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PROPERTIES OF CONCRETE CONTAINING PET PLASTIC WASTE FROM POST-CONSUMED BOTTLES

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Abstract: *Nowadays, plastic wastes from post-consuming containers or bottles has a serious attack to the environment, because of both land and water resources pollution problems. Civil engineers think that there a good chance to consume a large part of the total mass of plastic wastes via producing a recycled concrete containing this plastic waste, in the form of shredded particles or fibres. Relatively large amount of data on the basic properties of concrete containing different plastic wastes are available in the literature. However, there is a lack of information on the mechanical properties of concrete containing both shredded particles and fibres. This study was arranged to investigate properties of compressive strength and splitting tensile strength of concrete containing 10% of shredded polyethylene terephthalate (PET) waste particles and different volumes of PET waste fibre. Results indicate that the addition of PET fibre to the recycled concrete has some beneficial effect on the losses take place in compression containing shredded particles. The effect of addition PET fibre to the concrete was found more important for the splitting tensile strength property. It is concluded that the addition of both shredded PET particles and fibres to concrete can control the losses take place in strength and accordingly a higher quality of this type of recycled concrete can be produced.*

Keywords*: Compressive strength, PET waste fibre, Splitting tensile strength.*

1. Introduction

Concrete material is known to be weak in tension and cracking resistance. Conventionally, steel reinforcement is provided in concrete in order to carry the tensile forces and prevent any cracking. Adding short dispersed fibers could help in enhancing the flexural and tensile strength of the concrete. The main fibers used as concrete reinforcing materials are steel, glass, and polymeric fiber. The polymeric fibers that can be used in concrete reinforcements are nylon, aramid, polypropylene, polyethylene, polyester, etc. Polyethylene terephthalate (PET) is one of the most widely used plastics in the packaging industry because of high stability, non-reactivity with substances. Therefore, the productions of PET bottles have increased exponentially. The modern technology caused more waste materials productions for which the disposing problem exists. Utilizing these waste bottles in any form is advantageous, not only for the prevention of the environmental pollution but also energy saving in the disposal. Contributions of PET fiber in concrete using a different form of PET fibers have been explored [1-9]. The use of shredded plastics has known a growing interest as recycled materials in civil engineering construction. Shredded PET waste is added to concrete as a sand replacement, and this beneficial in many ways as it produces a lightweight concrete and also consumes less amount of aggregate compared with conventional lightweight concrete. The efficiency of PET waste fibers for reinforcing concrete has been considered in some investigations [1,2,3,9]. Fotti [9] have experimented on PET fiber reinforced concrete. An Important improvement in ductility behavior of concrete subjected to flexure was reported. Other tests [3] were focused on solid waste disposal of non-biodegradable materials used in concrete as a sand replacement. 0.5%, 1%, 2%, 4% and 6% volume of sand was replaced by PET bottle fibers. The waste PET bottles were collected, shredded into flakes or cut to make plastic fibers. The unit weight of concrete was found to be reduced for PET fiber reinforced concrete. It was observed that the compressive, split tensile and flexural strength were increased at 2% addition of fibers, thereafter reduction in strength was resulted.

Test data obtained by Albano et. Al [5] showed a reduction in the properties of compressive strength, tensile strength, and modulus of elasticity as a result of using shredded PET waste particles.

It is observed from past studies that the preparation of plastic waste is important on the residual properties of concrete, shredded particles have no good action in concrete but fibers have some enhancement of the tensile strength of concrete. The present work aimed to study the effect of PET waste fiber addition to concrete containing shredded PET waste particles on the properties of compressive strength and splitting tensile strength. Analysis of data is fairly made and compared with the properties of concrete containing PET waste shredded particles or fiber alone.

2. Experimental Work

2.1 Materials

Basic cconcrete materials used in this study are cement, fine aggregate, coarse aggregate and water.The cement used as ordinary Portland cement (Type I). Both fine and coarse aggregates used were on saturated surface dry (SSD) state with specific gravity equal to 2.64 and 2.65 for coarse and fine aggregates respectively. The maximum size of coarse aggregate was 19 mm.PET polymerwaste from post-consumer plastic containers origin was used in this study. PET particles as shown in Fig.1 shows PET waste shredded particles and fiber used in this investigation. PET waste was used in two different forms, shredded particles of 5mm average dimensions as partial replacement of fine aggregate by 10% and different amounts of fibers(length =30mm, width = 5 mm and thickness = 0.12 mm) as an addition by weight of cement.

2.2 Mix proportion and mixing

Mix proportion for control concrete was 1:2:3 (cement: fine aggregate: coarse aggregate) by weight with water/cement ratio equal to 0.45. No admixture was used in any mix batch. Concrete constituent materials, except water, where fed first to the electrical tilting drum mixer, and left to rotate for three minutes. Later, water was added and left to mix for another two minutes. For those mixes containing shredded PET plastic after the five minute mixing the particles were sprayed on fresh concrete inside the mixer continuously and left to mix for one minute. The same procedure was made for the case of PET fiber addition. For all mixes containing PET was particles 10% of fine aggregate was replaced with shredded PET waste. Fibers were added by weight of cement at percentages of 0.4, 0.8, 1,2 and 1.6. After 24 hours from casting concrete specimens taken from moulds and left in a water tank for 28 days of curing. Casting, mixing and curing were done in the laboratory at the temperature of 25±1^{o}C.

(a) Sredded particl (b) Fiber

Fig. 1. View of PET particles and fibers used in this study

2.3 Test specimens and testing

A total of fifteen 150 mm cube specimens and the same number of 150 x 300 mm cylinder specimens from five mix batches were cast and tested. After curing all specimens were left in the laboratory to dry for 7 days before testing. Measurements were taken for the density of dried concrete. Cubes were tested for compressive strength using the universal testing machine of 3000 kN capacity, at the rate of loading of 0.3 MPa/sec till failure. Splitting tensile strength test was carried out on cylinders using the same testing machine under the rate of loading of 0.2 MPa/sec. Average of three measurements were taken for the two measured strengths.

3. Results and Discussion

3.1 Test results

Table 1 shows test results of concrete density, compressive strength and splitting tensile strength for all concrete mixes. Specimen's designation is as follows, M is a mix, the first number is the ratio of shredded PET particles and the last number is the PET waste fibre ratio. Fig. 2 shows the variation of concrete density ratio with PET waste fiber. Fig. 3 shows the variation of compressive strength ratio with PET waste fiber and Fig. 4 shows the variation of splitting tensile strength ratio with PET waste fiber ratio.

Based on the results of Table 1 and Fig. 2 one can observe that the reduction in concrete density with PET shredded particles and fibre is quite small and not exceeds 0.8%. Therefore, it is concluded that the density is not changed when concrete contained 10% shredded particles and fiber ratio up to 1.6% by weight of cement. Based on the results of Table 1 and Fig. 3 it is observed that there is a moderate compressive strength loss as a result of adding shredded PET particles to concrete reaching 16.44% at 0.8% fiber content, but there is some recovery in the strength with increasing fiber content up to 1.6%. For the latter case, the compressive strength loss is 10.4%. Therefore, there is a moderate effect of PET fiber addition to control the compressive strength loss resulted from PET waste shredded particles added to concrete. Results of splitting tensile strength are somewhat different compared with those of compressive strength, and different from those obtained by other researchers, because there is no splitting tensile loss related to concrete tested in this investigation. This may be due to the fact that the strength of control concrete tested in this study is already small as a result of using a lean mix. The other reason is that the effect of fibre addition, even low, will have a beneficial effect on the splitting tensile strength. It is observed that the tensile strength increased with fibre ratio increase reaching 25% as a maximum value. Therefore, it is concluded that the effect of PET fibre addition is important for increasing splitting tensile strength containing 10% shredded PET waste particles up to 1.6% fiber ratio by cement weight. From the foregoing discussion, one can conclude that the mixture of shredded and fibres is better than using shredded particles alone for producing recycled concrete containing plastic wastes.

Table 1: Test results of dry density and concrete strengths

Specimen designation	Density (Kg/m^3)	Compressive strength (MPa)	Splitting tensile strength (MPa)
M0-0	2358	29.8	2.8
M10-0.4	2341	25.5	3.0
M10-0.8	2340	24.9	3.3
M10-1.2	2343	26.0	3.1
M10-1.6	2339	26.7	3.5

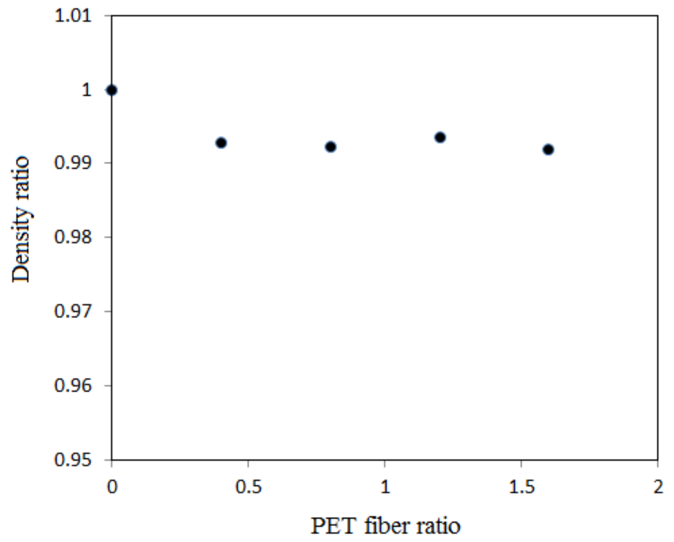

Fig. 2. Variation of concrete density ratio with PET fibre ratio

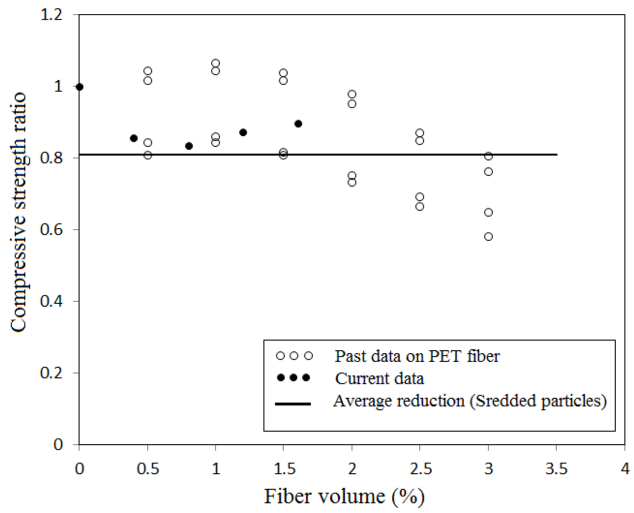

Fig. 3. Variation of compressive strength ratio with PET fibre ratio

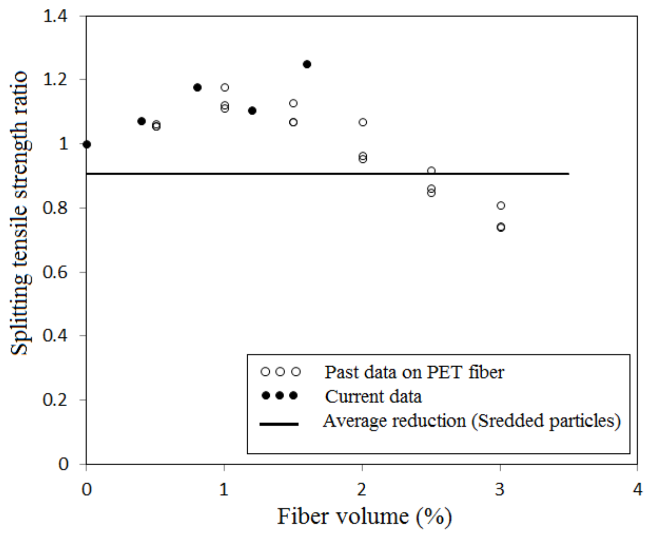

Fig. 4. Variation of splitting tensile strength ratio with PET fibre ratio

3.2 Comparison with the past test data

It is better to compare the obtained test data with those reported by the other researchers related to compressive and splitting tensile strengths of concrete containing PET waste particles or fibres. A total of 32 test data on the compressive strength of concrete containing 10% of PET waste shredded particles were taken from references [5-8] are used here. The compressive strength ratio is varied between 0.581 and 1.026. Average value of the residual compressive strength ratio is 0.808. A total of 18 test data on splitting tensile strength of concrete containing 10% of PET waste shredded particles were taken from references [4-8] are used here. The tensile strength ratio is varied between 0.519 and 1.056. Average value of the residual tensile strength ratio is 0.906. A total of 24 data point tested by Nibudey et al [9] of compressive strength and tensile strength were used for the comparison sake. Fig. 3 shows the variation of compressive strength of concrete with the fibre ratio variation based on the test data obtained in this investigation and those obtained by Nibudey et al [9] in addition to the average percentage reduction related to 10% shredded particles content. It is observed that the maximum strength loss measured in this investigation is smaller than the average strength loss which is 19.2% obtained by the other researchers. The reason of this is because of the existence of fibres. The compressive strength of concrete tested in this investigation is close to those measured by Nibudey et al [9] for concrete contained 30 mm fiber length which is close to that attempted in this investigation, but the optimum fiber content for the minimum loss is somewhat different. One can observe that the strength loss increased with fibre ratio larger than 1% tested by Nibudey et al. The behavior in tension is somewhat different. One can observe that the splitting tensile strength loss as a result of shredded PET waste particles is only 9.4%, smaller than that of compressive strength. The effect of fiber addition is beneficial for fiber content not larger than 2%. The best fiber content is 1% and at this fiber content the increase is splitting tensile strength is 17.8% for the 50 mm length PET fiber and 11.2% for the 30 mm length fiber tested by Nibudey et al [9]. The splitting tensile strength of concrete tested in this investigation is nearly similar to that obtained by Nibudey et al alone as observed from Fig. 4. Therefore, one can conclude that there is no problem related to the tensile strength of concrete contained shredded particles and fibre up to 1.6%.

4. Conclusions

The following conclusions can be drawn from this research study

1. There is a good chance to use a combination of both shredded and PET waste fibre for the production of recycled concrete containing plastic waste. Up to 10% shredded particles and 1.6% fibre ratio can be used for practical applications.
2. Compressive strength loss of the produced concrete is not larger than the average loss obtained by the other researchers which is 19.2%. The splitting tensile strength was found not reduced due to the combination of shredded and fibre wastes.
3. In general, properties of concrete containing both shredded and PET waste fibre is similar to those of concrete containing plastic fibres alone.

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