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INCORPORATING RECYCLED PET FIBERS FOR GREEN ROOF SLAB PANEL

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Abstract: High consumption of plastics leads to production of large amounts of plastic waste in today's world and plastic is non-biodegradable so its disposal has been a problem. In order to resolve this problem, recycled PET fibers were proposed to be used as reinforcement in concrete and recent studies show that they can be accepted as successful building material. This paper has discussed the effect of adding recycled plastic fiber (PET) to the precast concrete green roof panels. This research consists of two main stages. In first stage, different volumes of recycled PET fibers, i.e. 0%, 0.5%, 1.0% and 1.5% have been added as percentages of concrete by volume. The results show that the maximum volume of PET fiber for a desired compressive and tensile strength was 1.0%. It was observed that 15.3 % of increase in compressive, 22.44% of increase in flexural strength and 18.77% of increase in split tensile strength for the addition of 1% PET fibers to the concrete. In second stage, optimum fiber percentage (1.0%) selected from stage-1 was used to produce precast concrete panels. To check the structural performance of this slab panel, center-point line loading test and dropping weight test were conducted. Finally, permeability test was conducted to compare the permeability of plain concrete and recycled PET fiber introduced concrete.

Keywords: Recycled PET; PET Fiber reinforced concrete; Concrete roof slab; Permeability of concrete

1. Introduction

Dye–sensitized High consumption of plastics leads to the production of large amounts of plastic waste in world. Discarded polythene and plastics are one of the biggest problems encountered in waste management. Another reason is that they are not bio degradable, and remain in the environment once disposed it. Treatment method of plastics through incineration process will release toxic gas to the environment that could be dangerous to human health. Plastic-recycle process is one of the good solution for above problem. The highest percentage (93%) of recyclers use PP (Polypropylene) as a raw material in plastic recycling industry in Sri Lanka compared to other polymers (Gunarathna et al 2010) **[1].** Therefore, this research mainly focuses on utilize these recycled materials (PET fibers) in concrete related construction industry.

Even though concrete has many versatile properties, there are some drawbacks in the concrete. When compare with some of the typical building materials concrete has a relatively low tensile strength, low ductility and it is susceptible to cracking. In-order improve these mechanical properties of concrete, various researches are being conducted by researchers. From past experimental works, it was found that addition of recycled PET fibers to concrete show significant improvement in concrete mechanical properties. But there is no research found in literature that focus on the addition of recycled PET fibers with Blended cement to improve the mechanical properties of concrete.

The application of recycled PET fiber reinforced concrete is a major concern of the research. In current construction industry, the precast concrete floor and roof slab panel offers a number of important benefits. It provides increased stability and improved thermal insulation, as well as greater protection from potential hazards such as fires. But some of the properties still in improvement stage to reduce weight and cost of the slab panels. From the literature review, it was found that some of the required mechanical properties of precast slab panels can achieve through PET fiber reinforced concrete in low cost. Therefore, analyze the structural suitability of precast

PET fiber reinforced concrete green roof slab panel is the significant part of this research work.

Fraternali (2011) **[2]** conducted an experiment to determine the compressive strength of fiber reinforced concrete and identified that it has an improvement in the compressive strength compare to normal concrete. Also, it has been identified that compressive strength was increased with the increment of PET fiber diameter. Short PET fibers give more compressive strength than the long PET fibers. Marthong (2015) **[3]** identified that there is a reduction of compressive strength as the volumetric fiber percentage increases beyond 0.5%. Additionally, it was declared that compressive strength also varies with the geometry and the dimensions of fibers.

Ochi (2006) **[4]** conducted uniaxial compression test and identified that compressive strength of PET FRC was increased with the fiber content and this was valid up to 1% of PET fiber then the compressive strength was decreased with the increment of fiber content. Similar to the Ochi's findings, Sandaruwani (2012) **[5]** identified that compressive strength of PET FRC is increasing with the fiber content and this is valid up to 1% of fiber then the compressive strength is decreasing with the increment of fiber content.

According to the Marthong's (2015) **[3]** findings, it was found that the inclusion of PET fiber above 1.0% decreases the tensile strength. The inclusion of PET fiber improved the tensile property and showed the ability in absorbing energy in the post-cracking state due to the bridging action imparted by the fibers during cracking. But Sandaruwani (2012) **[6]** identified that fiber content can be increased up to 2% with an improvement in the tensile strength. After that the tensile strength will reduce as the fiber content increase beyond 2%. Rathnayaka (2015) **[7]** conduct an experiment to determine compressive and split tensile strength of fiber reinforced concrete and identified that it has been reduction in compressive strength compare to normal concrete but there is an improvement in tensile strength up to 3% of PET fiber content.

The main objectives of this study are to evaluate the possibility of using waste plastic fiber as a reinforcement material in concrete to produce green roof slab panel. The following objectives are also proposed

1. To investigate the appropriate mix proportions and resultant variations in strength characteristics of PET fiber reinforced concrete made with short PET fibers.
2. To investigate the structural suitability of precast PET fiber reinforced concrete roof slab panel

2. Methodology

2.1 Specimens for mix proportion identification

Re-cycled PET fibers obtained from Beira Group, Horana, Sri Lanka was introduced in to the concrete mix. PET fibber was added on the volume basis, and it would not replace any material in the concrete. PET fiber addition was done for water cement ratio of 0.3 samples as shown in Table 1. Fibers were added in 0%, 0.5%, 1%, and 1.5% of total volume to check the mechanical properties of the concrete mix.

Table – 1: PET FRC sample preparation

Sample	Fiber diameter (mm)	Fiber length (mm)	Water/ Cement ratio	PET fiber percentage (%)
A1	0.7	50±5	0.3	0%
A2	0.7	50±5	0.3	0.50%
A3	0.7	50±5	0.3	1.00%
A4	0.7	50±5	0.3	1.50%

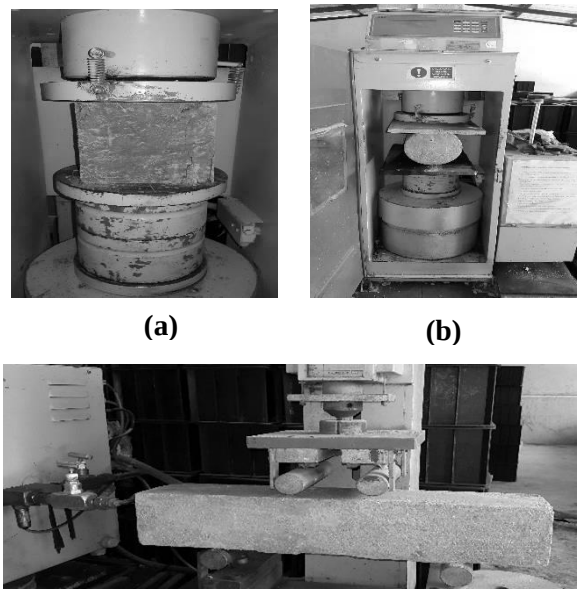
2.2 Experimental procedure

The experiment was conducted in two main stage. In first stage, different volumes of recycled PET fibers, i.e. 0%, 0.5%, 1.0% and 1.5% have been added as percentages of concrete by volume and compressive, split tensile and flexural strength tests were

performed to identify the optimum fiber percentage.

Compressive strength of concrete was tested using cube of 150x150x150 mm dimension. Cubes were casted according to BS 1881-108 (1988) and cured until the test day as described in BS1881-111(1988). Concrete is mixed based on the mix design in accordance with BS 5328 (Part2:1997). In order to achieve a workable mix admixture Optima 100 is added to the concrete mix. Slump was evaluated for each set of specimen on the day of mixing before casting the cubes (BS 1881-102). These test specimens were crushed on 7th, 14th and 28th day form they are casted as shown in Figure 1 (a). Compressive strength was measured in accordance with BS 1881-115(1988) and BS 1881-116(1988).

Cylindrical specimens of 150x300 mm were casted to test tensile strength of concrete. Tensile strength was evaluated by split tensile test as shown in the Figure 1 (b). Beam specimens of 100x100x500 mm were casted to test flexural strength of concrete and it is measured in accordance with BS EN 12390-5 (2000) as shown in figure 1 (c).



(a) (b)

(c)

Fig 01: Testing of specimens; (a) Compressive strength test, (b) Split tensile strength test, (c) Flexural strength test

In second stage, structural suitability of precast roof slab panel was checked. In order to perform the test, optimum fiber percentage (1%) received from stage 1 was used to prepare the specimen in stage 2. Slab panels are casted as shown in Figure 2. Following factors were considered in the selection of the economical size of the slab panels.

- Testing method and size of the available apparatus
- Handling capabilities of the slab panel
- Economies of constructing
- General size used in literature

By considering above factors 500x500mm and 100mm thick panel was selected.

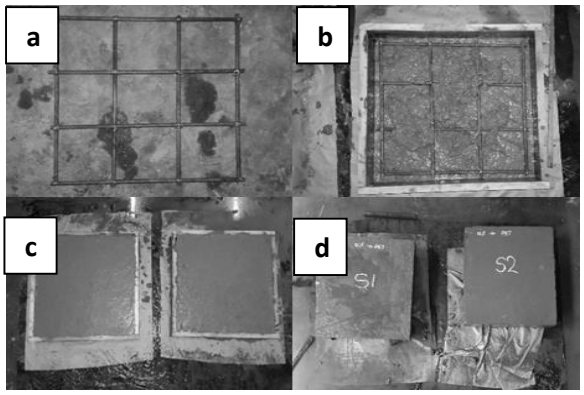


Fig 02: Preparation of slab panel; (a) Reinforcement arrangement, (b) and (c) Pouring of concrete, (d) Curing of slab panel

In order to check the structural suitability of precast slab panel, following tests were conducted.

- Impact resistance

Dropping weight test (ACI Committee 544)

- Flexural strength

Centre-point line loading test (ASTM C 293)

The simplest of the impact tests is drop-weight test. This test yields the number of blows necessary to cause prescribed levels of distress in the test specimen. This number serves as a qualitative estimate of the energy absorbed by the specimen at the levels of distress specified. The test can be used to compare the relative merits of different fiber-concrete mixtures and to demonstrate the improved performance of FRC compared to conventional concrete. The

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instrument setup for the drop-weight test is shown in Figure 3.

Fig 03: Instrumental setup for the impact resistance test

The flexural strength of slab panel was measured by conducting Centre-point line loading test according to ACI Committee 544 report. Figure 4 shows loading arrangement for the slab panel. In order to carry out this test universal testing machine was used.

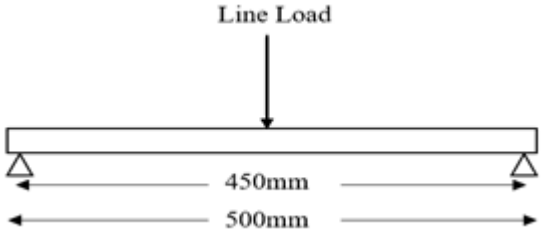

Fig 04: Loading arrangement for the slab panel

3. Results and Discussion

3.1 Variation of compressive strength with PET fiber content

For a blended cement mix of water cement ratio of 0.3, there is significant improvement in compressive strength compare to OPC. Figure 5 shows variation of compressive strength with PET fiber content. It revealed that 0.5% and 1% PET fiber specimen's compressive strength results are higher than the control specimen compressive strength but 1.5 % PET fiber specimen's compressive strength results are lower than the control specimen.

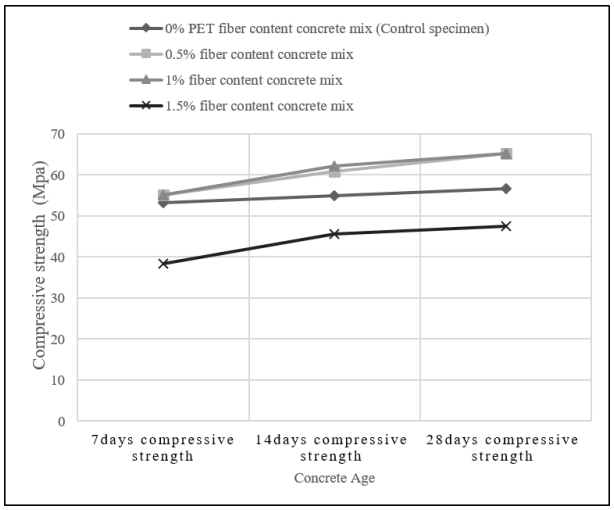

Fig 05: Variation of compressive strength with PET fiber content

3.2 Variation of flexural strength with PET fiber content

Figure 6 shows flexural strength results of PET fiber reinforced concrete. From the results, it was identified that flexural strength of PET fiber introduced concrete is higher than the control specimen results. It can be observed that there is an improvement in the flexural strength when increase of PET fiber content.

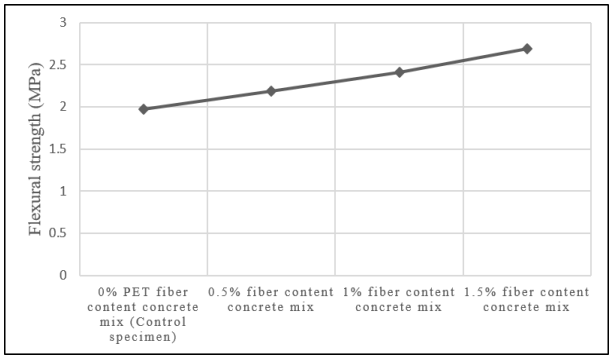

Fig 06: Variation of flexural strength with PET fiber content

3.3 Variation of tensile strength with PET fiber content

Figure 7 shows variation of split tensile strength with PET fiber content. It revealed that split tensile strength of PET fiber introduced concrete is higher than the control specimen results. It can be observed that there is an improvement in the flexural strength when increase of PET fiber content. Figure 7 indicates the improvement of

tensile strength compared to the control specimen.

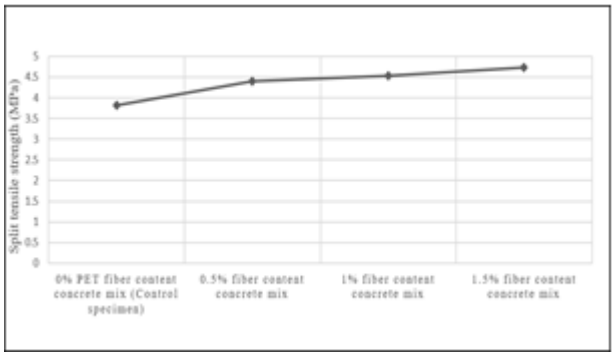

Fig 07: Variation of split tensile strength with PET fiber content

3.4 Variation of concrete workability with PET fiber content

To determine the workability of concrete slump value of the concrete was measured. As the fiber is introduced to the concrete slump value of the concrete starts to reduce as shown in the Figure 8.

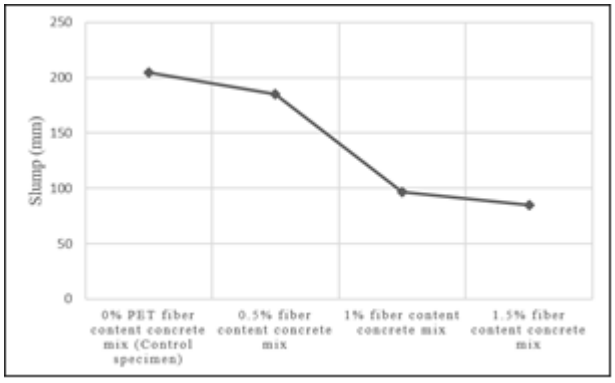

Fig 08: Variation of slump of concrete with PET fiber content

4. Conclusions

Specimens prepared from 0.3 water cement ratio with blended cement trial mix shows increase in compressive strength until 1% of PET fiber content after that the compressive strength of PET fiber reinforced concrete is reducing compare to control specimen. There is 15.3 % of increase in compressive strength for the addition of 1% PET fibers. But there is 16.04% of maximum reduction in the compressive strength for the addition of 1.5% PET fibers to concrete. So, optimum PET fiber percentage is 1% by considering the compressive strength of concrete.

Flexural strength of concrete is improved due to inclusion of PET fibers into blended cement concrete. The flexural strength of concrete is increase with PET fiber percentage. There is 36.28% of increase in flexural strength for the addition of 1.5% PET fibers and 22.44% of increase in flexural strength for the addition of 1% PET fibers to the concrete.

The split tensile strength of concrete also improved due to inclusion of PET fibers in to blended cement concrete. The split tensile strength of concrete is increase with PET fiber percentage. There is 23.79% of increase in tensile strength for the addition of 1.5% PET fibers and 18.77% of increase in split tensile strength for the addition of 1% PET fibers to the concrete.

Slump which indicates the workability of the mix. From the results, it was observed that increase of fiber content cause to reduction in slump value. But all the trial mixes considered in this research give workable concrete mix (slump value > 60mm) so there is no problem in handling and placement of concrete.

By considering the compressive, flexural and tensile strength of PET fiber introduced concrete, 1% fiber content considered as an optimum value and second stage of the research was conducted for the 1% of PET fiber. Further studies will continue to check structural suitability of precast PET FRC slab panel.

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References

[1]. Gunarathna, G.P.N., Bandara, N.J.G.J. and Liyanage, S., 2011, Analysis of Issue and construction associated with plastic recycling industry in srilanka, Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Sri Lanka.

[2] Fernando Fraternali a, Vincenzo Ciancia , Rosaria Chechile, Gianvittorio Rizzano, Luciano Feo, 2011. *Experimental study of the thermo-mechanical properties of recycled PET fiber-reinforced concrete. Composite Structures*, 93(9), pp. 2368-2374

[3] Comingstarful Marthong, Shembiang Marthong, 2015, *An experimental study on the effect of PET fibers on the behaviour of exterior RC beam-column connection subjected to reversed cyclic loading*, online research journal of the Institution of structural Engineers.

[4] Ochi T, Okubo S,Fukui K, 2007. Development of recycled PET fiber and its application as concrete-reinforcing fiber. Cement and Concrete Composites, 29(6), pp. 448-455.

[5] Sandaruwani A.H.W.E,and Bandara K.A.J.M, 2012. *Use of recycled short fibers in structural concrete to enhance mechanical properties*, Galle: Faculty of Engineering,University of Ruhuna, Undergraduate Research Thesis, 125 pp.

[6] Sandaruwini, A.H.W.E., Bandara K.A.J.M.,and De Silva G.S.Y., *Investigation on Mechanical Behavior of Concrete with Fibers Made of Recycled Materials*, Proceedings of International Conference on Sustainable Built Environment (ICSBE-2012), 14-15 December 2012, paper no. SBE/12/81

[7] Rathnayaka, R.M.M.P., Malshan, W.V. D, De Silva Sudhira and De Silva Subashi, *Incorporating recycled PET fibres for concrete Cylindrical Culverts*, Proceedings of International Conference on Structural Engineering and Construction Management, 11th-13th December 2015, paper no.SECM/15/135