EFFECT OF HYPER-PLASTICIZER ADDITIVE RATES ON THE PROPERTIES OF POLYPROPYLENE FIBRE TEMPERED CONCRETES

Prof. Dr. İlker Bekir TOPÇU[a *] and Öğr. Gör. Hasan BAYLAVLI[b]

[a *] Eskişehir Osmangazi University, Civil Engineering, Eskişehir, Turkey, ilkerbt@ogu.edu.tr

[b] Hitit University, Civil Engineering, Corum/Turkey, hasanbaylavli@hitit.edu.tr

Abstract

In this study, effect of different rates of hyper-plasticizer additives on the physical and mechanical properties of polypropylene fibre tempered concretes. The factors of slump and compaction, which are fresh concrete properties, were also examined. In the study, different types and rates of polypropylene fibres were used. Polypropylene fibres and hyper-plasticizer additives were used in three different rates in the mixture. As polypropylene fibre amount increased in the mixture, hyper-plasticizer additive amount also increased. Fresh concrete slump values were measured between 15-19 cm. Impaction factor value was between 0,89- 0,99. In some mixtures, it was seen that the relation between the slump value and impaction value was disrupted. Abrasion and water absorption values, which were physical properties of the hardened concrete, were calculated. In abrasion tests, it was seen that concretes with C, D and E fibres were eroded less. Polypropylene fibre additive increased the water absorption value of concrete. Its effect on splitting-tensile strength, which was a hardened concrete property, was examined. In splitting-tensile strength experiment, 15x30 cm cylinder samples were used. It was seen that the polypropylene fibres increased the splitting-tensile resistance of the concrete at the rate of %80 compared to the polypropylene fibre additive free mixture. Also, deformation meters were placed on the sample in splitting-tensile resistance. Horizontal deformations of samples were measured at the moment of breaking. While horizontal deformation values increased in 7 day samples compared to propylene fibre additive-free mixture, they decreased in 28- day samples. 7-day horizontal deformation values of the samples were measured to be higher than the 28-day horizontal deformation values. This situation can be explained with brittleness of the concrete at the end of 28 days as it gains resistance.

Keywords: Fibre, hyper-plasticizer, fresh concrete, abrasion, splitting-tensile.

1. Introduction

Polypropylene fibers have recently widely been used in the building materials.Many studies have been performed regarding usuage of polypropylene fibers in concrete and mortars [1-7]. In the study in which polypropylene fibers additives of 0.45 kg/m^3, 0.90 kg/m^3 and 1.80 kg/m^3 by weight were used , water absorption and water permeability values increased and wet shrinkage values decreased as well with fly ash and polypropylene fibre additives. They reported that freeze-thaw resistance of polypropylene fibre reinforced concrete slightly increased compared to non-fibrous concrete [8]. They reported that unit weights of concretes, reinforced with polypropylene fibre and fly ash in the ratio of 0.05%, 0.1% and 0.20% by volume , decrease even a little , workability decreases , workability increases with addition of fly ash .

The abrasion losses and water absorption values of the concrete, reinforced with fibre in the ratio of 0.2 % by volume, increased [9]. 900 g/m^{3}polypropylene fiber additive by weight increased concrete abrasion resistance from 0.2860% to 0.3966 [10]. 910 g/m^3 polypropylene fiber additive by weight increased concrete abrasion resistance by 21.24 % [11]. The abrasion losses of 0.18% was obtained in the concrete, reinforced with 425% polypropylene fibre by volume. It didn't have much effect on unit weight [12]. Water absorption and water permeability values of concrete, reinforced with 0.45 kg/m^3, 0.90 kg/m^3 and 1.80 kg/m^3 polypropylene fibre by weight, increased with fly ash and polypropylene fibre additives and wet shrinkage values of those decreased [13]. Industrial wastes and polypropylene fibre additive of 0.2 % by volume increased capillary absorption value and water absorption value by weight of concrete [14].

Water absorption values of concrete , reinforced with polypropylene fibre of 2 % by volume , and that of concrete ,in different water-cement ratios and reinforced with different plasticizer additives, decreased. Abrasion resistance value reliased as 0.8 in additive inclusion of 2%, and 1.97 in additive inclusion of 1% by volume [15].

It was stated that 3.5 kg/m^3-weighed fiber-reinforced concretes are effective, safe and low-cost solutions for road structuring; inside tunnels particularly noting [16]. Addition of 1%-volume fibres procured from recycled PETs increased the flexure strength of the concrete [17]. Addition of 0.1% and 0.5 %-volume polypropylene fiber on the other hand decreased compression and flexure strength of the concrete [18]. 12 mm-long polypropylene fiber additive containing metacholinium and art-of-stone-cutting flexure increased its deflection ratio in strength [19]. 0.25%, 0.50% and 0.75% polypropylene fiber ratio in different sizes decreased concrete density by 10%-30 but increased compression strength by a ratio of 14% [20]. 0.5%-volume polypropylene fiber additive lowered the compression strength by approximately 37.5% whilst this

ratio increased the flexure strength by 30% [21]. It was reported that fiber additive triggered high-unit deformation in low-strength concrete in particular and the fiber created a bridge effect whilst in high- strength concrete it diminished the bridge effect of fibres. It was thus concluded that fiber additive increased the ductility of concrete [22]. 1% and 1.5% volume carbon fiber additive, when pure concrete compression strength was measured as 52.8 MPa, compression strength values of carbon fibrous concrete fluctuated between the ratios of 51.2-53 MPa. It was thus concluded that not a significant amount of change occurred in compression strength [23].

Vertical abrasion and water absorption tests of concretes with hyper plasticizer and polypropylene fibre additives in different ratios were done in this study. The effect of polypropylene fibre additive and admixtures ratio on abrasion and water absorption of hardened concrete was analyzed. Splitting-tensile strengths of samples were analyzed. Besides, horizontal deformations in splitting-tensile strength were measured. Effects of different fibres on horizontal deformation were investigated.

2. Test Programs

2.1. Materials and Specimens

Only CEM I 42.5 R type cement was used as a binding agent. Admixture with hyper plasticizer was used. Amount of admixture was also increased with increasing of fiber in the mixtures. Thus, fluency of fresh concrete was preserved. The additive ratios in the mixtures were, 0.6%, 0.8%, 0.9% and 1.1% of weight of cement. Sand of 0-4 mm and crushed stone with dimensions of 7-15 mm and 15-22,4 mm were used as aggregate. As polypropylene fiber, 8 different fiber types listed such way A,B,C,D,E,F,G,H were employed (Figure 1).

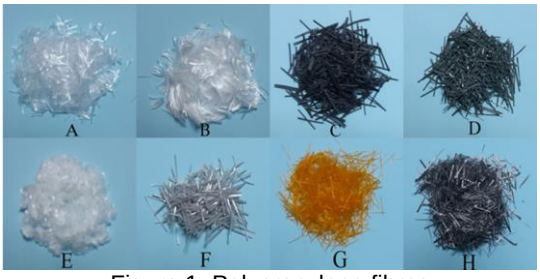


Figure 1. Polypropylene fibres

Table1. Technical properties of polypropylene fibers

Fiber	Length (mm)	Width (mm)	Thickness (mm)	Shape
A	12	0.48	0.30	Circular
B	19	0.48	0.30	Circular
C	30	1.20	0.30	Ribbed
D	30	1.20	0.45	Double Hook
E	30	0.48	0.30	Circular
F	40	0.433	0.433	Flat
G	18	0.3	0.50	Circular
H	20	0.6/1.3	0.18/0.22	Flat

2.2. Mixture ratios

Experimental studies were carried out on 25 series of concrete mixtures. One of these mixtures was a control mixture and the others were mixtures with polypropylene fibers. Fiber ratios in the mixture are 600, 1200 and 1800 g/m^3. The polypropylene fibers were indicated by A, B, C, D, E, F, G, and H. For example; A6 indicates containing an additive of 600 g/m^3 of fiber A, B12 indicates containing an additive of 1200 g/m^3 of fiber B, C18 indicates containing an additive of 1800 g/m^3 of fiber C. The control mixture was indicated with CNL. Water-cement ratio (W/C=0.52) was stabilized in all mixtures. The mixture ratios are given in Table 2.

Table2. The mixture ratios

Ingredients		CNL	Mixtures with fibre, (g/m^3)		
			600	1200	1800
Sand (0-4 mm)	(kg/m^3)	1127	1127	1127	1127
Gravel (7-15 mm)	(kg/m^3)	451	451	451	451
Gravel (16-22,4 mm)	(kg/m^3)	301	301	301	301
Water	(kg/m^3)	156	156	156	156
Cement	(kg/m^3)	300	300	300	300
Polypropylene Fiber	g/m³	-	600	1200	1800
Admixture	%	0,6	0,8	0,9	1,1
Water-cement ratio	W/C	0.52	0,52	0,52	0,52
Unit weight	(kg/m^3)	2335	2335	2335	2335

3. Concrete Tests and Findings

3.1. Fresh Concrete Properties

The slump value of the control sample was measured as 170 mm. The slump values of the mixtures were measured in the range of 150-190 mm. The compression factors of the mixtures were measured in the range of 0.89-0.99. Fiber additive decreased workability and increased plasticizer additive need. It was observed that fiber additives, being added into mixtures, decrease workability of fresh concrete. Fiber aggregation and segregation weren't observed in the mixtures with fiber additive of 600 and 1200 g/m^3. However, when the amount of fiber in the mixture exceeded the value of 1800 g/m^{3,} aggregation and segregation were observed (Table 3). Therefore, the amount of fiber didn't exceed the value of 1800 g/m^3.

Table3. Fresh concrete properties

Mixture	Slump (cm)	C.F	Mixture	Slump (cm)	C.F
CNL	**17**	**0.97**	**CNL**	**17**	**0.97**
A/6	17	0.97	E/6	17	0.96
A/12	18	0.93	E/12	16	0.95
A/18	16	0.91	E/18	15	0.94
B/6	16	0.94	F/6	15	0.96
B/12	17	0.89	F/12	17	0.96
B/18	15	0.89	F/18	17	0.94
C/6	16	0.99	G/6	16	0.95
C/12	19	0.93	G/12	17	0.95
C/18	17	0.93	G/18	18	0.94
D/6	17	0.93	H/6	18	0.95
D/12	17	0.94	H/12	19	0.96
D/18	17	0.95	H/18	19	0.96

3.2. Vertical abrasion Test

Test was done, abrading the samples, 70x70x115mm in size, prepared in accordance with the EN 1338 standard, with F80 aluminum oxide abrasive powder in 75 min/cyclic at vertical abrasion device. The abrasion depths were measured from three points on the abraded surface and the average depth of abrasion was calculated (Figure 2,3).

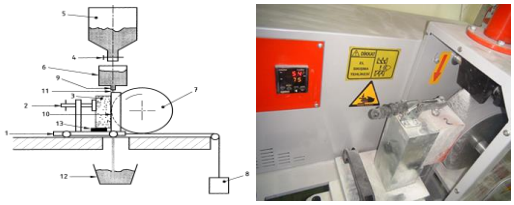


Figure 2. Vertical Abrasion Test Device

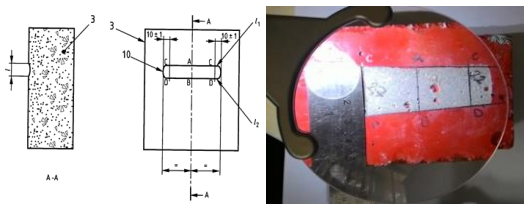


Figure 3. Measurement of Abrasion Depths

Abrasion widths on the samples were measured at the end of the test. Abrasion widths of C12, D6, D12 and E12 samples were measured lower than those of control sample. In other words, these samples exhibited less abrasion compared to control samples. The abrasion widths of other samples were measured higher than those of control sample. The abrasion width of the control sample was measured as 21.5 mm. The abrasion widths of the fibrous samples vary between 20 mm and 27.5 mm. The highest abrasion width was measured at the sample C6.The lowest abrasion width was measured at the sample D6 (Figure 4).

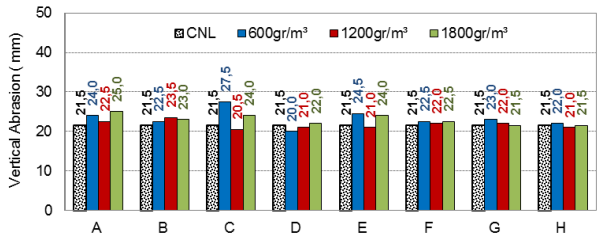


Figure 4. Vertical Abrasion Test Results

3.3. Water Absorption Test

The samples, weighing less than 5 kg, were prepared for total water absorption test. The samples dimensions were 70x70x115 mm. The samples prepared were maintained in the container filled with water until they reached to a constant mass (M_1) at temperature of 20±5 ^{0}C. The water layer was adjusted in such a way that it would be kept at least 20 mm over the samples. The samples were maintained in water at least for 3 days and weighed every 24 hours. The samples, getting out of water for weighing operation, were dried with a damp cloth, soaked and dewatered. Then weighing was conducted.

When the mass difference between two successive weighing yields less than 0.1%, steady saturated mass was considered to be reached. The samples, considered to have reached to saturated mass, were placed to a drying oven so as to remain at least 15 mm distance between them, and they were dried until reaching to a constant dry mass (M_2) at temperature of 105±5 ^{0}C. The samples were maintained in the drying oven at least for 3 days and weighed every 24 hours. When the mass difference between two successive weighing yields less than 0.1%, constant mass was considered to be reached.

The water absorption value (Wa) of each sample was calculated (Figure 5). Fiber ratio and admixtures contained in the mixtures increased water absorption values of the samples. The water absorption value of the control sample was calculated as 3.43%. The water absorption values of the fiber mixtures vary between 2.79% and 4.63%. The lowest water absorption value was calculated in D12 mixture, the highest water absorption value was calculated in F12 mixture. The water absorption value increased in all fiber and admixture ratios of the mixtures with B, E and H fibers. It exhibited change depending on ratio of fiber and additive in other fibers.

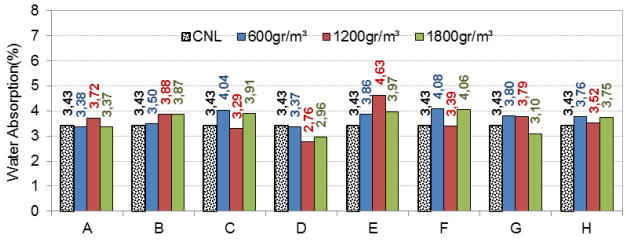


Figure 5. Water Absorption

3.4. Splitting-tensile experiment

7-day and 28-day splitting-tensile strengths of cylinder samples were measured as per EN 12390-6 standard. As 7-day splitting-tensile strengths are analyzed it can be argued that as fiber content in C and G fibrous mixtures increased, a corresponding rise was measured in their splitting-tensile strengths. The highest splitting-tensile strength in fibrous mixtures A was measured in A6 sample. In A12 sample it decreased compared to A6 sample but in A18 sample it increased compared to A12 sample. The highest splitting-tensile strength in fibrous mixtures B was measured in B6 sample. Splitting-tensile strengths of B12 and B18 samples received approximate values.

The highest splitting-tensile strength in fibrous mixtures D was measured in D6 sample. Splitting-tensile strengths of D12 and D18 samples were measured as lower compared to D6 sample. In fibrous mixtures E and F splitting-tensile strengths of E6 and F6 samples were measured to be lower compared to control sample. In E12, E18, F12 and F18 samples as the fiber amount in mixture increased their splitting-tensile strengths demonstrated a parallel rise. In the 7-day splitting-tensile strength, the best performance was observed in fibrous mixtures H. In H12 sample splitting-tensile strength increased by 92,99% compared to control sample (Figure 6).

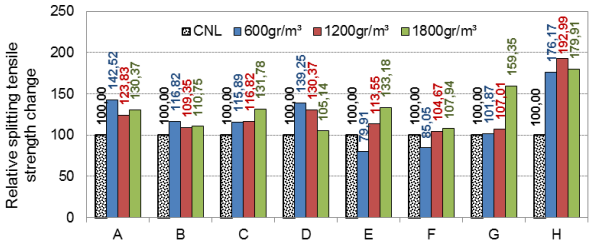


Figure 6. Relative Splitting-tensile strength chance

As 28-day splitting-tensile strengths were analyzed it was spotted that splitting-tensile strengths of F6 and G6 mixtures were measured to be lower compared to control sample. In the rest of mixtures, splitting-tensile strengths varied with respect to fiber ratio. In the entire set of mixtures, there was a relative rise compared to control sample. The best performance was measured in fibrous mixtures H. The highest splitting-tensile strength was measured in mixture H12. 7-day and 28-day splitting-tensile strengths of fibrous mixtures H were identical (Figure 7).

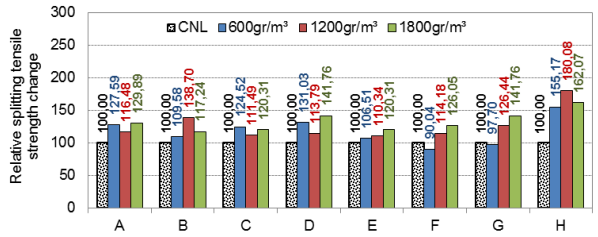


Figure 7. Relative Splitting-tensile strength chance

3.5. Horizontal deformation

Horizontal deformations of samples in splitting-tensile experiment were measured. In splitting-tensile experiment the transducer, positioned in the exact center of the sample, could measure horizontal deformation in both sides (Figure 8).

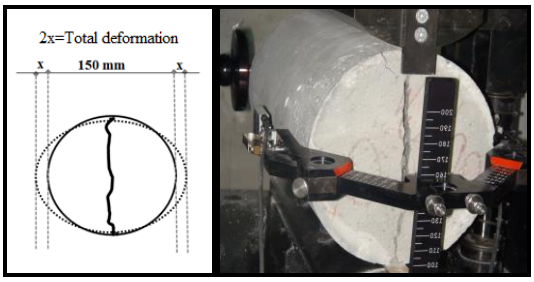


Figure 8. Horizontal deformation measurement

As horizontal deformations in splitting-tensile strength were analyzed it was identified that in 7-day samples, among all mixtures with B, D, E, F and G fibers, horizontal deformation value declined compared to control sample. The lowest deformation was measured in sample E6. In sample E6it decreased approximately by 41% compared to control sample. In fibrous mixtures A it increased in fiber A6 solely. This same value decreased in other mixtures. In fibrous mixtures C there was a slight rise. The highest horizontal deformation increase was measured in fibrous mixtures H. In sample H6, there was a rise of 138% (Figure 9).

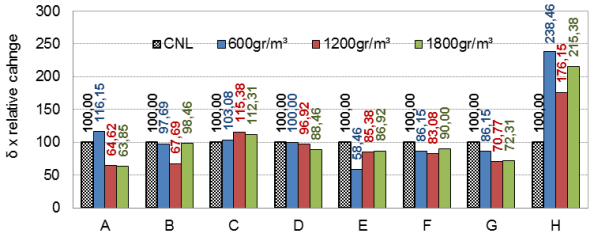


Figure 9. Horizontal deformation change (7-day)

As 28-day horizontal deformations of samples are analyzed it can be detected that horizontal deformation values of samples B12, D12, E12 and G12 increased compared to control sample whereas in other fiber ratios there was a fall. Within all fiber ratios the ratio was lower compared to control sample in A and F fibrous mixtures. Horizontal deformation of sample C6, compared to the rise in control sample, decreased in the rest of fiber ratios. The best horizontal deformation value was once again measured in H fibrous mixtures. Horizontal deformation value of H12 sample increased approximately by 83% (Figure 10).

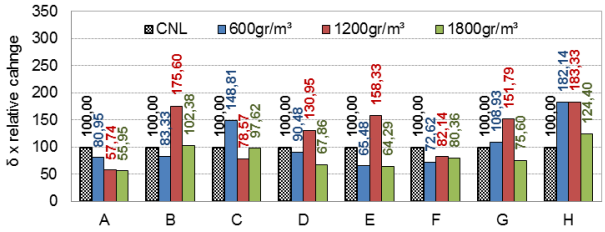


Figure 10. Horizontal deformation change (28-day)

Figure 11 displays the images of certain samples in the aftermath of splitting-tensile strength. As the amount of fiber additive in the mixture climbed, there was less disintegration of the sample. Specific fibres performed a better bridge performance between two parts. Fibers C and D in particular performed better as bridges since they were clip-hook and ribbed shape. The same instance was evident in fiber H as well. This instance also positively contributed to horizontal deformation at the moment of splitting-tensile.

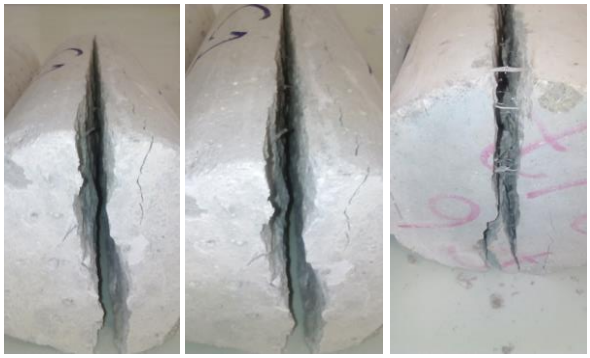


Figure 11. Post-experiment samples

4. CONCLUSIONS

It was seen that polypropylene fiber additive in mixture decreases workability of fresh concrete. Plasticizer additive increases with increasing of fiber additive as well. It was seen that segregation occurred especially when fiber additive of 1800 g/m^3 was exceeded and fibers formed aggregation in mixture. Therefore, fiber additive is recommended not to exceed value of 1800 g/m^3 for the performance of fresh concrete. The abrasion width of the control sample was measured as 21.5 mm. The abrasion widths of the fibrous samples vary between 20 mm and 27.5 mm. The highest abrasion width was measured at the sample C6.The lowest abrasion width was measured at the sample D. It can be said that amount of fiber additives and admixtures in mixtures haven't a positive effect on concrete abrasion.

Fiber ratio and admixture in mixtures increased water absorption values of the samples. This case can be explained with more easily penetration of water into gaps, formed by fibers in concrete. Water absorption value of the control sample was calculated as 3.43%. Water absorption values of fibrous mixture vary between 2.79% and 4.63%.

Fibres increased the splitting-tensile strength of concrete. In fibrous mixtures, 7-day the highest splitting-tensile strength was measured in H12 sample and the lowest value was measured in E6 sample. Splitting-tensile strengths of 7-day E6 and F6 samples were measured to be lower than splitting-tensile strength of control sample. 28-day highest splitting-tensile strength was measured in H12 sample and the lowest value was measured in F6 sample. 28-day splitting-tensile strengths of all mixtures were measured to be higher than 7-day splitting-tensile strengths. In splitting-tensile strength the best performance was measured in fiber H. 7 -day splitting-tensile strength of H12 sample increased around 93%, whilst 28-day splitting-tensile strength roughly increased by 80%.

In horizontal deformation the best performance was measured in fibrous mixtures H. In all fibres except fiber H, horizontal deformation values of 7-day samples primarily decreased. In H-fibrous 7-day samples, horizontal deformation value increased approximately by 138%. In H-fibrous mixtures among 28-day samples there was an approximate increase by 83%. It can be argued that fiber H provided the concrete a better level of ductility. In 28-day horizontal deformations of samples, particularly in 1200 g/m^3 fiber ratio, there was a significant improvement.

In connection with the rise of fibers in mixtures there was less disintegration in the sample utilized for splitting-tensile experiment. It was identified that fibres played the role of a bridge between two separated parts in splitting-tensile experiment. The incident was more evident in fibres C, D and H at most. Since fibres C and D were clip-hook and ribbed it was evidenced that fibres enabled greater bonding with the mortar. Conducted experiments manifested that the best ideal fiber ratio was between the range of 600 and 1200 g/m^3. As the fiber ratio inside concrete exceeded 1200 g/m^3 it started to pose a negative impact on the splitting-tensile strength and deformation.

References

[1]. Kurt, G., "Effects of Finre Content and Water-Cement Rate on the Mechanical Behaviours of the Fibro-concrete", Master's Thesis, İstanbul University Institute of Science, Construction Engineering Department, İstanbul, 2006.

[2]. Altun, F., Tanrıöven, F. and Dirikgil, T., "Experimental İnvestigation of Mechanical Properties of Hybrid Fiber Reinforced Concrete Sample Sand Prediction of Energy Absorption Capacity of Beams by Fuzzy-Genetic Model", Construction and Building Materials, 44, 565-574. 2013.

[3]. Kunieda, M., Ueda, N. and Nakamura, H., "Ability of Recycling on Fiber Reinforced Concrete", Construction and Building Materials, 67, 315-320. 2014.

[4]. Noushini, A., Samali, B. and Vessalas, K., "Effect of Polyvinyl Alcohol (PVA) Fibre on Dynamicand Material Properties of Fibre Reinforced Concrete", Construction and Building Materials, 49, 374-383. 2013.

[5]. Campelloa, E., Pereirab, M.V. and Darwish, F., "The Effect of Short Metallic and Polymeric Fiber on the Fracture Behavior of Cement Mortar", Procedia Materials Science, 3, 1914–1921. 2014.

[6]. Pliya, P., Beaucour, A.L. and Noumowé, A., "Contribution of Cocktail of Polypropylene and Steel Fibres in İmproving the Behaviour of High Strength Concrete Subjected to High Temperature", Construction and Building Materials, 25, 1926–1934. 2011.

[7]. Martinez-Barrera, G., Urena-Nunez, F., Gencel, O. and Brostow, W., "Mechanical Properties of Polypropylene Fiber Reinforced Concrete after Gamma İrradiation, Composites: Part A, 42, 567–572. 2011.

[8]. Karahan, O. and Atiş, C.D. "The Durability Properties of Polypropylene Fiber Reinforced fly ash Concrete", Materials and Design, 32, 1044–1049. 2011.

[9]. Karahan, O., "Properties of Fibre-Supported Fly Ash Concretes", Dissertation, Çukurova University, 274s. 2006.

[10]. Arslan, M., Subaşı, S., Durmuş, G., Can, Ö. and Yıldız, K., "Alternative Concrete and Production Method Researches in Concrete Road Covering,", Gazi University Scientific Research Project Ankara, Turkey, 145s. 2007.

[11]. Grdic, Z.J., Curcic, G.A.T., Ristic, N.S. and Despotovic, I.M., "Abrasion Resistance of Concrete Micro-Reinforced with Polypropylene Fibers", Construction and Building Materials, 27, 305-312. 2012.

[12]. Bolat, H., Şimşek, O., Çullu, M., Durmuş, G. and Can, Ö., "The Effects of Macro Synthetic Fiber Reinforcement Use on Physical and Mechanical Properties of Concrete", Composites, 29, (in press). 2014.

[13]. Alani, A.M. and Beckett, D., "Mechanical Properties of a Large Scale Synthetic Fibre Reinforced Concrete Ground Slab", Construction and Building Materials, 41, 335-344. 2013.

[14]. Özcan, A., "Industrial Waste and Polypropylene Fibre Area Concrete Properties Research", Master's Thesis, Zonguldak Karaelmas University, 83s. 2006.

[15]. Açıkgenç, M., Arazsu, U. and Alyamaç, K.E., "Resistance and Durability Properties of Polypropylene Fibre Concretes with Different Mixture Rates", SDU International Technologic Science, 4, 41-54. 2012.
[16]. Nobili, A., Lanzoni, L. and Tarantino, A.M., "Experimental İnvestigation and Monitoring of a Polypropylene-Based Fiber Reinforced Concrete Road Pavement", Construction And Building Materials, 47, 888-895. 2013.
[17]. Fraternali, F., Ciancia, V., Chechile, R., Rizzano, G., Feo L., and Incarnato, L., "Experimental Study Of the Thermo-Mechanical Properties Of Recycled PET Fiber-Reinforced Concrete", Composite Structures, 93, 2368-2374. 2011.
[18]. Manolis, G.D., Gareis, P.J., Tsonos, A.D., and Neal, J.A., "Dynamic Properties of Polypropylene Fiber-Reinforced Concrete Slabs", Cement And Concrete Composites, 19, 341-349. 1997.
[19]. Rashiddadash, P., Ramezanianpour, A.A., and Mahdikhani, M., "Experimental Investigation on Flexural Toughness of Hybrid Fiber Reinforced Concrete (HFRC) Containing Metakaolin and Pumice", Construction and Building Materials, 51, 313–320. 2014.
[20]. Yap, S.P., Alengaram, U.J., and Jumaat, M.Z., "Enhancement of Mechanical Properties in Polypropylene and Nylon Fibre Reinforced Oil Palm Shell Concrete", Materials and Design, 49, 1034-1041. 2013.
[21]. Wang, H., and Belarbi, A., "Flexural Durability of FRP Bars Embedded in Fiber Reinforced Concrete", Construction and Building Materials, 44, 541-550. 2013.
[22]. Cifuentes, H., García, F., Maeso, O. and Medina, F., "İnfluence of the Properties of Polypropylene Fibres on The Fracture Behaviour of Low, Normal and High-Strength FRC", Construction And Building Materials, 45, 130-137. 2013.
[23]. Tabatabaei, Z.S., Volz, J.S., Keener, D.I. and Gliha, B.P., "Comparative İmpact Behavior of Four Long Carbon Fiber Reinforced Concretes", Materials and Design, 55, 212–223. 2014.