Experimental Investigation on Jute Fibre Reinforced Concrete with Partial Replacement of Fine Aggregate by Plastic Waste

M Kalaivani¹, G Shyamala², S Ramesh¹ and I Rajasri Reddy³
¹K.S.Rangasamy College of Technology, Tamilnadu, India
²SR University, Warangal, Telangana.
³Sumathi Reddy Institute of Technology for Women, Warangal, India.

E-mail: mkalaivani85@gmail.com

Abstract. Plastic waste is the major cause of environmental pollution and hence it should be recycled or reused to reduce it. Plastic wastes are used as fine aggregate in several quantities in the jute fibre reinforced concrete and check their aptness. This study investigates the effect of using plastic waste as an alternative for fine aggregate. The PET plastic bottle is injurious to land and health, hence the usage of plastic waste in the concrete will lead to protect the environment and human health. The partial replacement of fine aggregate and coarse aggregate are the major components in the concrete. In India tons of plastic wastes are produced per year hence by reusing in the concrete can decrease the wastages. The jute fibre is one of the natural fibre and it is used in plastic waste concrete to increase the split tensile strength and flexural strength of the concrete. The present study has been conducted on M20 grade concrete, by replacing fine aggregate by PET plastic waste for varying percentages such as 5, 10, 15 and 20%. The PET plastic concrete is optimized as 10% from the mechanical properties of concrete. The jute fibre is added for 0.25, 0.5, 0.75, 1% for various proportions by volume of optimized plastic waste concrete. The properties of fresh and hardened concrete were evaluated and compared. The experimental results of companion specimen show that the mechanical properties of plastic waste concrete increases with 0.25% of jute fibre in concrete. Utilization of M Sand and PET plastic aggregates in concrete leads to minimize the cost of construction and leads to sustainable environments. The natural fibres in concrete increase the strength of concrete.

1. Introduction

Concrete is the most generally utilized material in civil construction. It has the properties of high strength, low cost, structural stability & durability etc. Therefore, it is mandatory to include recycled materials as a replacement to construction materials are necessary to reduce the space occupied for landfill and also reduces the demand of natural sources[1]. The generation of Waste materials increased now a days with more population and most of these waste materials are non-degradable. The use of plastic in concrete improves the basic properties of concrete, so PET waste utilization in concrete is a strategy to take out destructive impacts of PET to condition thus less ecological debasement happens. Generally after use the PET bottles are thrown up and also it be converted into plastic waste[2]. These plastic wastes can be recycled or reuse in order to protect the environment form pollution and also to safe guard the human health. In order to address these problems there is a need to search the proper way of disposal of plastic waste[3]. The utilisation of recycled plastic waste
aggregates in concrete is one of the effective method of making concrete for construction purpose and also its strength depends upon the type of plastic waste and also the characteristics of plastic used[4]. It concluded the utilisation of plastic waste in concrete which decreases the cost of construction and also environmental pollution since the amount of sand utilized in concrete will be greatly reduced[5].

The incorporation of short discrete fibres in concrete has become popular nowadays due to its versatile advantages over plain concrete. Jute is cheap and abundant in natural fibres[6]. Thus, the combination of jute fibre and concrete may be one of the important approaches to the development of concrete technology. The objective of this study is to investigate the mechanical properties of jute fibre reinforced concrete (JFRC) for different combinations of fibre volume and length and compare the results with plain concrete[7]. Cylinders and prisms of standard sizes containing JFRC were prepared for compressive, split tensile and flexural strength tests and all the tests were carried out after 28 days moist curing. The smaller reduction in compressive strength of concrete will be taking place for a higher volume fraction of jute fibre content also the ductility of concrete increased gradually in the post cracking stage due to the addition of jute fibre[8], [9]. The jute fibre is cut at a length of 10 mm [10]and the fibre is soaked at a NaOH solution for about 24 hours after that jute fibre is dried for about 24 hours. Before mixing with concrete, jute fibres were cut into two different lengths and treated with NaOH solution[11]. The natural fibres with the treatment of NaoH solution provides strength and stiffness. Natural fibres like jute fibres increases the first crack load carrying capacity and also increases the flexural strength[12]. It was observed that NaOH treatment reduced the water absorption capacity of fibres. The utilisation of superplasticizer in concrete increases the flowability of fibre reinforced concrete[13]. Plastic waste aggregate concrete improves the strength of concrete and provides good bonding between the aggregates and cement paste[14]. The use of PET waste in concrete will provide a solution for the demand of natural aggregates and also the utilisation of natural source materials in concrete can be reduced. With increasing the quantity of plastic waste aggregates in concrete lower the compressive strength[15]. The Plastic waste should may lesser density and also in size when compared to conventional aggregate concrete[16]. This leads to permeability and also water absorption in concrete. By increasing the size of plastic waste aggregates and also uniform grading of aggregates these problems can be reduced. When increase in the percentage volume of plastic aggregates in concrete will reduce the workability of fresh concrete[17].

The natural fibres utilization in concrete leads to the production of ecofriendly concrete and also it is called as sustainable material[18]. Jute fibres are very less in dimension and also increases the flexural properties of concrete. Since it has shorter length the fibre dispersion and uniformity in the mix can be arrived. The jute fibres in concrete increases the permeability of concrete also. However, the quantity of fibres added to be limited to upto 0.5-0.6% by volume of concrete. With further increase in the volume fraction of concrete leads to decrease in the mechanical properties of concrete specimen[19]. The jute fibres should be washed with clean water prior utilising it in concrete. The chemical treatment is required with NaOH solution in order to remove the lignin will is occurred the surface of the fibre[20]. The properties of PET aggregate concrete mainly depends on the PET aggregates volume, Chemical composition of PET aggregates and also the density of concrete [21]. With these investigations an attempt has been made to study the combined effect of both PET waste and Jute fibre in concrete and also to produce an eco-friendly construction material. Hence, the aim of the present study is to investigate the performance of jute fibre reinforced concrete with fractional replacement of M-Sand with PET aggregates[22].

2. Experimental Investigation

2.1 Materials Used

Portland Pozzolona Cement (PPC) 53 grade is used as a binding material in the concrete and it gets its strength from chemical reactions between the cement and water. The cement has a specific gravity of 2.95. The properties of cement were tested and it meets the requirements of IS 12269-2013. The M-sand passes through 4.75mm and retained on 150 micron sieve was used as fine aggregate. The M-sand has a specific gravity of 2.65 and a fineness modulus of 2.75. A crushed stone of angular size was
used as coarse aggregates in concrete. The coarse aggregate has a specific gravity of 2.78. The properties of M-Sand and coarse aggregate meets the requirements of IS 383-1970. The Waste PET bottles were used in concrete for replacement of M-sand. The specific gravity of PET Aggregates was 2.61 and a fineness modulus of 2.89. The natural fibre called jute fibre with various volume fractions was used in concrete. The length of fibre was 10mm and the diameter of fibre was 0.5mm with the aspect ratio of 20 was used. The jute fibre is soaked in the NaOH solution for 24 hours to remove all impurities and then dried completely. Water available in our laboratory was used and it meets the requirements of IS 456-2000. Figure 1 shows the PET plastic waste and jute fibre used in concrete.

Figure 1. (a) PET Plastic Waste (b) Jute Fibre (c) Soaking of jute fibre in NaOH Solution

### 2.2 Mix Proportion

M20 grade of concrete was used for manufacturing concrete. Mix design was calculated based on the guidelines recommended in IS 10262:2019 and the Mix proportion was obtained as 1:2.1:3.72 with water cement ratio of 0.45. Ceraplast 300 was used as water reducing admixture which is of Sulphonated Napthalene based. Superplasticizer was used as 1% by weight of cement for all mixes inorder to achieve the required workability of concrete. Table 1 shows the mix proportion and the quantity of materials used for various concrete mixes. The jute fibres were added upto 1% by volume of concrete. The PET aggregates can replace for natural aggregates upto 20% in order to achieve sustainable concrete.

### Table 1. Mix Proportions of concrete mixes

| Mix ID | PET plastic Waste (%) | Jute fibre Vol.% | Cement (Kg/m³) | FA (Kg/m³) | PET plastic Waste (Kg/m³) | CA (Kg/m³) | Water (Kg/m³) | SP (Kg/m³) | Jute Fibre (Kg/m³) |
|--------|-----------------------|------------------|----------------|-----------|---------------------------|------------|----------------|-----------|------------------|
| PAC0   | 0                      | 0                | 338            | 714       | -                         | 1258       | 152            | 3.38      | --               |
| PAC5   | 5                      | 0                | 338            | 678       | 36                        | 1258       | 152            | 3.38      | --               |
| PAC10  | 10                     | 0                | 338            | 642.6     | 71.4                      | 1258       | 152            | 3.38      | --               |
| PAC15  | 15                     | 0                | 338            | 607       | 107                       | 1258       | 152            | 3.38      | --               |
| PAC20  | 20                     | 0                | 338            | 571       | 143                       | 1258       | 152            | 3.38      | --               |
| JFPAC1 | 10                     | 0.25             | 338            | 642.6     | 71.4                      | 1258       | 152            | 3.38      | 0.071            |
| JFPAC2 | 10                     | 0.5              | 338            | 642.6     | 71.4                      | 1258       | 152            | 3.38      | 0.142            |
| JFPAC3 | 10                     | 0.75             | 338            | 642.6     | 71.4                      | 1258       | 152            | 3.38      | 0.213            |
2.3 Preparation and Testing of Test Specimens
Totally nine different concrete mixes was prepared for making specimens. First mix was with Jute fibre and plastic waste aggregate called control mix, Second mix was the fine aggregate was replaced upto 20% for M Sand and third mix was Concrete with optimized plastic aggregate and Jute fibre in different volume fractions up to 1%. In order to determine the performance of concrete, the cube specimens of size 150mm for compressive strength, Cylinder of length 150mm and diameter 100mm for split tensile strength and a prism of size 500mm in length and 100 mmX100 mm in cross section for flexural strength. The specimens were cast and demoulded after 24 hours and then immersed in water for curing. After the required time period the specimens were taken out of the curing tank and dried.

3 Results and Discussion

3.1 Fresh Concrete Properties
The Slump values of all the mixes realized are given in Figure 2. All the mixes containing PET aggregates shows same slump value as like conventional concrete. The replacement for PET aggregates in concrete does not influence the fresh concrete properties. Small Percentage of PET aggregates does not affect the water absorpt. But while adding the Jute fibre the slump value is increased, meanwhile the workability of jute fibre reinforced concrete getting reduced. The percentage volume of jute fibre rises, simultaneously the workability of concrete getting reduced.

![Figure 2. Slump value for all mixes](image)

3.2 Compressive strength
The compressive strength of Plastic waste aggregate concrete and jute fibre reinforced plastic waste aggregate concrete is shown in Figure 3. The conventional concrete with 10% replacement of M-sand by plastic waste aggregate gives maximum compressive strength. The PAC10 concrete increases compressive strength of 15.47% when related to PAC0. The conventional concrete with 10% replacement of M-sand by plastic waste aggregate with 0.25% of Jute fibre gives the optimum results. The JFPAC1 concrete increases the compressive strength of 27% when compared to PAC0. From the Figure2 it can be understood that jute fibre upto 0.25% increases the compressive strength and further increase in volume of jute fibre there will be decrease in compressive strength. By adding the plastic waste upto 10% for the replacement sand will increases the compressive strength, further increment in the quantity of plastic waste there is a negative impact on the compressive strength.
3.3 Split Tensile Strength

The split tensile strength of Plastic waste aggregate concrete and jute fibre reinforced plastic waste aggregate concrete is shown in Figure 4. 64% of increase in split tensile strength was observed in concrete containing 10% of PET aggregate concrete when compared with conventional concrete. Jute fibre reinforced PET plastic aggregate concrete with 0.5% volume fraction of Jute fibre increases 100% of split tensile strength when compared to conventional concrete. From the Figure 3 it can be understood that jute fibre upto 0.5% increases the split tensile strength and further increase in volume of jute fibre there will be decrease in split tensile strength. With the presence of Treated Jute fibre, the PET aggregate concrete gives more tensile strength for a jute fibre dosage of 0.5%. When compared to compressive strength the tensile strength in increases double times due to jute fibre addition. The split tensile strength of JFPAC1 and JFPAC2 specimen was founded to be 30% and 43% more when compared to JFPAC0 specimen. When increasing the volume fraction of Jute fibre the tensile strength of concrete also rises. Further increase in fraction of fibres there will a decrease in split tensile strength.

3.4 Flexural Strength

The flexural strength of Plastic waste aggregate concrete and jute fibre reinforced plastic waste aggregate concrete is shown in Figure 5. 19% increase in flexural strength is observed in concrete containing 10% of PET aggregates when compared with conventional concrete. Jute fibre reinforced PET plastic aggregate concrete with 0.5% volume fraction of Jute fibre rises 35% of flexural strength when compared to conventional concrete. From the Figure 3 it can be understood that jute fibre upto 0.5% increases the flexural strength and further increase in volume of jute fibre there will be decrease.
in flexural strength. The flexural strength of JFPAC1 and JFPAC2 specimen was founded to be 15% and 32% more when compared to JFPAC0 specimen. There is no appreciate increment was founded in the flexural strength results for JFPAC3 and JFPAC4 specimens.

Figure 5. (a) Flexural Strength of PAC; (b) Flexural Strength of JFPAC

4 Sem Analysis
SEM analysis was carried out on the plastic aggregate concrete specimens in order to identify the bonding amongst the plastic aggregate and cement paste. Figure 6 has 4 types of images scanned the plastic aggregate concrete specimen (a) denotes the sample specimen were scanned by 1 micron, (b) denotes the sample specimen were scanned by 2 micron, (c) denotes the sample specimen were scanned by 5 micron and (d) denotes the sample specimen were scanned by 10 micron. SEM images shows that in the transition zone between the waste plastic aggregates and the cement paste shows a tendency to the formation of (C–S–H) gel which is responsible for hardening of cement matrix compared with that of conventional aggregates.

Figure 6.SEM images of 10% PET plastic aggregate specimen

4. Conclusion
From the present study, the following conclusions are drawn

- The workability of concrete will be decreased when increasing the percentage volume of jute fibre.
This experimental study shows that the 10% of PET plastic fine aggregate gives the higher strength when replaced with a fine aggregate.

Jute fibre reinforced concrete containing 10% of PET Aggregate with 0.25% volume fraction of jute fibre is found to be optimum for the compressive and 0.5% volume fraction of jute fibre is found to be optimum for split tensile strength.

Jute fibre reinforced concrete containing 10% of PET Aggregate with 0.5% volume fraction of jute fibre is found to be optimum for the flexural Strength.

Thus, by Using PET Plastic as Replacement for fine aggregate we can reduce the usage of natural fine aggregate and to reduce the wastages of plastic which is dumped in the soil.

From the experimental investigation, it was concluded that the inclusion of aggregates of jute fibre and plastic waste improves the overall concrete efficiency.

Acknowledgement
Authors highly gratify the Management, K.S.Rangasamy College of Technology, Tiruchengode for extending permission to perform the work and for publishing this work.

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