Materials and Mix Proportions

Materials

Cement: Ordinary Portland cement (OPC) type I from Badoosh manufacture (Nineveh/Iraq) was used in this study, the characteristics and chemical compositions of cement according to IQS: 5/1984 are shown in Tables 1 and 2 [11].

Table 1: Characteristics of Ordinary Portland cement

Test	Produced cement	IQS : 5/1984[11]
Initial setting time	130	Min. 45 minute
Final setting time (minute)	155	Max. 600 minute
Fineness (Blain cm^2/g)	2636	More than 2300
Compressive strength 3 days, N/mm^2 7 days, N/mm^2	 23.0 30.0	 ≥15 MPa ≥ 25 MPa

Table 2: Chemical Compositions of Ordinary Portland cement

Oxide	Content of OPC (%)	Limit of Iraq specification No.5/1984[11]
CaO	62.20	-
SiO_2	21.31	-
Al_2O_3	5.89	-
MgO	3.62	≥5.0%
Fe_2O_3	2.67	-
SO_3	2.60	≥2.8%
L.O.I	1.59	≥4.0%
Main compounds		
C_3S	33.37	-
C_2S	35.92	-
C_3A	11.09	-
C_4AF	8.12	-

Sand: Natural river sand used as a fine aggregate supplied from Kanhash site (Nineveh/Iraq) with a specific gravity of 2.62. The grading limits according to IQS: 5/1984 are given in Figure 1 [12].

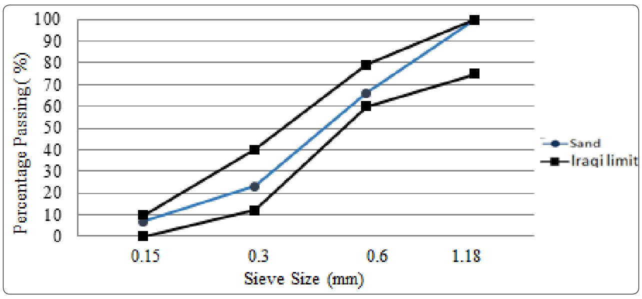

Figure 1: Grading of Sand

Fiber: Straight shape micro-polypropylene fiber with 12 mm length was used; their characteristics are presented in Table 3.

Table 3: Characteristics of Polypropylene Fiber

Fiber properties	Quantity
Average fiber length (mm)	12
Diameter (mm)	0.018
Tensile strength (MPa)	137-689
Young's Modulus (GPa)	3.4-4.8
Toughness (GPa)	8.82
Elongation (%)	25 -40
Specific gravity	0.9
Melting point (°C)	160

Superplasticizer: High-range water-reducing (HRWR) admixtures (superplasticizers) were used conformance to ASTM C494, Type F [13].

Water: Tap water was used for mortar mixtures as a medium for cement hydration.

Mix Proportions

Cement mortar mix proportion is seen in Table 4. Mortar mixes were prepared using water-cement ratio of 0.40. The amount of Superplasticizer varied from 1.5% to 2.2% by weight of binder content to maintain suitable flowability for all the mixes. The mix design of the reference mix (PP-0%) was carried out by the trial mix to achieve the criteria of mortar. Polypropylene fibers were included to the mixes at volumetric fraction of 0.2%, 0.4%, 0.6% and 0.8% in the preparation of mixes (PP-0.2% to PP-0.8%).

Test Methods

After completion of mixing materials, the flow test for the mixes was performed with a desirable flow of 100% to 130%. Three cube specimens (50×50×50 mm) have been used for each mix to test the density and compressive strength. The cube specimens were left in the mounds for 24h at 20°C. After demoulding, the specimens were transferred into the water for curing until the age of test. The compressive strength test was done immediately after determining the density test specimens. The flexural strength of the specimens (40×40×160 mm) was conducted and cylinders were cast (100 mm in diameter and 200 mm in height) to determine the splitting tensile strength (indirect tensile strength) and tested at age 28 days [14-18].

Table 4: Fiber-Mortar Mix Proportions

Index	Cement Kg/m^3	Sand Kg/m^3	SP (%)	W/C	Polypropylene Fiber (%)	Flow (%)
PP-0%	585	1462	1.5	0.40	-	130
PP-0.2%	585	1462	1.5	0.40	0.2	120
PP-0.4%	585	1462	1.8	0.40	0.4	110
PP-0.6%	585	1462	2.0	0.40	0.6	110
PP-0.8%	585	1462	2.2	0.40	0.8	100

Results and Discussions

Flowability

It is clear from Table 4, that the presence of polypropylene fiber in mortar mixes reduces the flowability therefore; increasing amounts of high range water reducer admixture (Superplasticizer) were needed along fiber volume fraction increase. Flowability of mortar mixes varied between 130-100%, the flow was about 130% for reference mix (PP-0%), and reduced with increase of polypropylene fibers. Thus, the use of 0.8% of polypropylene fibers gave up most reduction in the flow to 100%, this reduction in flow was confirmed by the majority of reinforced concrete researches. Noticed that the addition of polypropylene fibers in mortar presents a large reduction in the workability and the use of a Superplasticizer is a necessity [19-20].

Dry Density

From the results show in table 5, it can be noticed that the addition of polypropylene fibers led to a reduction in the mass of the hardened mortar, which was an expected result due to the low specific gravity of fiber which reduce the overall density of mortar, therefore the higher volume fraction 0.8% PP fiber revealed 4% reduction in density. Show incorporated polypropylene fibers in cement mortars with the aim of reinforcing the composite material reducing its weight [21].

Table 5: Mechanical Properties of Mortar Mixes

Index	Dry Density (Kg/m^3) 28-day 28-day	Compressive strength (MPa) 7-day	Compressive strength (MPa) 28-day	Compressive strength (MPa) 56-day	Flexural strength(MPa) 28-day	Split tensile strength (MPa) 28-day
PP-0%	2190	42.3	50.6	55.4	9.0	3.1
PP-0.2%	2185	46.8	52.5	58.2	10.1	3.5
PP-0.4%	2142	45.5	54.8	56.4	9.8	3.5
PP-0.6%	2113	44.0	55.8	57.7	9.6	3.1
PP-0.8%	2102	40.4	51.0	56.8	9.4	3.0

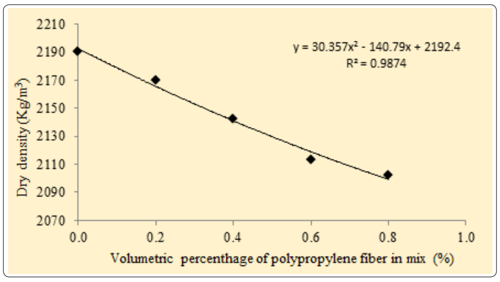

Figure 2: Relation between Fiber Content and Saturated Surface Dry Density at 28 Days

Mechanical Properties

Although the influence of the PP fibers on the mechanical properties of mortar have been thoroughly investigated by several studies [2, 20, 21], an analysis of the obtained results for the main mechanical properties was necessary due to their effects by the mechanical and geometrical properties. As well as; the dosage of fibers, which interacted with the behaviour of high performance mortar. Table 4 shows the mechanical properties obtained for all mortar mixes reinforced with polypropylene fiber.

In all mortar mixes the trend of the results led to an improvement in mechanical properties of HPM when low dosages of polypropylene fiber were added. In the case of compressive strength, the results show increases in compressive strength till 0.6% of PP fiber as volumetric fraction of the mix, but beyond this fraction, compressive strength reduces clearly, this behavior related with the fact of less workable material those compaction was. As well as an excessively large amount of polypropylene fibers may be affected with the continuity and prevented the material from generating a coherent matrix. This fact is consistent with the conclusion of who stated that discontinuities along the mortar structure would lead to a decrease in mechanical strengths. Figure 3, show the increase of fiber from 0% to 0.2% increases the compressive strength at 7, 28 and 56 days by about (4-10%) in spite of the decrease in density. Figure 4 illustrates the relation of compressive strength and density for the fiber reinforced high performance mortar at 28 days [22-23].

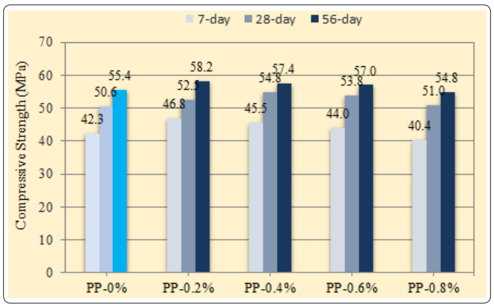

Figure 3: Relation between Fiber Content and Compressive Strength

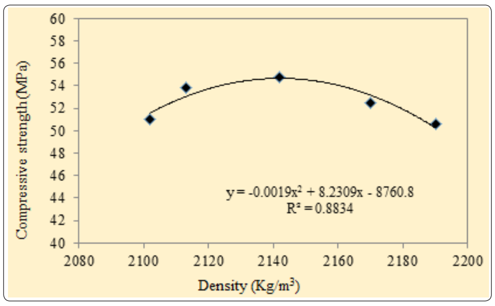

Figure 4: Relation between and Compressive strength and density at 28 Days.

For the PP-0.2% mortar mix incorporating with 0.2% fiber volumetric fraction shows increase of 12% in the flexural strength and 13% in splitting tensile strength this increasing in strengths is compatible with the compressive strength increase, and also, Figures 5&6 illustrates the increase of the flexural strength of 0.2 % volumetric fraction of polypropylene fiber in the mix and beyond this percentage the decrease in strengths. This related to the lowest dosage used of fiber the matrix causes a reduction of the amount of larger pores and increase in the small ones and this led to a more compact material, thus explaining the lower water vapour permeability and the higher mechanical strengths. On the other hand, the highest amount of fiber produced a less compact mortar, which is in agreement with the lower density, the higher air content, the larger water vapour permeability and the lower mechanical strengths [24].

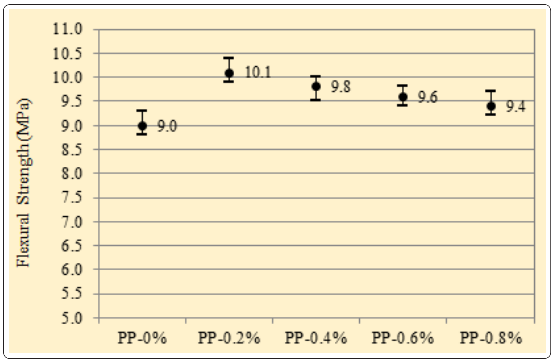

Figure 5: Relation between Fiber Content and Flexural Strength

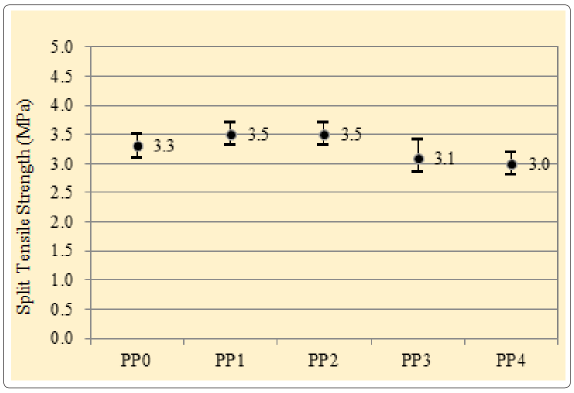

Figure 6: Relation between Fiber Content and Direct Tensile Strength

Conclusion

The experimental study on the mortar reinforced with various volume fractions of polypropylene fibers reveals the following conclusions:

1. Addition of polypropylene fibers in mortar decreases their workability. Beyond 0.4% of polypropylene fibers volumetric fraction, additional dosage of a Superplasticizer is a necessary to achieve the target flowability.
2. The use of polypropylene fiber reduces the density and this may consider as a significant factor if it's compatible with acceptable ranges of mechanical strength.
3. The compressive strength results show that the use of 0.2% of the polypropylene fiber as volumetric fraction increase the strength at 7, 28 and 56 days by about (4-10%)
4. The flexural strength results show that the use of 0.2% of the polypropylene fiber as volumetric fraction increase the strength by about 12% and it's increase by about 4% using 0.8% of fiber volumetric fraction.
5. The split tensile strength results show that the use of low dosage of polypropylene fiber 0.2% and 0.4% as volumetric fraction increase the strength by about 13%, beyond this percentage there is a decrease in split tensile strength by about 4% using 0.8% of fiber volumetric fraction.

References

1. B Boulekbache, M Hamrat, M Chemrouk, S Amziane (2010) Flowability of reinforced concrete and its effect on the mechanical properties of the material. Construction and Building Materials 24: 1664-1671.
2. S. Singh, A. Shukla, R. Brow (2004) Pullout behaviour of polypropylene fibers from cementitious matrix. Cem Concr Res 34: 1919-1925.
3. E Naaman, T Wongtanakitcharoen, G Hauser (2005) Influence of different fibers on plastic shrinkage cracking of concrete. ACI Mater J 102: 49-58.
4. MN Soutsos, TT Le, AP Lampropoulos (2012) Flexural performance of fiber reinforced concrete made with steel and synthetic fibers. Construct Build Mater 36: 704-10.
5. Z Zheng, D Feldman (1995) Synthetic fiber-reinforced concrete, Prog Polym Sci 20: 185-210.
6. A M López-Buendía, M D Romero-Sánchez, V Climent, C Guillemb (2013) Surface treated polypropylene (PP) fibers for reinforced concrete, Cement and Concrete Research 54: 29-35.
7. L Sarvaranta, M Elomaa, E Jarvela (1993) A study of spalling behaviour of PAN fiber-reinforced concrete by thermal analyses, Fire Mater 17: 225-230.
8. L Sarvaranta, E Mikkola (1994) Fiber mortar composites under fire conditions: effects of ageing and moisture content of specimens, Mater Struct 27: 532-538.
9. P Kalifa, G Chéné, C Gallé (2001) High-temperature behaviour of HPC with polypropylene fiber. From spalling to microstructure, Cem Concr Res 31: 1487-1499.
10. N. Banthia, R Gupta (2006) Influence of polypropylene fiber geometry on cracking in concrete, Cem Concr Res 36: 1263-1267.
11. Iraqi Standard No (5) for the year (1984) "Portland cement", the Central Agency for Standardization and Quality Control.
12. Iraqi Standard No (45) for the year (1984) The Ruins of the natural Resources used in the Concrete and Construction, the Central Agency for Standardization and Quality Control.
13. ASTM C494 (2004) Standard Specification for Chemical Admixtures for Concrete. Annual book of ASTM Standards.
14. ASTM C 1437 (2001) Standard Test Method for Flow of Hydraulic Cement Mortar, Annual book of ASTM, standards.
15. ASTM C109 (2002) Standard Test Method for Compressive Strength. Annual book of ASTM Standards.
16. ASTM C 642-97 (1997) Standard test method for density, absorption, and voids in hardened concrete', annual book of ASTM, standards, vol 04: 02.
17. ASTM C348 (2002) Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars. Annual book of ASTM Standards.
18. ASTM C496 (1996) Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. Annual book of ASTM standards.
19. M Hashem, A Al-Mattarneh, A Zakiah (2002) Characterization of Natural Fiber Concrete using Destructive and Non-Destructive Testing Methods, Proceeding of the 6th International Conference on Concrete Technology for Developing Countries, Amman, Jordan 551-560.
20. K Bendjillalia, MS Gouala, M Chemroukb, Z Damenea (2011) Study of the reinforcement of limestone mortars by polypropylene fibers waste, Physics Procedia 21: 42-46.
21. A García Santos, JM Rincó, Romero M, Talero R (2005) Characterization of a polypropylene fibered cement composite using ESEM, FESEM and mechanical testing. Constr Build Mater 19: 396-403.
22. F Puertas, T Amat, A Fernandez-Jimenez, T Vazquez (2003) Mechanical and durable behaviour of alkaline cement mortars reinforced with polypropylene fibers. Cem Concr Res 33: 2031-2036.
23. J Lanas, JI Alvarez (2003) Masonry repair lime-based mortars: factors affecting the mechanical behavior. Cem Concr Res 33: 1867-1876.
24. A Izaguirre, J Lanas, JI Alvarez (2011) Effect of a polypropylene fiber on the behaviour of aerial lime-based mortars, Construction and Building Materials 25: 992-1000.