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Mechanical behavior and durability of steel fiber reinforced concrete made with recycled material

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ABSTRACT

Concrete is a composite material consisting of Mortar and aggregate. The main problem in the concrete is the formation of cracks. In this study, to control the cracks into the concrete steel fibers are added. Now a day the use of PET (Polyethylene Terephthylate) is highly recommended. This thesis has studied the incorporation of Polyethylene Terephthalate (PET) waste in concrete as a substitute for natural coarse aggregate and has found an optimal combination of components that produces a useful concrete product. The waste PET was first reduced in coarse aggregate by shredding and then combined with the rest of the components. A traditional method will use for the partial replacement of Polyethylene Terephthalate (PET) as coarse aggregate to its weight with the addition of steel fiber, which is 1%, 1.5% and 2% by volume in plain concrete. Specimens of specified are used for testing, which is designed according to the Indian standard code. Compressive, tensile and flexural strength of this specimen compared to the control sample and then 5%, 10%, 15% and 20% of Polyethylene Terephthalate (PET) are partially replaced as coarse aggregate samples. Furthermore compressive, tensile and flexural strength of this new specimen compared to the control sample. The material used in this experiments are; Cement, fine aggregate, coarse aggregate, PET as a partial replacement of course aggregate and water. Therefore, the main objective of this study is to use PET as a partial replacement of course aggregate in concrete. The safety, durability, and stability of the structure depend to a large extent on the properties of the concrete and, therefore, it is imperative to prepare the concrete with adequate strength.

Keywords*— SFRC, Steel Fiber (SF), PET, Replacement*

1. INTRODUCTION

Polyethylene Terephthalate (PET) is one of the most widely used materials in the packaging of various types of products. The packages made with PET are light, transparent and with high impact resistance, do not interact chemically with the binding materials and are not toxic. The waste PET bottles were reworked to drinking bottles by dissolving the melt, which proved to be too expensive. An alternative approach is to recycle waste PET bottles as ecological aggregates to reduce the cost of rework. If the waste PET bottles are reused as aggregates for SFRC concrete, positive effects are expected in the recycling of waste resources and in the protection of environmental control. In this study, lime stone as coarse aggregates in concrete are partially replaced with PET. This PET is obtained as a by-product when recycling molten PET bottles. The molten PET is then collected and cooled to obtain PET aggregate. The properties of concrete with partially replaced PET are studied and recommendations are formulated.

The main objective of this study is first to develop Steel Fiber Reinforced Concrete (SFRC) using steel fibers with the addition of 1, 1.5, 2% of steel fiber to the volume of concrete in the specimen and then to characterize the mechanical properties, such as compressive strength and tensile strength of SFRC. Furthermore, mechanical properties of SFRC are compared between control specimens and 5%, 10%, 15% and 20% partially replaced (PET) poly ethylene terephthalate as coarse aggregate specimens. In this experiment length and diameter of steel fiber are 50 mm and 1 mm respectively. The aspect ratio of steel is 50. Tensile strength of steel fiber is 1100 MPa and specific gravity is 7.85.

2. SFRC

SFRC is produced using conventional hydraulic cement, fine and coarse aggregates, water and SF. The American Concrete Institution (ACI) defines SF as short and discrete steel lengths that have an aspect ratio (length to diameter ratio) in the range of 20 to 100 with any of the various cross sections. They are small enough to disperse easily and randomly into a fresh concrete mix using conventional mixing procedures. The behavior of the SFRC can be classified into three groups based on its application, the percentage of fiber volume and the effectiveness of the fiber; For example, the SFRC is classified according to its fiber volume percentage as follows:

(a) The very low volume fraction of SF (less than 1% by volume of concrete) which has been used for many years to control withdraw plastic as floor reinforcement.
(b) The moderate volume fraction of SF (from 1% to 2% by volume of concrete) which can improve the Modulus of Rupture (MOR), bending strength, impact resistance and other desirable mechanical properties of the concrete.
(c) The high volume fraction of SF (more than 2% by volume of concrete) used for special applications such as impact structure and explosion resistance; these include SIFCON (Concrete Infiltrated Suspended Fiber), SIMCON (Suspended Reinforced Concrete Suspension).

2.1 SFRC benefits

The beneficial influence of SFRC in concrete depends on many factors such as the type, shape, length, cross-section, strength, fiber content, matrix strength, mix design and the concrete mix. The addition of steel fiber in the members of conventional Reinforced Concrete (RC) has various advantages, such as-
(a) Steel fiber increases the tensile strength of the matrix, which improves the bending strength of the concrete.
(b) The crack mechanism of the steel fiber and its tendency to uniformly redistribute the stress in the whole matrix contributes to the post-crack resistance and to the restriction of the cracks in the concrete.
(c) Increase the ductility of the concrete.
(d) The SFRC is more resistant and useful than the conventional RC.

2.2 Application of SFRC

At the present time, SFRC is being used as an increasing rate in various applications, such as the following-
- Highway and air-field pavements.
- Hydraulic Structures.
- Tunnel lining and bridge repair.
- Refractory Concrete.
- Manhole covers, concrete pipes, and machine bases and frames.

3. PET

Polyethylene Terephthalate (PET) has the fastest growth rate in consumption all over the world. It means that the growth is directly proportional to the plastic waste. The main flow of PET waste comes from soft drinks and food packaging. Moisture barrier properties, high breaking strength and exceptional gas, it made it suitable for bottle production. They created more free water and their water absorption properties increased the slump. Furthermore, it is lighter than the natural aggregate. This creates the potential of PET in the development of lightweight concrete.

In this thesis polyethylene Terephthalate (PET) was used as part of the course aggregate in which lime stones were partially replaced by this. PET is a thermoplastic polymer. Natural PET is a semi-crystalline colorless resin. Depending on how it is processed, it can be semi-rigid or rigid. This PET is obtained as a by-product in the molten state while the PET bottles are recycled. Thus, the molten PET is collected and cooled to obtain a PET mold which is then ground to be used as a coarse aggregate. Therefore, this PET was sieved according to the ASTM standard for raw aggregates.

3.1 Advantages and disadvantages of using plastic

The rheological properties such as flow and compaction in the concrete are modified by the addition of PET. The plasticity and consistency of fresh concrete have decreased with increasing PET content. Furthermore, the compressive strength increased proportionally to the resin content which also showed the characteristic of the resin in filling the gaps.

The shape of the PET has influenced the properties of its concrete. It showed that the shape of the PET aggregate affects the design of the water and cement ratio. In that research, the addition of soft and almost spherical PET increases the value of the slump while reducing the ratio of water to cement.

3.1.1 Advantages of using plastic in concrete

- Lighter than other materials that reduce fuel consumption during transportation.
- Durability and longevity
- Resistant to chemical water and impact.
- Excellent thermal and insulation electrical properties.
- Comparatively lesser production cost.

3.1.2 Disadvantages of plastics

- Plastics have low bonding properties, so as to reduce the strength of concrete, such as compressive strength tensile strength and flexural strength.
- The melting points of the plastic are low, so they cannot be used in furnaces because they melt in contact with the heat at high temperatures.

4. CASTING AND TESTING DETAILS

4.1 Casting of specimen

- To test the variation of the compressive strength with the variation of the steel fiber content, three cubic samples are manufactured each with a steel fiber content of 1%, 1.5% and 2% that is a total of 18 cubic samples. Again to test the variation of the compressive strength with the variation of the PET aggregate with the constant percentage of steel fiber, three cubic samples are prepared with a PET aggregate content of 5%, 10%, 15% and 20%, that is total of 24 cubes are made.

- To test the variation of the flexural strength with the variation of the steel fiber content in the design mix, three prism samples are made for each with a steel fiber content of 1%, 1.5% and 2%. Again to test the variation of the flexural strength with the variation of the PET aggregate with the constant percentage of steel fiber, three cubic samples are prepared with a PET aggregate content of 5%, 10%, 15% and 20% that is total 12 prisms are made.
- To test the variation of tensile strength with the variation of the steel fiber content in the design mix, three cylindrical samples are made for each with a steel fiber content of 1%, 1.5% and 2%. Again to test the variation of the tensile strength with the variation of the PET aggregate with the constant percentage of steel fiber, three cubic samples are prepared with a PET aggregate content of 5%, 10%, 15% and 20%, that is total 12 cylinders are made.

4.2 Details of the test specimen

Table 1: Details of moulds

S no.	Specimen	Size of specimen
1.	Cube	150×150×150mm
2.	Cylinder	Dia-150mm, height-300mm
3.	beam	700×150×150mm

4.3 Compressive strength tests

Table 2: Compressive strength of SFRC with partial replacement of PET as course aggregate

S no.	Designation of mix (SF+PET)	Compressive strength after 7 days N/mm^2	Compressive strength after 14 days N/mm^2	Compressive strength after 28 days N/mm^2
1.	(0%+0%)	31.31	34.36	47.27
2.	(2%+5%)	60.24	67.31	74.88
3.	(2%+10%)	62.34	70.13	78.32
4.	(2%+15%)	57.36	65.42	71.92
5.	(2%+20%)	51.96	58.61	66.29

4.4 Split tensile strength test

Table 3: Split tensile strength of SFRC with partial replacement of PET as course aggregate

S no.	Designation of mix (SF+PET)	Tensile strength after 7 days N/mm^2	Tensile strength after 14 days N/mm^2	Tensile strength after 28 days N/mm^2
1.	(0%+0%)	3.0	3.31	3.75
2.	(2%+5%)	11.72	13.34	15.02
3.	(2%+10%)	18.11	20.04	22.19
4.	(2%+15%)	13.61	15.68	17.42
5.	(2%+20%)	12.16	13.72	14.22

4.5 Flexural strength test

Table 4: Flexural strength of SFRC with partial replacement of PET as course aggregate

S no.	Designation of mix (SF+PET)	Tensile strength after 7 days N/mm^2	Tensile strength after 14 days N/mm^2	Tensile strength after 28 days N/mm^2
1.	(0%+0%)	3.72	4.08	4.47
2.	(2%+5%)	6.34	6.86	7.29
3.	(2%+10%)	5.24	6.70	7.30
4.	(2%+15%)	4.74	6.52	7.28
5.	(2%+20%)	4.43	6.13	7.25

5. CONCLUSION

It has been noted that compressive strength, tensile strength and flexural strength of SFRC increased up to 1.5% of steel fiber. These three stresses are decrease by 4% and 6% of steel fiber in SFRC. Hence the percentage of steel fiber in SFRC up to 2% will be reasonable. Use of plastic in SFRC increased the compressive and tensile strength up to 10% replacement of PET as course aggregate in SFRC. The effect of the w / c ratio in strength development is not important in this case as plastic aggregate reduces the bond strength of the concrete and sometimes it becomes the reason for the failure of concrete. Due to the low specific weight of PET, it has helped to reduce the unit weight of the concrete, which can be advantageous for the creation of lightweight concrete structures. The workability of concrete is improved by increasing the percentage of PET used due to the shape and surface conditions of Polyethylene Terephthalate (PET). Therefore, a reduced water cement ratio could be used in the design of the concrete mix while PET is used as a coarse aggregate and greater strength and workability is obtained.

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