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MECHANICAL CHARACTERIZATION OF RECYCLED POLYPROPYLENE AND COPOLYMER MACRO FIBERS IN CONCRETE

Mehmet Alpaslan KÖROĞLU
[1]Necmettin Erbakan University, Engineering & Architectural Faculty, Konya, TURKEY
makoroglu@konya.edu.tr

Abstract: *Waste materials have been an increasing problem every year. Disposal of waste materials has presented very serious problems to the human community in the world. Currently, some research has been studied to the recycle of different wastes in concrete. Recent study is focusing on the usage of a unique blend of recycled polypropylene and copolymer macro fibers (RPCMF) designed specifically for concrete mixture. The different weight of RPCMF is mixed in concrete to in order to investigate the effect on mechanical properties. By adding RPCMF obtained a satisfactory improvement on cracking control, compressive strength, flexural strength and also tensile strength, Moreover, compressive, flexural and tensile strength was positively affected by the addition of RPCMF for some mixtures. More percentage of weight fractions added gives high result in tensile strength. However, the workability of the concrete reinforced with RPCMF was negatively affected.*

Keywords: Recycled Polypropylene, Copolymer Macro fiber, concrete, compressive strength, flexural strength

1. Introduction

Polypropylene (PP) fibers have been widely used to reinforce concrete as an alternative to steel fibers. The reinforcing effect of the PP fiber is directly proportional to its tensile strength and Young modulus. Polypropylene fibers have been widely used in concrete, plaster, mortar, and shotcrete applications nowadays. The additions of these fibers to concrete considerably improve the structural characteristics of concrete such as flexural strength, impact strength, tensile strength, ductility and toughness [1].

Polypropylene fibers are manufactured in different size and shape, and with various properties which are hair-like or made of plastic with the chemical structure containing a long chain of individual molecules.

PP fibers are manufactured with three different geometrics. Monofilaments, film and extruded tape are the typical PP geometries which the last two forms are used widely for concrete reinforcement [2]. The PP has a high melting point (165°C), alkali resistance and low cost of raw material but has a low tensile strength [2]. And also, since it is hydrophobic material, water absorption of pp is zero that leads preventing adhesion to the concrete [3]. However, PP has some weakness points such as: sensitivity to oxygen and sunlight, poor fire resistance, low modulus of elasticity and poor bond with the matrix [2].

The objective of the current research is to study the mechanical properties of concrete reinforced individually with weight percentage of with 0.125, 0.25, 0.5 % of RPCMF to evaluate their strength.

2. Materials and Method

Recycled polypropylene and copolymer macro fibers (RPCMF) is a unique blend of recycled polypropylene and copolymer macro fibers produced for concrete applications that consists of 100% recycled polypropylene fibrillated (network) fibers and a high-performance twisted-bundle macro-monofilament fiber. The specific gravity of RPCMF is 0,9 and has the tensile strength of 570 MPa. 58 mm length RPCMF is used in this study (Figure 1).

Fig. 1 *Recycled polypropylene and copolymer macro fibers*

Following materials utilized in the present research:

Ordinary Portland cement according to TS EN 197-1, CEM I 32.5 R cement was used for every concrete mixture. Raw materials used in this research include cement, fine aggregate (natural river sand), coarse aggregate and fibers. Natural river sand with a maximum size of 5 mm, specific gravity of 1.52, SSD water absorption of 1.37%, and SSD density of 2512 kg/m^3 was used in this study. Course aggregate with a max a maximum aggregate size of 15 mm was used. Specific weight of course aggregate is found as 2690 kg/m^3 and SSD water absorption of 0.6 %. Both natural river sand and course aggregates were batched in a dry condition.

For preparation of all the samples, a water–cement ratio (w/c) of 0.55 (by weight) was used. Table 1 represents the details of the mixture proportions.

Table 1. *Concrete mix design*

Sample	Fine Aggregate (gr)	Course Aggregate (gr)	Cement (gr)	Water (gr)	Weight Percent (%)
Reference	18090	22110	9900	5400	0
0,125%	18090	22110	9900	5400	0,125
0,25%	18090	22110	9900	5400	0,25
0,5%	18090	22110	9900	5400	0,5

All standard steel moulds for cubes, cylinders and prisms specimens has been prepared by oiling the inner surface of the formwork before casting in order to remove the mould after the concrete hardened.

Concrete mixing process was performed to ensure that steel fibers were distributed uniformly in the concrete mix. In the first stage, all ingredients (cement, fine aggregate, water and course aggregate) were mixed well then after steel fibers are added gradually.

2.2. Slump Test

In order to obtain workability of fresh concrete mixture slump test is applied to all mixtures (Figure 2). Slump height for the control specimen which is plain concrete is 90 mm. Slump height was decreased since the addition of fiber into concrete mixture. From 0.125% until 0.5%, the slump height was decreasing. Slump height is calculated to be 70 mm for 0.125% of fiber weight, 45 mm for 0.25% of fiber weight and 20 mm for 0.5% of fiber weight. It is indicates that the slump of the mixture was decreased when the RPCMF content increased.

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Fig. 2 *Slump test*

The compressive strength test for the cubes was applied at the ages of 28 days. A total of 18 concrete cubes with the dimensions of 150×150×150mm were prepared. 3 specimens were prepared for each percentage weight fraction of RPCMF (0.0%, 0.125 %, 0.25%, 0.5 %). ASTM C 109 is use to determine compressive strength for the concrete that is used in this study (Figure 3.).

Fig. 3*. Compressive strength test*

A total of 3 prismatic specimens with the overall dimensions of 150×150×400 mm were tested for each percentage weight fraction of RPCMF (0.0%, 0.125 %, 0.25%, 0.5 %). The 3 point flexure test was carried out at the age of 28 days with the standard of ASTM D790 (Figure 4.).

Fig 4 *Beam specimen after 3 point flexure test*

The results of split tensile strength test were based on cylinders with various weight fraction of tire fiber for 28th days. In the course of split tensile strength test, specimens were tested by applying an increasing load throughout the vertical diameter until split failure occurs. Failure of the specimens comes of along its vertical diameter, owing to tension developed in the transverse direction.

3. Results

The concrete properties with different weight fraction of RPCMF are summarized in Table 2.

Table 2*. Concrete properties with different weight fraction of RPCMF*

Weight of Fiber %	Slump (mm)	Unit Weight (kg/m^3)	Compressive Strength (MPa)	Flexural Strength (MPa)	Tensile Strength (MPa)
0	90	2210	25,05	2,99	2,36
0,125	70	2232	27,96	3,11	2,57
0,25	45	2239	30,68	4,29	2,64
0,5	20	2255	30,93	4,38	2,79

From Table 2. above, the highest average compressive strength is is at 0.25% which is 30.68 MPa of fiber weight whereas the lowest strength is at 0% which is 28.05 MPa. Although stress for 0.5% fiber weight sample is lower than 0.125% fiber weight sample, the strain is more. Figure 5. shows that increasing fiber content also increase ductility of the concrete under compression force. Increasing fiber content not only develop ductility of concrete but also compression strength.

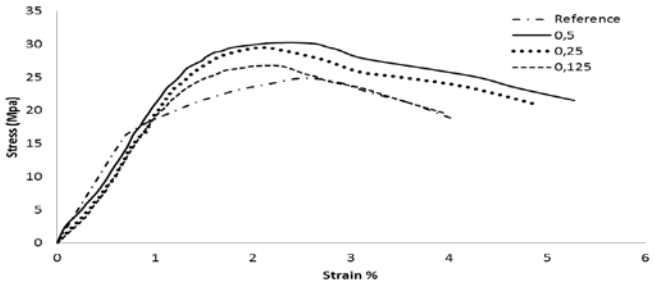

Fig 5*. Stress-strain diagram for RPCMF concrete*

Result of tensile strength of the control cylinder is found to be 2.36 MPa and decrease until 2.57 MPa at 0.125% and increase again at 0.25% which is 2.64 MPa. It is seen from Table 2., the highest flexural strength is at 0.5% of fibre content which is 4.38 MPa and the lowest strength is at 0% of fibre volume which is 2.99 MPa.

4. Conclusions

This research has proved that the performance of RPCMF reinforced concrete is much better compare to conventional plain concrete. The conclusions from this research based on the experimental results are:

- The test result shows that as the fiber weight of fraction increase the workability tend to decrease significantly. Moreover, it can be realized that, the slump test decreases when the weight of fiber increases.
- RPCMF reinforced concrete may be used in order to increase the mechanical properties of concrete. High percentage of weight fraction gives high flexural strength of the concrete.
- The concrete with RPCMF absorb more energy before and after fail. The RPCMF in concrete grips the concrete particles when load is applied on it until failure.
- The crack opening width can be controlled by using RPCMF in concrete.
- Split tensile test and 3 point flexural test indicate that concrete reinforced with RPCMF has much greater toughness compared to plain concrete. The cylinder does not split during tensile test since the presence of RPCMF in concrete. Moreover, concrete prism also does not break into two because of the RPCMF reinforced in concrete.

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