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EXPERIMENTAL STUDY ON UTILIZING THE PET BOTTLE FIBRES IN THE PRODUCTION OF CONCRETE

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ABSTRACT

Waste plastic bottles are the major reason for solid waste disposal. Polyethylene Terephthalate (PET) is usually used for carbonated beverages and water bottles. The waste plastic bottles are difficult to biodegrade and involve processes either to recycle or reuse. The construction industry is in require of finding cost effective materials for increasing the strength of concrete structures. This paper deals with the possibility of using the waste PET bottles as the different aspect ratios of 17, 33, and 50, size of fibre added into the concrete with 0.5%, 1%, and 1.5% PET bottle fibres for fine aggregate were produced and compared against control mix with no replacement. Cube specimens, cylinder specimens of 27 numbers each were cast cured, and tested for 3 days, 7 days, and 28 days strength. Compression tests, splitting tensile tests, and flexural strength tests were done and the results were compared with control specimens.

Keywords: partial replacement, self-weight PET bottle, fibbers, cement, sand, aggregate, water, steel.

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1. INTRODUCTION

Concrete is the most widely used construction material due to its high compressive strength, long service life, and low cost, etc. However, concrete has inbuilt disadvantages of low tensile strength and crack resistance. To improve the weaknesses of the material, several studies on fiber reinforced concrete have been performed. The research result showed that the addition of fibers considerably improves the performance of concrete. The use of fiber reinforced concrete has increased in the last decade. Poly Ethylene Terephthalate commonly abbreviated as PET. It is a thermoplastic polymer resin of the polyester family and is used in synthetic fibers, PET is one of the most important and extensively used plastics in the world, especially for manufacturing beverage containers, food, and other liquid containers PET Bottles are also recycled as-is (re-used) for various purposes PET bottles are filled with water and left in the sun to allow disinfection by ultraviolet radiation. Most PET bottles used for beverage containers are thrown away after a single usage and disposed PET bottles are treated by landfills and burning, which creates serious environmental problems waste is one of the challenges to dispose of and manage. It has one of the major environmental, economic, and social issues. PET bottles in fiber form can be used to get better the mechanical properties of concrete. The compressive strength, tensile strength, and flexural strength behavior of concrete are discussed. The PET fibers addition in concrete is an innovative material that can be promoted in construction field.

The increased necessity for high-rise concrete structures, as a result of the increase in population density, lack of spaces, urban development, and others, has led to considerable attention to the use of deep beams. ACI Code defines deep beams as those "which have a clear span to total depth less than four, or the shear span to the effective depth is less than two and should be loaded on the top face and supported on the bottom face". Thus, compression struts can be developed between loads and support points. The application of reinforced concrete deep beams has appeared in high-rise buildings, offshore structures, foundation walls, transfer girders that support the load from one or more columns as well as in some walls and pile caps. Beams are the more critical part of any concrete structure as they transfer loads to supports or columns and they can suffer from two types of failure such as shear and flexural failure. The former can occur abruptly without sufficient warning, unlike the latter failure. Besides, the shear width cracks are more significant than those owing to the flexural loads. Figure-1 shows the behaviour of plain and fiber reinforced concrete under tensile load, which demonstrates the change in failure mode from brittle to quasi-ductile.

Concrete is one of the most common building materials used for constructive civil engineering structures. Concrete can be cast in any desirable shape. It exhibits some excellent properties such as good compressive strength, durability, specific gravity, and fire resistance and lacks tensile strength and ductility. The introduction of fibers in concrete makes an excellent composite building material. Nowadays, fiber reinforced concrete is becoming more popular. It is a composite material consisting of mixtures of water, fine aggregate, coarse aggregate, and discontinuous, discrete, uniformly dispersed suitable fibers. They are of different types like glass, polypropylene, polyethylene terephthalate, polyester, carbon, macro synthetic, micro synthetic, natural, cellulose, etc., and properties with many advantages. Within these different fibers, the character of fiber reinforced concrete changes with varying fiber material, concrete, geometries, orientation, and densities. The length, shape, and dimension of fiber are essential in making reinforced concrete. A short and thin fiber, for instance, will only be effective during the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase its tensile strength. The addition of fibers in the mix improves the mechanical characteristics of Fiber Reinforced Concrete i.e. fracture strength, toughness, impact resistance, wear and tear, flexural strength, and fatigue resistance. The primary reason for the addition of fibers in concrete is to enhance the post-cracking response of the concrete i.e.to enhance its energy absorption capacity and apparent ductility and to provide crack resistance and crack control. Also, it assists in maintaining structural integrity and cohesiveness in the material. The fiber is described by a parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. The typical aspect ratio ranges from 30 to 150. The use of Polyethylene terephthalate (PET) as fiber in concrete is especially important as such wastes are continuously increasing, bringing serious ecological and economic problems since the extent of biodegradation of commodity plastics is very low.

2. LITERATURE REVIEW

Waste plastic bottles are the major reason for solid waste disposal. Polyethylene Terephthalate (PET) is usually used for carbonated beverages and water bottles. The waste plastic bottles are difficult to biodegrade and involve processes either to recycle or reuse. The construction industry is in require of finding cost effective materials for increasing the strength of concrete structures. This paper deals with the possibility of using the waste PET bottles as the different aspect ratios of 17, 33, and 50, size of fibre added into the concrete with 0.5%, 1%, and 1.5% PET bottle fibres for fine aggregate were produced and compared against control mix with no replacement. Cube specimens, cylinder specimens of 27 numbers each were cast cured, and tested for 3 days, 7 days, and 28 days strength. Compression tests, splitting tensile tests, and flexural strength tests were done and the results were compared with control specimens.

This study attempts to apply the concept of sustainability by reducing the environmental pollution of plastic waste, especially Polyethylene Terephthalate (PET) that is used in the production of soft drink bottles. The plastic bottles were collected, and roughened) Roughen the surface by using a metal clip after exposing it to heat, and then place it on smooth surfaces) and shredded into fibres of specific size and shape with an aspect ratio (L/D) of 34.5. Various proportions of PET (i.e. 0.5, 1.0, and 1.5%) have been used in the production of ordinary concrete. The influence of PET fibers on the properties of concrete was studied, such as workability, compressive, and splitting tensile strengths. Furthermore, the shear characteristics of continuous reinforced concrete deep beams with dimensions of (150×300×2000) mm produced from such concrete were also investigated. For all percentages of replacements, the fresh property, compressive strength, and tensile strength of PET fibre encapsulated cement concrete was investigated.

This research investigated using waste polyethylene terephthalate (PET) bottle fibres in concrete. Experimental tests were conducted to evaluate the mechanical properties of PET fiber-strengthened concrete. The effects of the fibre volume fraction and fibre length were studied to obtain optimal values. Moreover, a thorough statistical analysis was performed to identify the parameter that impacts the inclusion of PET fibres in concrete. Furthermore, the study explored the effect of PET fibres on reinforced concrete beams of shear failure mode. The results showed that incorporating PET fibres significantly enhances the ductility of the concrete material and reduces shrinkage. It also promotes the initial stiffness, the inelastic absorbed energy, and the ductility of steel-reinforced concrete beams.

The deficiency to merge recycled materials in building manufacture is becoming more significant than ever before. The use of recycled materials in concrete mixtures decreases the waste material in landfills and decreases the exhaustion of virgin materials. The basis for this research was to investigate the effects of using recycled materials, in varying amounts, on the fresh and hardened concrete properties. The recycled materials used in this study consisted of Waste Plastic Bottle (PET) Fibers and Recycled Coarse Aggregate. Percentage of the waste PET bottles 0, 1, 2, 3% and recycled coarse aggregate (crashed concrete) 0, 100% from the neutral coarse aggregate. Fifteen reinforced concrete beam specimens of dimensions (250×120×2000 mm) were prepared in the current research, and divided into five main groups of three beams each, based on % recycled fiber, % recycled concrete coarse aggregate (RCA), and reinforcement steel details (BC, BS, BF). All the specimens of the experimental work were cast and strengthened at the Concrete Research and Material Properties Laboratory, "Faculty of Engineering, Fayoum University".

Food and beverage packets yield 31.1% of plastic waste around the world, bottle and container caps 15.5%, plastic bags 11.8%, and plastic bottles yield around 7.27% of plastic waste. More than 480bn drinking bottles made up of plastic were sold in 2016 across the world, up from about 300bn ten years ago. If placed end to end, they would lead more than halfway to the sun. By 2021 this number will increase to 583.3bn. Recycling of these PET bottles costs about 30-31 rupees in India as of 2021. These PET bottles can be disintegrated into fibers which can be used to increase the properties of concrete. Fiber-reinforced concrete has been used for the past 20 years as a new construction material. The tensile strength, ductility, fracture strength, toughness, impact resistance, flexural strength, fatigue resistance, and other properties of concrete are improved by the addition of these fibers. It also helps in reducing the bleeding of freshly mixed concrete and makes it impermeable in the hardened stage. Therefore, the fiber-reinforced concrete becomes economical (considering the recycling cost) and the self-weight of concrete is reduced. Thus, it is preferred to use PET fiber reinforced concrete over reinforced concrete from a structural point

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of view. This paper portrays the strength results of fiber-reinforced concrete with varying percentages of PET fibers. Recycled PET bottles are considered the best eco-friendly alternative for resolving disposal problems and also new construction.

3. MATERIALS AND EQUIPMENT

Concrete is a construction material composed of cement, fine aggregates (sand), and coarse aggregates mixed with water which hardens with time. The grade of concrete denotes the strength required for construction. The normal Grade of Concrete varies from M5 to M20. The standard Grade of Concrete varies from M25 to M45. High Strength Concrete Grade varies from M50 to M70. The minimum grade of concrete required for pavement is M40, as it should withstand temperature and wheel stresses. Cement is a binder, that binds sand and gravel (aggregate) together. Ordinary Portland cement (OPC)-53, OPC 53 Grade cement is required to conform to BIS specification IS: 12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/sq cm. It was tested for physical properties by Indian Standard Specifications. Coarse aggregates collected from approved quarry and aggregates having sizes ranging from 10mm to 20mm and specific gravity of coarse aggregate 2.8. The tests are carried out on coarse aggregate as per IS 2386-1963. Figure-1 shows the sieve analysis.

M sand passing through a 4.75mm sieve is used and it has a specific gravity of 2.65. The grading zone of fine aggregate is Zone II. Physical properties of fine aggregates determined per IS 383-1970. The water is available on the college campus conforming to the requirements of water for concreting and curing as per IS: 456- 2000. Different tests were conducted for testing cement, aggregate like course aggregate and fine aggregate. Sieve analysis is a standard method for determining the particle size distribution of aggregates. For both fine and coarse aggregates, the procedure involves collecting samples, preparing them, and passing them through a set of sieves with varying openings.

Figure-1. Sieves of fine aggregate.

4. MIX DESIGN

For the preparation of the mix design of M30 grade concrete, the Indian Standard code (IS 10262: 2019) is used. By considering all the things about the material and environmental condition corrections are applied and decided the material quantity. Water cement ratio=0.4, Ratio 1:1.57:2.98.

5. RESULT AND TESTING

The uniaxial compression test on cube specimens was performed concerning IS-516 (Load increasing (@ 14 MPa/min.). Compressive loading was applied to the cube specimens. Cylinders of 10 cm diameter and 20 cm length were prepared and tested under increasing loading @14 MPa/min. The Split Tensile Strength is determined by $2P/\pi ld$ Where P= Load at which the sample fails, L= length of the specimen cylinder, D= diameter of the specimen cylinder. We have tested 2 samples for conventional beam and 2 samples for partially replaced PET Bottles on the loading frame. Figure 2 and 3 show the graph about load and deflection. The range of loading was 1kN to 160kN for both conventional beams and partially replaced beams. From the results, it is observed that the average deflection of conventional beams is 6mm and the average deflection of partially replaced beams is 9.8mm. Through comparison, it is found that the deflection in the partially replaced beam is greater than conventional beam.

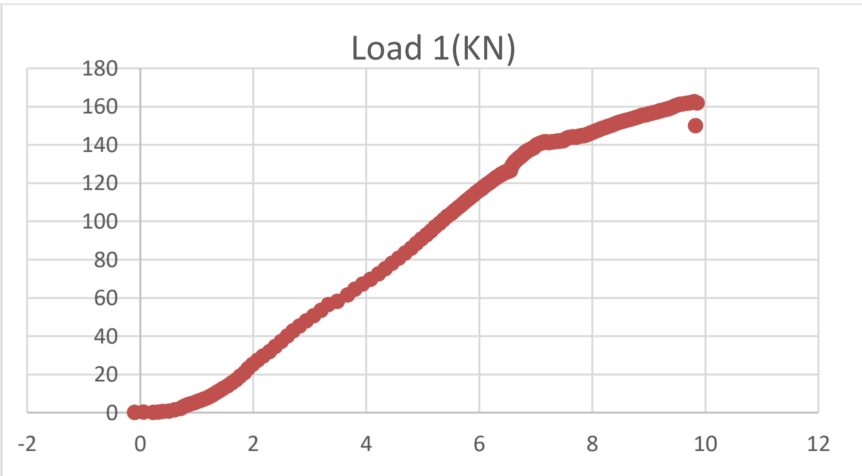

Figure-2. Graph of replaced with PET bottles beam.

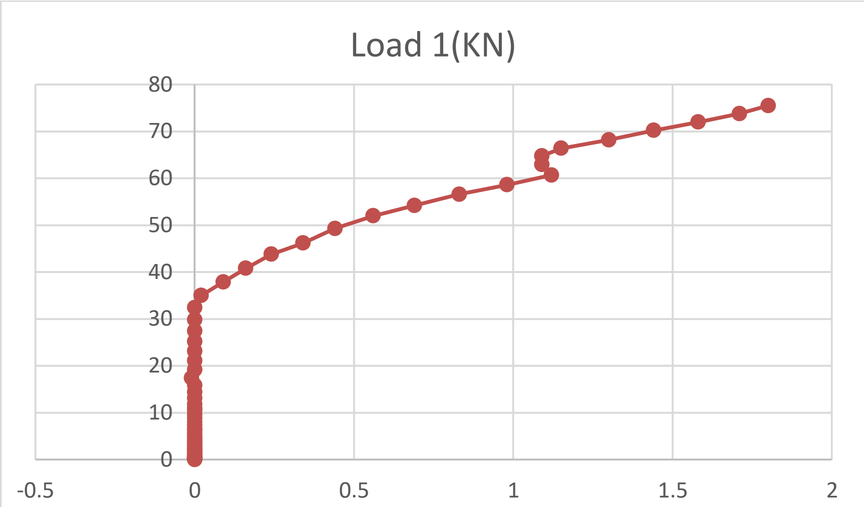

Figure-3. Graph of the conventional beam.

CONCLUSIONS

The use of PET fibers in casting continuous reinforced concrete deep beams of three percentages (0.5, 1, and 1.5 present) was investigated experimentally. Four beams were subjected to a two-point bending test with a shear span to an effective depth ratio of 1.5 to complete this research. Some of the essential points that can be deduced from the experimental findings are as follows:

The increase in waste plastic fibers percentage led to a decreasing workability of concrete mixes and the value of this decrease was almost (25%) at fibers content (1.5%).

Experimental results showed the effect of waste plastic fibers on the compressive strength of concrete was slight for all fibers percentages with almost (5.95 %) at (7) days and (8.47 %) at (28) days with 1.5%. However, there is no increase in compressive strength for higher values of PET% due to fiber collections during the process of mixing. PET effect on splitting tensile strength more than the compressive strength. Increased the splitting tensile strength with increasing of fibers content until the percentage of (1%) that recorded a significant increase in tensile strength by (15.18%) at 28 days. Besides, the width of the axial crack for the tested cylinders became very small after failure within corporating the waste plastic fibers.

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