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PROPERTIES OF CONCRETE PAVEMENTS PRODUCED WITH DIFFERENT TYPE OF FIBERS

(This article was presented first to the PPM2017, then submitted to JOTCSB as a non-peer-reviewed article)

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Abstract: Researches demonstrate that fibers boost performance of concrete incredibly. It's determined that in literature steel fibers increase flexural strength and energy absorption capacity of the cementitious composites. However concrete highways consist of steel fibers in corrosive conditions eliminate fiber's effect. Therefore producers of polymeric fibers launch fibers which can withstand corrosive environments and chemicals, and launch polyester and polypropylene fibers alternative to steel fibers. This research intends to determine the performance of concretes consist of polyester fiber, polypropylene fiber and steel fiber against traditional concrete. For this reason, fresh and hardened concrete properties of the concrete mixtures produced with 0%, 1% and 2% are determined by laboratory tests. The mechanical behaviors of these concrete specimens are investigated by compressive strength and tensile strength tests on 150x150x150 mm cubic and 100x100x500 mm prismatic specimens respectively. The abrasion resistance of the pavement concrete is measured by Bohme abrasion test on 70x70x70 mm cubic specimens. Test results showed that fibers are reinforced concrete against external effects which can be occurred during the service life of the rigid pavements. Significant developments are determined with the polymer fiber additives on concrete abrasion resistance and mechanical behavior of concrete.

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INTRODUCTION

Concrete has many advantages due to its fresh and hardened properties however; brittleness and lower tensile strength are the weakest points of this widely used construction material. Technical properties of concrete can be improved by adding different materials to concrete. Today, the necessity of using concrete in different areas has led to some developments in concrete technology. One of these developments is the production of fiber reinforced concrete. Adverse weather conditions, heavy service loads and corrosive environments are the harmful factors that reduce the service life of concrete. When the fibers are placed as a component in the concrete it is possible to reduce these harmful effects of such factors [Singh and Kaushik, 2003].

The fibers are very effective and useful when they are homogeneously dispersed in concrete and used in the most suitable amount. The main function of the fibers is to reduce the cracks while at the same time increasing the toughness of the composite. For example, while steel fibers are under the influence of stress and tensile forces, steel fibers prevents a large number of micro cracks [Simsek, 2016]. It is recommended that superplasticizing agents should be used instead of more water to avoid loss of workability in micro synthetic fibers and to facilitate the use of fiber reinforced concrete mix. As a result of researches carried out by researchers, it has been found out that steel fibers are important structural contributions to concrete. However, continuous exposure of concrete road pavements to adverse weather conditions and heavy traffic loads, in other words, continuous fatigue due to repeated loads and persistent corrosive environment, may cause the steel fibers to lose their properties over time [Choi and Chen, 2005].

In this study, we investigated the usability of concretes produced with steel, polyester and polypropylene fiber in highway superstructure concrete. For this reason, reference concrete specimen was produced at C30 strength class therefore the improvements of fiber concrete was compared and determined with the help of experimental study results.

Concrete Pavement

The road pavement is divided into asphalt pavement and concrete pavement according to the materials used. The former and the latter are classified as a flexible pavement and a rigid pavement, respectively, according to the stiffness of the pavement system. The use of concrete pavements has been grown over the past few decades because concrete pavements
Have superior durability and longer structural life than asphalt pavements, and supply and demand analysis of its material is relatively easy [Yang *et al*., 2017]. However, rigid pavement application is not widely used in Turkey when compared with elastic pavement. This choice cause high import cost of bitumen.

Concrete coating is rigid and it works like a plate that rests on an elastic soil and spreads the loads on it to a much wider area and transmits it to the soil. For this reason, the concrete coating, which is a rigid superstructure, gives better results on weak soils compared to flexible superstructures. As a result, in roads under heavy traffic, concrete pavement application is much better and more convenient due to its durability [Davis *et al.,* 2004]

Fiber Reinforced Concrete

The energy absorption capacity of the concrete and the increase of its ductility and the stopping of the crack progression are the important properties that fibers give to concrete. Already the most important feature of joining steel fibers to concrete is these properties. The energy factor also plays an important role in both the design of the mix and the static calculations made for industrial floor concrete, heavy concrete, prefabricated concrete elements and concrete elements that are exposed to heavy loads in developed countries such as America, Japan, Norway and Netherlands [Yerlikaya, 2005].

In general, as fiber length and amount increase, the energy absorption capacities of plate concretes also increase. While the fibers do not significantly affect the ultimate fracture strength of the concrete, the energy swelling feature is increased in significant amounts. Researchers stated that steel fiber reinforced concrete and polypropylene fibrous concretes show higher strength than those of rebound hammer and high surface hardness and compressive strength non-fiber concrete respectively. It is stated that in the abrasion test made in the same work, the fiber reinforced concrete suffers less abrasion loss [Can *et al.,* 2009].

MATERIALS AND METHOD

Materials

The experimental studies were performed in Bilecik Seyh Edebali University, Materials Science Laboratory. The raw materials for the fiber reinforced concrete pavement production were obtained from different sources. The CEM I 42.5 R type Portland cement was supplied from SANÇİM cement factory. Aggregates were supplied from Dağ-İş ready mixed concrete plant in dimension with 0-5 mm, 5-12 mm and 12-22 mm. The consistency of concrete is adjusted by using GRACE Dracem 200 superplasticizing agent. The steel fiber concrete (SFC) mixtures are prepared by using Bekaert RC-65/60-BN type low carbon steel fibers. The polypropylene fiber concrete (PPFC) mixtures are produced by using Polyfibers Mono 18 type fiber. The polyester fiber was supplied from Polifibers Company named as Polymacro 39 for the production of the polyester fiber concrete (PLFC) mixtures. The fibers used in this study can be seen on Figure 1.

Figure 1: Fibers used in this study.

Method

Before the production of the FRC, the particle size distribution of aggregates is determined by sieve analysis. The unit weight and water absorption tests were performed on oven dry aggregate specimens. Mix designs of the specimens are performed according to the characterization results of the ingredients. Reinforcement fibers are used at 1% and 2% replacement ratios. The workability of the fresh FRC are determined by slump test. Compressive strength and ultrasound pulse velocity (UPV) tests are performed on 150×150×150 mm cubic specimens by uniaxial compression testing apparatus. Flexural strength is determined on prismatic 100×100×500 mm specimens. The abrasion resistance of the FRC specimens is determined with 70×70×70 mm cubic specimens by using Dorry abrasion testing device (Figure 2). These specimens were cured in lime saturated water at 20±3°C for 7 and 28 days. The pore structure of the FRC specimens is evaluated by ultrasound pulse velocity (UPV) test.

Figure 2: Bending and abrasion tests.

TEST RESULTS

Aggregate Analyses and Design

Physical properties of the aggregates are presented in Table 1.

Table 1: Physical properties of the aggregates.

Aggregate	Specific Gravity	Humudity (%)
0-5 mm	2.42	1.5
5-12 mm	2.58	1.25
12-22 mm	2.58	1.05

The sieve analyses of the aggregates are determined and shown in Table 2. The amounts of the aggregates are calculated depending on these results.

Table 2: Sieve analyses of the aggregates.

Sieve Opening mm	Passing 0-5 %	5-12 %	12-22 %
31.5	100	100	100
16	100	100	51.13
8	100	80.60	48.65
4	98	8	0
2	74.25	0.95	0
1	30.35	0	0
0.5	8.64	0	0
0.25	2.34	0	0

Mix design of the reference and fiber reinforced concrete specimens are given in Table 3. Cement dosage is taken as 350 kg/m^3 with water cement ratio of 0.5.

Table 3: Mix design of the FRC specimens for 1 m^3

Mixture	Cement kg	Water kg	0-5 kg	5-12 kg	12-22 kg	Plasticizer kg	Fiber kg
Reference	350	175	780	608	402	4.1	-
PPFC1	350	175	772	608	402	4.1	2.92
PPFC2	350	175	764	608	402	4.1	5.84
PYFC1	350	175	772	608	402	4.1	3.02
PYFC2	350	175	764	608	402	4.1	6.04
SFC1	350	175	772	608	402	4.1	23.7
SFC2	350	175	764	608	402	4.1	47.4

Workability and Unit Weight

Workability of the FRC specimens are obtained by slump test. According to test results the consistency of concrete is reduced with the fiber usage. Polypropylene fiber reduced the slump value 33 % for the PP2 mixture. These results are shown in Table 4.

Table 4: Slump and unit weight results

Mixture	Slump mm	Unit Weight kg/m^3
Reference	75	2472
PPFC1	55	2419
PPFC2	50	2311
PYFC1	65	2450
PYFC2	55	2382
SFC1	70	2484
SFC2	70	2454

Ultrasound Pulse Velocity

The UPV values of the specimens are given in Figure 3. The fiber usage affected the UPV values of the FRC.

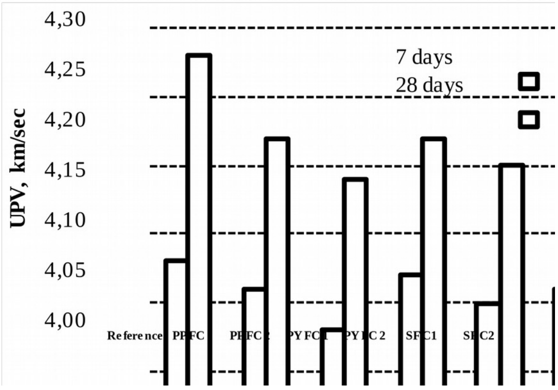

Figure 3: UPV test results of FRC.

According to the results, the UPV values are reduced slightly with the increased amounts of fiber usage. This behavior can be dependent on the reduced workability and compaction with the increased porosity of the FRC specimens. Polypropylene fiber showed higher reduction for the PPFC2 mixture.

Compressive & Flexural Strength

The compressive strength of the FRC specimens is presented in Figure 4. As seen from the results, the optimum fiber usage ratio is 1%. PYFC1 showed 11% higher strength than the reference concrete. Polymer fibers showed better performance than steel fiber for the compressive strength test results.

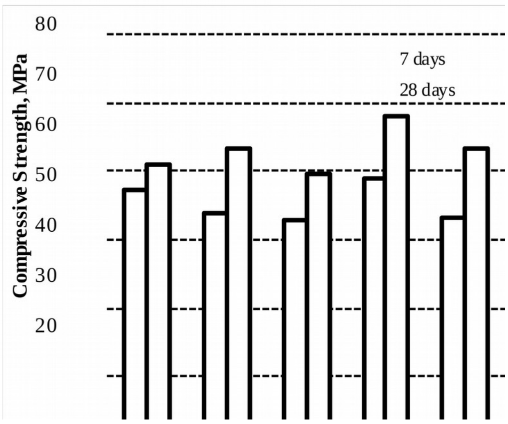

Figure 4: Compressive strength results.

The four point flexural strength test results are given in Figure 5. According to test results all fiber types increased the flexural strength of the FRC specimens. The strength values increased up to 25% when compared with the reference concrete specimen. Steel fiber showed better performance than other polymer fibers especially for the 2% utilization ratio. Polyester fiber reached 16.38 MPa for the 1% usage at 28 day strength result. These results showed that fiber usage in concrete composite is more effective for the tensile property of the concrete than the compression behavior.

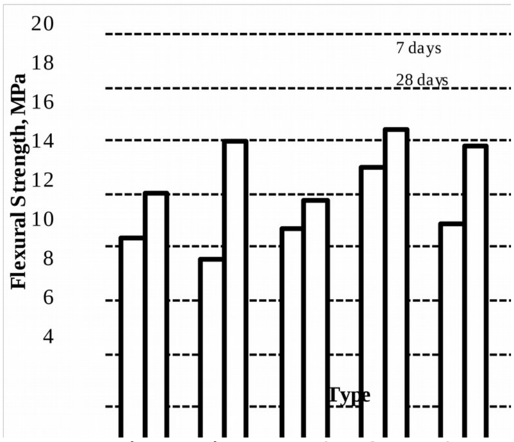

Figure 5: Flexural strength of specimens.

Abrasion Resistance

Abrasion resistance test was carried out on 28-day cured concrete specimens. Test results of the FRC specimens are given in Table 5. According to test results it can be clearly concluded that addition of fiber in concrete increased the abrasion resistance of concrete. Polymers are more effective than steel fiber for this property.

Table 5: Abrasion results of FRC.

Mixture	Abrasion by Volume %	Abrasion by Weight %
Reference	5.57	4.84
PPFC1	4.14	3.50
PPFC2	3.86	4.04
PYFC1	4.57	3.93
PYFC2	4.29	3.67
SFC1	5.71	4.69
SFC2	5.86	4.51

CONCLUSIONS

According to results of this study the following conclusions can be drawn out.

- The fresh workability properties of FRC reduced with the increased utilization amounts.
- Superplasticizers should be used in these mixtures to overcome this problem.
- Rigid pavements generally subjected to compression, bending and abrasion effects under heavy traffic loads. Utilization of fibers in these pavements will increase the performance of the concrete pavements against harmful effects.
- Polymer fibers are more effective on strength & abrasion behavior of FRC.

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