IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. VI (May- Jun. 2016), PP 50-57
www.iosrjournals.org

The Influence of Polypropylene Fiber and Silica Fume on Compressive and Tensile Strengths of Concrete

K.I.M. Ibrahim
Construction Engineering Dept., College of Engineering at Qunfudha , Umm-Al-Qura University- KSA on Sabbatical leave from higher Institute of Engineering and Technology of Kafr-EL-shiekh – Egypt

Abstract: *This paper investigates the effect of polypropylene fiber(PPF) and silica fume(SF) on the compressive and tensile strengths of concrete. Effects of key variables such as fiber and silica fume contents were studied. An experimental program was conducted to achieve the required objectives. The work focused on concrete mixes having a fixed water/binder ratio of 0.40 and a constant total binder content of 500kg/m3.the percentages of silica fume that replaced cement in this research were 0%,6%,12% and 18%. Polypropylene fiber with 19mm length and four volume fractions of 0%, 0.25%,0.5% and 0.75% are used. The results show that silica fume has great improvement on the compressive strength and splitting tensile strength of concrete. The increase of replacement levels of silica fume from 12% to 18% has not much significant change on the development of compressive and tensile strengths. The addition of polypropylene fibers caused an adverse effect on the compressive and tensile strengths of normal and silica fume concretes.*
Keywords: *silica fume , polypropylene fibers ,compressive strength and tensile strength*

I. Introduction

Silica fume consists of very fine particles about 100 times smaller than the average cement particles, the extreme fineness of the silica fume particles allows it to fill the microscopic voids between cement particles . Silica fume is among one of the most recent pozzolanic materials currently used in concrete. It was first used in 1969 in Norway but only began to be systematically employed in North America and Europe in the early 1980. Since then, the use of silica fume in concrete has been increasing rapidly , it has been used either as a partial replacement for cement or as an additive when special properties are desired [1]. The rapid increase in the use of silica fume is attributed to its positive effects on the mechanical properties of cementitious composites . During the last decade considerable attention has been given to the use of silica fume as a partial replacement of cement to produce high-strength concrete. the addition of silica fume to Portland cement concrete marginally decreased the workability of concrete but significantly improved its mechanical properties[2] .

Bhanja et al. investigated the isolated effect of silica fume on concrete and suggested the optimum content of silica fume with regard to the compressive strength of concrete [3].

However, a lot of research achievements indicate that silica fume can cause the concrete to have a more brittle structure , and ductility improvement is an important goal in concrete science and must be taken into account by researchers .[4,5] Short fibers have been known and used for centuries to reinforced brittle materials like cement or masonry bricks . Now, there are numerous fiber types available for commercial use, the basic types being steel, glass, synthetic materials, and some natural fibers .[6-10] Because polypropylene fiber is a kind of man-made synthetic fiber with the properties of low modulus of elasticity, high strength, excellent ductility, excellent durability, and low price , many experimental works related to the use of polypropylene fibers in cement matrix composites have been published.[11-12]

The effect of polypropylene fibers on the properties of hardened concrete varies depending on the type length and volume fraction of fiber, the mixture design, and the nature of the concrete materials used.

The general results are that permeability, abrasion and impact resistance are all significantly improved by the addition of polypropylene fibers[13] The effect of polypropylene fibers on flexural, compressive and tensile strength as well as on toughness and elastic modulus is not quite clear. Most work shows either no effect or modest improvements in these properties. However, in some cases the addition of polypropylene fibers has been known to decrease the ultimate strength of hardened concrete. The use of PPF in natural pozzolanic cement concrete(NPC) combined with SF can be recommended to reduce long-term impact of early age cracking ,and enhance durability ,the combination of 10%SFand 0.07% PPF volumetric fraction mitigated early age cracking and significantly reduced water permeability and carbonation depth[14]. However, little information is presently known regarding the combined effect of polypropylene fiber and silica fume on the mechanical properties of concrete . Therefore, the present work investigates silica fume , and polypropylene fiber using an extensive range of mixes : silica fume (by mass) from 6% to 18 % , and polypropylene fiber (by volume) from 0.25% to 0.75% .

II. Materials

Local materials were used in concrete mixes and tested according to Egyptian Standard Specification (ESS) and American Standard of Testing Materials (ASTM) . basalt as a coarse aggregate was used with maximum size 25mm and particle shape was approximately flaky .fine aggregate used in this research was natural sand and it composed mainly of siliceous material .Ordinary Portland Cement was tested to assure its compliance with ESS 373-1991.supper-plasticizer was added to keep the water binder ratio =0.40 with slump ranges from 6-10cm.PPF of 19mm length was used. A commercial silica fume was used for preparing the SF concretes.

III. Concrete Mixes Proportion

In all, 16 mixture proportions were made, and the first one was control mix (without SF and PPF). There are three proportions of PPF mixed in concrete by volume ranged from 0.25% to 0.75% and three proportions with SF replacing the same quantity of cement by mass ranged from 6% to 18% . Another nine proportions were arranged with SF replacing the same quantity of cement by mass ranged from 6% to 18% with PPF mixed in concrete by volume ranged from 0.25% to 0.75% . Mix proportions are given in Table (1) .

Table (1) : Concrete Mixes Proportion

Mix No.	PPF content %	SF content		Cement (kg/m^3)	basalt (m^3)	Sand (m^3)	Water (lit)	Super plasticizer (kg)
		%	Kg/m^3					
1	0	0	0	500	**0.80**	**0.40**	**200**	9.25
2	0.25	0	0	500				9.25
3	0.50	0	0	500				9.5
4	0.75	0	0	500				9.5
5	0	6	30	470				9.25
6	0	12	60	440				9.5
7	0	18	90	410				9.5
8	0.25	6	30	470				9.5
9	0.50	6	30	470				9.75
10	0.75	6	30	470				10
11	0.25	12	60	440				9.5
12	0.50	12	60	440				9.75
13	0.75	12	60	440				10.25
14	025	18	90	410				9.75
15	0.50	18	90	410				9.75
16	0.75	18	90	410				10.25

IV. Description Of Tested Specimens

48 cubes 15x15x15cm and 48 cylinders 15x30cm were cast for compressive strength and splitting tensile strength .Concrete was cast vertically in the forms ,and was mechanically compacted using external vibrator to ensure full compaction of concrete inside the forms. The specimens were tested by using 2000KN hydraulic compression machine .

V. Test Results And Discussion

Compressive strength

Compressive strengths of concrete mixes were determined at 28 days of curing. The test results are given in Tables 2-7 and Figures 1-6. Table 2 and figure 1 show the variation of compressive strength of polypropylene fiber reinforced concrete(PPFRC). From the results , it can be seen that ,with the increase of fiber volume dosage, the compressive strength is decreasing gradually and the decrease is so great at the fiber volume dosage = 0.75%. Compared with the control mix (without PPF and SF) the decrease of compressive strength was 19.7 % , 24.6 % and25 % for 0.25% , 0.50% and 0.75% PPF volume dosage respectively.

Table 3 and figure 2 show the variation of compressive strength of silica fume concrete(SFC)mixes , from the results it can be seen that ,the compressive strength increases with the increase of SF contents and the strengths of different SF contents are larger than that of control mix. Compared with the control mix, the compressive strength increases of about 12.82 % , 45.05 % and 22.95 % for SF contents 6% , 12% and 18% respectively.

Silica fume acts as a filler due to its smaller particle size , and the pozzolanic reaction of the silica fume produces additional C-S-H gel , which grows into the capillary spaces that remain after the hydration of the cement in mortar mixes [15]. Therefore , it would appear that silica fume acts both physically (as filler) and chemically (reacting with Ca(OH)2 to form C-S-H) to aid in the strength improvement of mixes .

Tables 4-6 and figures 3-5 show the variation of the compressive strength of PPFRC at the same ratio of SF contents. It was observed that with the increase of PPF contents, the compressive strength of SFC decreases. At SF content 6%, the compressive strength decreases with about 25%, 29% and 30% for PPF contents 0.25%, 0.5% and 0.75% respectively as for SF content 12% the reduction was about 28%,39% and 41%, also for SF content 18% the reduction was about 22%, 32% and 33% respectively.

Table (2): Results of compressive strength [kg/cm2] of PPFRC

SF content%	PPF content%	Compressive strength [kg/cm^2]
0	0	386.50 [control]
0	0.25	310.20[-19.7%]
0	0.50	291.25[-24.6%]
0	0.75	287.10[-25.7%]

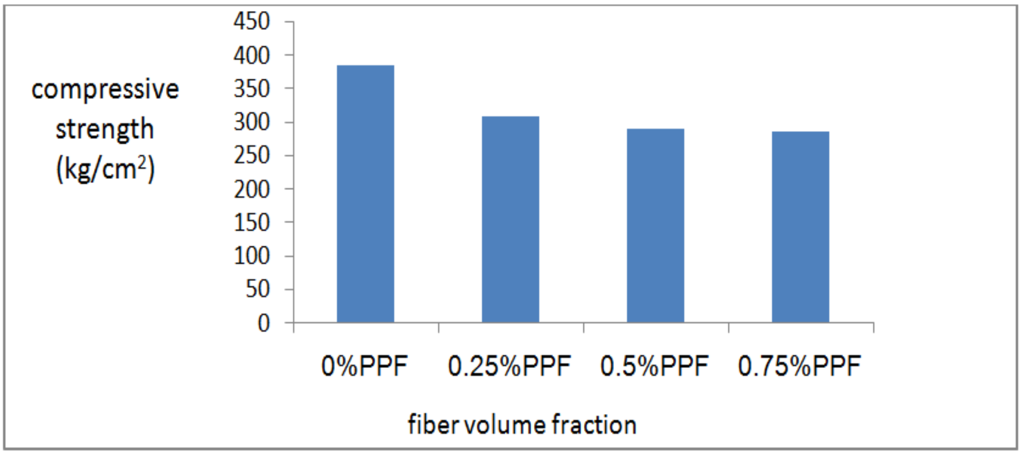

Fig.(1) : the compressive strength (kg/cm2) of PPFRC

Table (3): Results of compressive strength [kg/cm2] of SFC

SF content%	PPF content%	Compressive strength[kg/cm^2]
0	0	386.5 [control]
6	0	436.05 [12.82%]
12	0	560.6 [45.05%]
18	0	475.2 [22.95%]

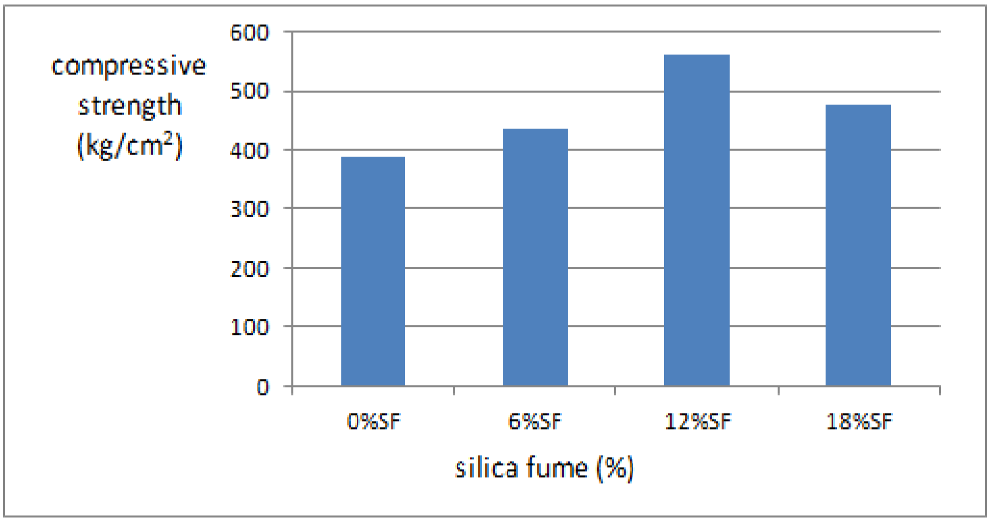

Fig.(2) : the compressive strength (kg/cm2) of SFC

Table (4): Results of compressive strength [kg/cm2] of PPFRC with SF content =6%

SF content%	PPF content%	Compressive strength[kg/cm^2]
6	0	436.05 [control]
6	0.25	324.18 [-25.6%]
6	0.50	308.40 [-29.3%]
6	0.75	304.50 [-30.2%]

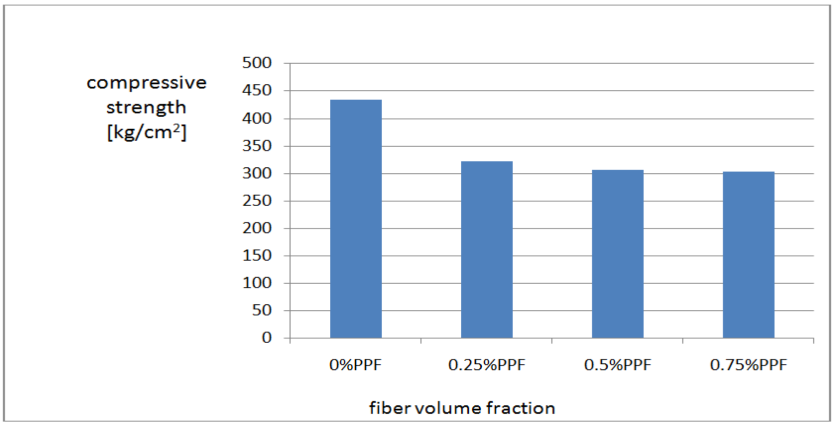

Fig.(3) : the compressive strength (kg/cm2) of PPFRC with SF content 6%

Table (5): Results of compressive strength [kg/cm2] of PPFRC with SF content =12%

SF content%	PPF content%	Compressive strength[kg/cm^2]
12	0	560.60 [control]
12	0.25	399.86 [-28.7%]
12	0.50	337.96 [-39.7%]
12	0.75	327.90 [-41.5%]

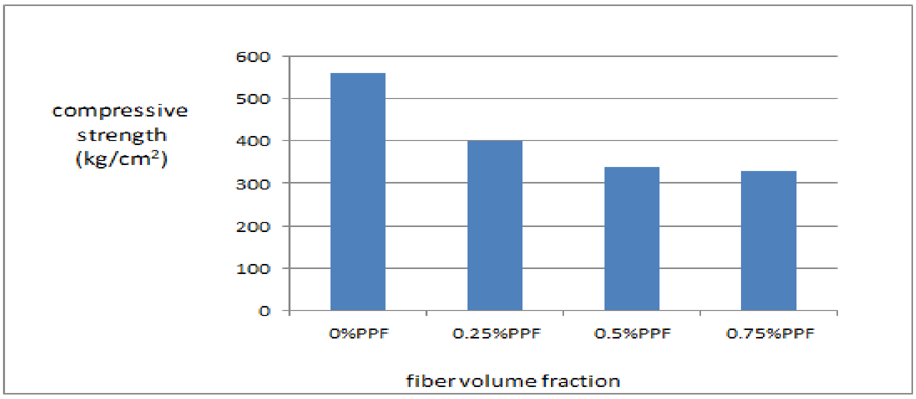

Fig.(4) : the compressive strength (kg/cm2) of PPFRC with SF content 12%

Table (6): Results of compressive strength [kg/cm2] of PPFRC with SF content =18%

SF content%	PPF content%	Compressive strength[kg/cm^2]
18	0	475.20 [control]
18	0.25	369.20 [-22.3%]
18	0.50	321.57 [-32.3%]
18	0.75	315.20 [-33.7%]

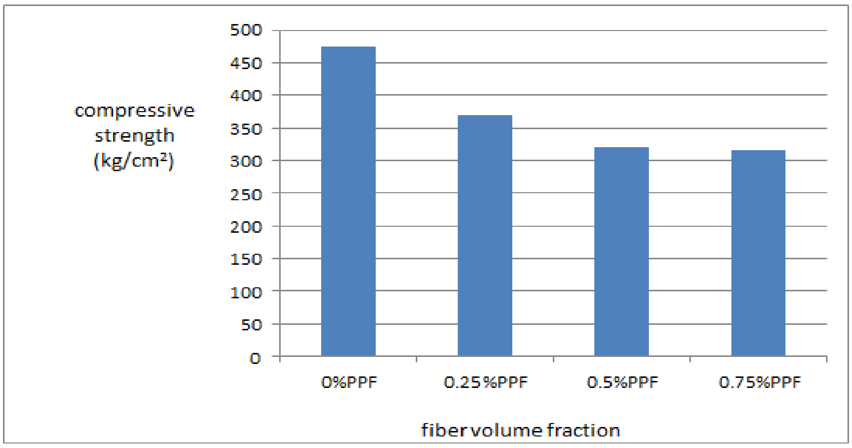

Fig.(5) : the compressive strength (kg/cm2) of PPFRC with SF content 18%

Table (7): Summary of compressive strength results [kg/cm2]

PPF content%	The compressive strength [kg/cm^2] at SF content			
	0%	6%	12%	18%
0	386.50 [control]	436.05[12.82%]	560.60 [45.05%]	475.20 [22.95%]
0.25	310.20 [control]	324.18 [4.51%]	399.86 [28.90%]	369.2 [19.02%]
0.50	291.25 [control]	308.40 [5.89%]	337.96 [16.04%]	321.57[10.41%]
0.75	287.10 [control]	304.50 [6.06%]	327.9 [14.21%]	315.2 [9.79%]

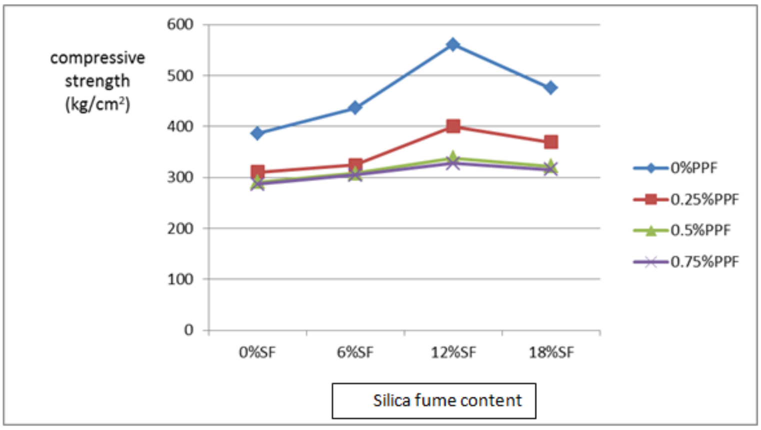

Fig.(6) : the compressive strength (kg/cm2) of all concrete mixes

Splitting tensile strength

Splitting tensile strengths of concrete mixes were determined at 28 days curing. The test results are given in Tables 8-13 and Figures 7-12. Table 8 and figure 7 show the variation of splitting tensile strength of PPFRC. From the results , it can be seen that ,with the increase of fiber volume dosage, the tensile strength is decreasing gradually . Compared with the control mix (without PPF and SF) the decrease of tensile strength were 10.3 % , 18.3 % and 15.85 % for 0.25% , 0.50% and 0.75% PPF volume dosage respectively.

Table 9 and figure 8 show the variation of tensile strength of SFC mixes , from the results it can be seen that ,the tensile strength increases with the increase of SF contents and the strengths of different SF contents are larger than that of control mix. Compared with the control mix, the tensile strength increases of about 10.94 % , 24.53 % and 21.62 % for SF contents 6% , 12% and 18% respectively. Tables 10-12 and figures 9-11 show the variation of the compressive strength of PPFRC at the same ratio of SF content. It was observed that with increase of PPF content, the tensile strength of SFC decreases. At SF content 6%, the tensile strength decreases with about 9%, 15% and 15% for PPF content 0.25%, 0.5% and 0.75% respectively as for SF content 12% the reduction was about 18%,24% and 23%, also for SF content 18% was about 20%, 28% and 22% respectively.

Table (8): Results of tensile strength [kg/cm2] of PPFRC

SF content%	PPF content%	Tensile strength[kg/cm^2]
0	0	37.1 [control]
0	0.25	33.27 [-10.3%]
0	0.50	30.32 [-18.3%]
0	0.75	31.22 [-15.85%]

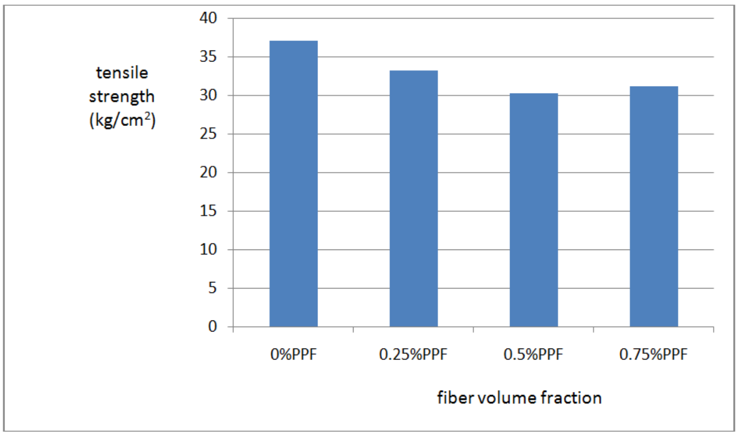

Fig.(7) : the tensile strength (kg/cm2) of PPFRC

Table (9) Results of tensile strength [kg/cm2] of SFC

SF content%	PPF content%	Tensile strength[kg/cm^2]
0	0	37.1 [control]
6	0	41.16 [+10.94%]
12	0	46.2 [+24.53%]
18	0	45.12 [+21.62%]

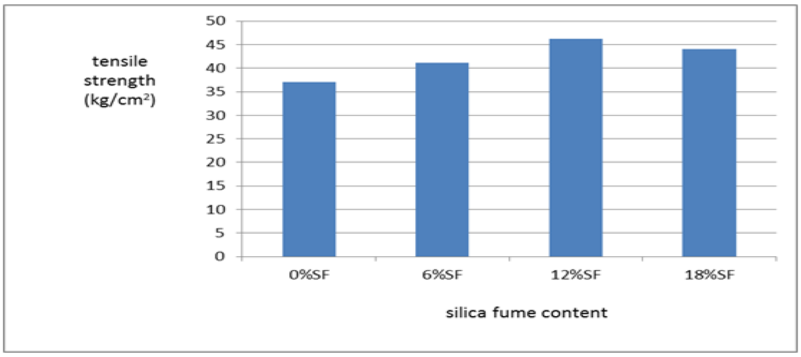

Fig.(8) : the tensile strength (kg/cm2) of SFC

Table (10): Results of tensile strength [kg/cm2] of PPFRC with SF content =6%

SF content%	PPF content%	Tensile strength[kg/cm^2]
6	0	41.16 [control]
6	0.25	37.2 [-9.62%]
6	0.50	34.68 [-15.74%]
6	0.75	34.76 [-15.55%]

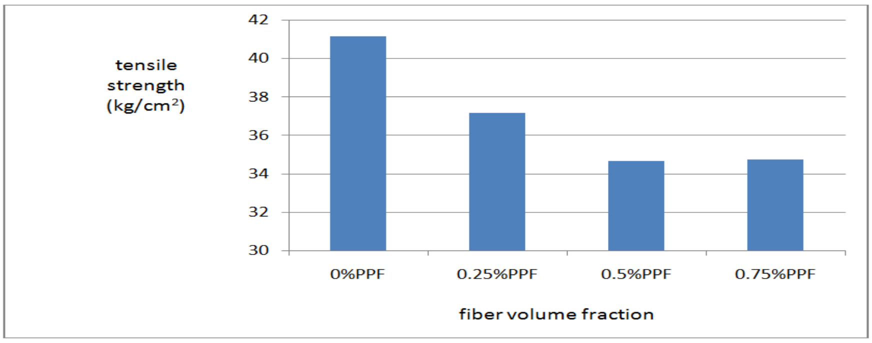

Fig.(9) : the tensile strength (kg/cm2) of PPFRC with SF content 6%

Table (11): Results of tensile strength [kg/cm2] of PPFRC with SF content =12%

SF content%	PPF content%	Tensile strength[kg/cm^2]
12	0	46.2 [control]
12	0.25	37.68 [-18.44%]
12	0.50	35.04 [-24.16%]
12	0.75	35.28 [-23.64%]

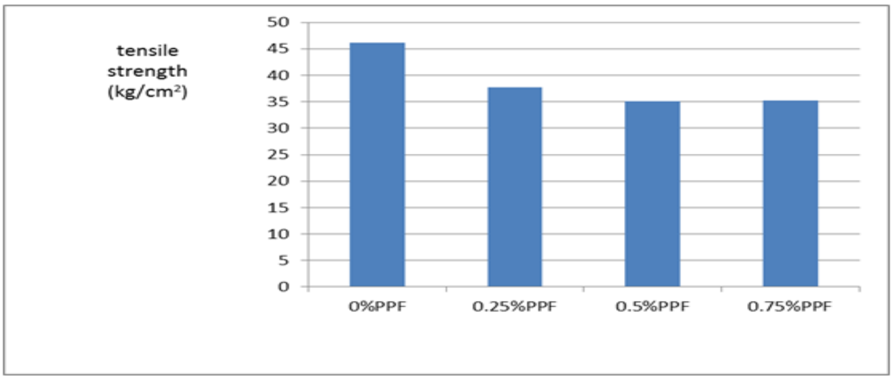

Fig.(10) : the tensile strength (kg/cm2) of PPFRC with SF content 12%

Table (12): Results of tensile strength [kg/cm2] of PPFRC with SF content =18%

SF content%	PPF content%	Tensile strength[kg/cm^2]
18	0	45.12 [control]
18	0.25	36.12 [-19.95%]
18	0.50	32.28 [-28.46%]
18	0.75	35.04 [-22.34%]

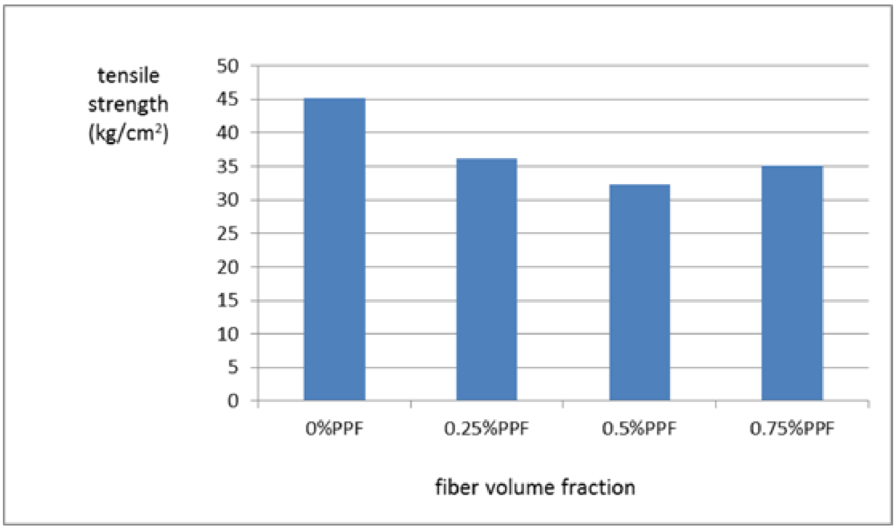

Fig.(11) : the tensile strength (kg/cm2) of PPFRC with SF content 18%

Table (13): Summary of tensile strength results [kg/cm2]

PPF content%	The compressive strength [kg/cm^2] at SF content			
	0%	6%	12%	18%
0	37.1 [control]	41.16 [+10.94%]	46.2 [+24.53%]	45.12 [+21.62%]
0.25	33.27 [control]	37.2 [+11.81%]	37.68 [+13.26%]	36.12 [+8.57%]
0.50	30.32 [control]	34.68 [+14.38%]	35.04 [+15.57%]	32.28 [+6.46%]
0.75	31.22 [control]	34.76 [+11.34%]	35.28 [+13%]	35.04 [+12.24%]

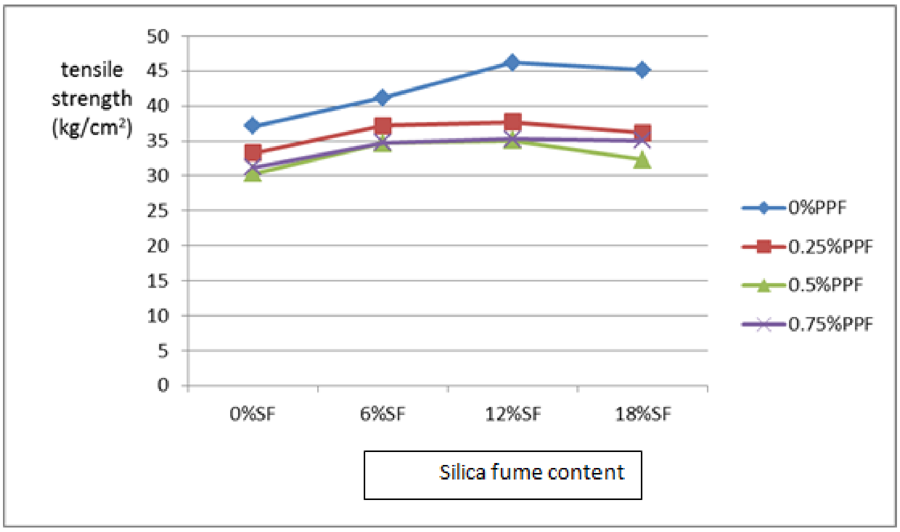

Fig.(12) : the tensile strength (kg/cm2) of all concrete mixes

VI. Conclusions

This article reported experimental results of compressive strength and splitting tensile strength studies conducted on silica fume concrete composite reinforced with polypropylene fiber. The following conclusions can be drawn from the results presented in this article:

1. Silica fume appeared to have an adverse effect on the workability of fiber concrete.

2. Silica fume has great improvement on the compressive strength and splitting tensile strength of concrete, the compressive strength and splitting tensile strength of concrete increase gradually with the increase of silica fume content.
3. The compressive strength increases with the increase in silica fume compared with normal concrete. The maximum increase in compressive strength was up to 12.82 %, 45.05 % and 22.95 % for 6% , 12% and 18% of silica fume replaced by cement re respectively.
4. The tensile strength increases with the increase in silica fume compared with normal concrete. The maximum increase in strength was up to 10.94 %, 24.53 % and 21.62 % for 6% , 12% and 18% of silica fume replaced by cement respectively.
5. The increase of replacement levels of silica fume from 12% to 18% has not much significant change on the development of compressive and tensile strengths. Therefore the optimum dosage of replacement of silica fume in the concrete in this study was considered 12%.
6. The addition of polypropylene fibers caused an adverse effect on the compressive and tensile strengths of normal and silica fume concretes.
7. However , the addition of polypropylene fibers resulted in a significant decrease in compressive strength than tensile strength.
8. It was observed that the decrease in compressive strength and tensile strength are directly proportional to the fiber content.

References

[1]. A.T.Houssam, E.Tahar, The influence of silica fume on the compressive strength of cement paste and mortar, Cement and Concrete Research, 25(1995) 1591-1602 .

[2]. A.A.Almusallam, H.Beshr, M.Maslehuddin, O.S.B. Al-Amoudi Effect of silica fume on the mechanical properties of low quality coarse aggregate concrete, Cement and Concrete Composites. 26(2004) 891-900.

[3]. S.Bhanja, B.Sengupta, S.K.Kaushik, P.Kumar , Optimum silica fume content and its mode of action on concrete , ACI Materials Journal, 101(2004) 327-328.

[4]. Nili M and Afroughsabet V. Combined effect of silica fume and steel fibers on the impact resistance and mechanical properties of concrete . Int J Impact Eng 2010; 37: 879-886.

[5]. Tanyildizi H. Effect of temperature carbon fibers , and silica fume on the mechanical properties of lightweight concretes. New Carbon Mater 2008; 339-344.

[6]. Aktas M. The influence of hole diameter on residual stresses and plastic zone expansion in steel fiber- reinforced aluminum metal-matrix laminated composite plates under transverse loading J Reinf Plast Compos 2006; 25(11): 1149-1164.

[7]. Arslan N and Ozben T. An elastic-plastic stress analysis of a woven reinforced steel fiber thermoplastic composite cantilever beam subjected to transverse uniform loads on the upper surface . J Reinf Plast Compos 2005; 24(14): 1493-1508.

[8]. Ghugal YM and Deshmukh SB. Performance of alkali-resistant glass fiber reinforced concrete . J Reinf Plast Compos 2006;(6): 617-630.

[9]. Kumutha R and Palanichamy MS. Investigation of reinforced concrete columns confined using glass fiber-reinforced polymers. J Reinf Plast Compos 2006; 25(16): 1669-1678.

[10]. Mohan TP and Kanny K. Influence of nanoclay on rhe-ological and mechanical properties of short glass fiber-reinforced polypropylene composites. J Reinf Plast Compos 2011; 30(2): 152-160.

[11]. Zhang P and Li QF. Experimental study on shrinkage properties of cement –stabilized macadam reinforced with polypropylene fiber. J Reinf Plast Compos 2010; 29(12) : 1851-1860.

[12]. [Niu PF, Liu BY and Wei XM. Study on mechanical properties and thermal stability of polypropylene / hemp.

[13]. Balaguru PN, Shah SP. Fiber reinforced cement composites .New York :McGraw-Hill, Inc. 1992 -367p.

[14]. N. Flores Medina , G. Barluenga , F. Hemandez-Olivares Combined effect of polypropylene fibers and silica fume to improve the durability of concrete with natural pozzolans blended cement . Construction and Building Materials ,2015(96):556-566.

[15]. Blanco F , Garcia MP , Ayala J , Mayoral G and Garcia MA. The effect of mechanically and chemically activated fly ashes on mortar properties. Fuel 2006; 85: 2018-2026.