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STRUCTURAL PERFORMANCE OF E-WASTE CONCRETE REINFORCED WITH DIFFERENT FIBRES

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Abstract-E-waste is growing at a pace of 3-4% a year, and it is estimated that by the year 2025 its production will be increased to 55 million tons. The production of concrete in the year 2022 stood at 4.4 billion tons if we consider the percentage of aggregate at 60%-70% it comes out to be approx. 3 billion tons. The consumption of natural aggregates at this massive scale has put enormous pressure on mining resources and excessive mining has led to serious environmental and socio-economic problems. The studies so far have shown that addition of e-plastic waste as plastic aggregates results in deterioration of mechanical properties of concrete. This study aims to study the effect of addition of carbon and steel fibers on the mechanical properties E-waste concrete. Two sets of four types of concrete mixes were produced with substitution of manufactured plastic aggregate with natural concrete aggregate (NCA) up to 40% replacement levels. One set was added with carbon fibers and the other one with steel fibers. Both fibers were added in the fixed quantity of 1% by weight of binder material for each sample. The results indicated that the compressive strength of both sets of samples reduced in the range of 4-55% and 20-33% for e-waste concrete with carbon fibers and steel fibers respectively. The splitting tensile strength was reduced in the range of 5-47% and 13-32% for e-waste concrete containing carbon and steel fibers respectively.

Keywords**:** Fibre reinforced concrete, plastic aggregates, natural concrete aggregate (NCA) steel fibres, carbon fibres

1 Introduction

Electronic waste in crushed form has been used in various studies but there is very little research on using E-waste to produce manufactured plastic aggregates for use in concrete, the novelty of this research is that in this research manufactured plastic aggregates are used with combination of carbon and steel fibres.
Zeeshan ullah et al. [1] investigated the mechanical and durability characteristics of electronic waste concrete and discovered that for coarse aggregate replacement ratios of 10% and 20%, respectively, the compressive strength of E-waste concrete decreased in the range of 6.3%-17.1% and 23.5%-32.4%. Concrete's workability and durability were enhanced by the addition of E-waste. Sorptivity coefficient reduction, UPV values abrasion loss reduction, and enhanced performance when compared to alternative drying and wetting cycles.
C. Albano et al. [2] studied the influence of content and particle size of waste pet bottles in concrete. They found out increasing percentage of pet bottles decrease compressive strength, splitting tensile strength, modulus of elasticity and ultrasonic pulse velocity.

Semiha Akçaözog˘lu [3] found out that thermal coefficient, unit weight and compressive strength of concrete containing waste PET lightweight aggregate was decreased. The maximum drop in thermal conductivity was at 60% replacement of lightweight PET aggregate but compressive strength was dropped more than 80% which indicates that concrete can only be used for non-structural work.

Study conducted on review of recycled fine aggregates is cementitious composites. Results indicate mechanical properties like compressive strength, compressive and flexural strength decreases, similarly UPV also decrease.

Properties like water absorption, permeability and carbonation increase as percentage of plastic aggregate increase which indicates a porous concrete structure [4].

Synthetic aggregate produced by using mixture of recycled plastic made from linear low-density polyethylene (LLDPE) in powder form and red dune sand in the ratio of 70% and 30% respectively. The coarse aggregate ware replaced with synthetic aggregate in the ratio of 25%,50% ,75% and 100%. The mixes prepared with synthetic aggregate had slump reduction in the range of 11-23% as compared to control mix. The 28-day compressive strength of concrete containing synthetic aggregate decreases in the range of 15-63%, similarly the splitting tensile strength reduced in the range of 12-31% [5]. S. Bahij et al studied concrete containing different forms of plastic waste. Concrete porosity and water absorption increases. There compressive strength of concrete was reduced significantly. It was also reported that flexural strength and splitting tensile strength were also reduced [6].

The compressive strength of M20 grade concrete with coarse aggregate replaced by PCB plastic, CRT LCD Monitor, and other E-waste was compared to that of standard concrete by Saurav Dixit et al. They created four different sample kinds with varying E-waste contents (7%, 12%, 17%, and 22%). According to the study, replacing coarse aggregate with E-waste boosts concrete's compressive strength by up to 7% and up to 12% for M20 concrete. of substitution. The research suggested using e-waste as aggregate at a rate of 7–10% [7].

Aamar Danish et al added nano silica in the E-waste concrete in the range of 1-3% by the weight of binder. The purpose of research was to counter the negative effects of addition of electronic waste in the concrete on the mechanical properties. The research revealed that the compressive properties enhanced significantly [8].
A study on the sustainable reuse of E-waste in the form of coarse aggregate was conducted by S.Janani et al. In this study natural aggregates were replaced by electronic waste aggregates in the ratio of 5,10,15 and 20%. The study concluded that that plastic aggregate can be used in the replacement range of maximum 10% without having significant effect on the compressive strength of concrete [9].

2 Materials

2.1 Cement

Ordinary Portland Cement was used in preparation of concrete mixes in accordance with ASTM C150 [10].

2.2 Aggregates

Well graded coarse aggregate as per ASTM C33-03 were used in production of concrete mi along with sand as fine aggregate.

2.3 Plastic Aggregate

Plastic aggregate in the size range of 25mm to 4.5mm were used in as partial replacement of course.

2.4 Carbon Fibres

Carbon fibres in the in the mix were used as 1% by weight of binder material.

2.5 Steel Fibres

To improve flexural properties steel fibres were used as 1% of binder by weight.

Table 1 Material Properties (Steel and Carbon fibers)

Fibre Type	**Length (mm)**	**Diameter (mm)**	**Aspect Ratio (L/D)**	**Tensile Strength (N/mm2)**
Steel Fibre	30	0.55	55	1150
Carbon Fibre	30	0.40	75	5650

Table 2 Mix Design per meter cube of concrete.

Mix ratio	**Cement (kg/m3)**	**Water (Liters)**	**Fine Aggregates (kg/m3)**	**Coarse Aggregates (kg/m3)**	**Admixture (superplasticizer) (kg/m3)**	**Steel Fibers (kg/m3)**	**Cabon Fibers (kg/m3)**
1:1:2	520.78	223.93	520.78	1041.56	6.25	7.9	2.0

2.6 Admixture

To improve workability superplasticizer was used as 1% by weight of binder.

2.7 Water

Tap water free from impurities was used for producing concrete.

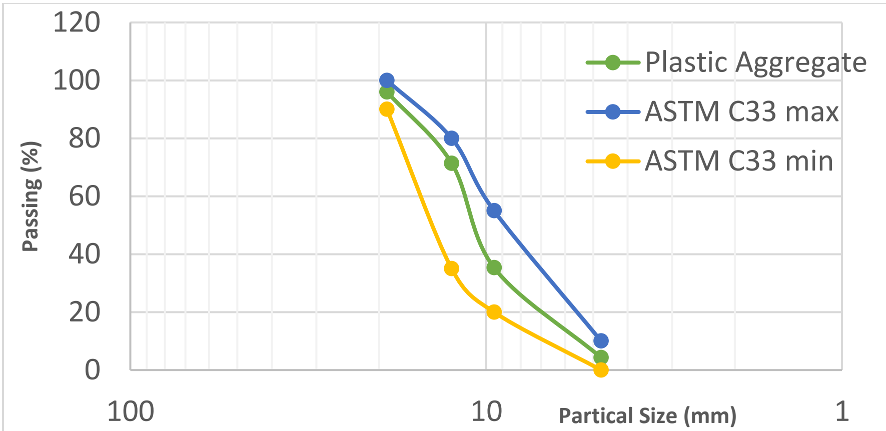

Figure 1: Gradation Curve Plastic Aggregate

3 Research Methodology

Plastic aggregates were used for replacement of coarse aggregate in varying percentages. Total 24 cylinders were cast,12 containing different percentages of Plastic aggregate with carbon fibre and remaining 12 with steel fibres.
The varying percentage of plastic aggregate were used from 10% to 40% and the ratio of fibres were kept constant as 1% of total binder content. Tested specimens having dimensions 12" height and 6" dia were prepared using concrete ratio of 1:1:2. Compressive strength and splitting tensile strength test were done on Compression Testing Machine (CTM) having loading capacity of 3000 KN..Stress-strain relationship was calculated using linear displacement sensor and strain reading at interval of 25 KN was noted. P3-stain indicator was used to measure readings from LDS at interval of 25 KN. To check the stress-strain behaviour, deflections, and maximum energy absorption of the cylinders the compressive strength test was conducted. The compressive strength test was conducted in compression testing machine (CTM).

Figure 2: Manufactured Plastic Aggregates and Carbon Fibres

Table 3: Description of Samples

Sample Designation	Description of samples
S1 PA+SF	Cylinder Specimen with Steel fibres and 10% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S2 PA+SF	Cylinder Specimen with Steel fibres and 20% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S3 PA+SF	Cylinder Specimen with Steel fibres and 30% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S4 PA+SF	Cylinder Specimen with Steel fibres and 40% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S1 PA+CF	Cylinder Specimen Carbon fibres and 10% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S2 PA+CF	Cylinder Specimen with Carbon fibres and 20% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S3 PA+CF	Cylinder Specimen with Carbon fibres and 30% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S4 PA+CF	Cylinder Specimen with Carbon fibres and 40% replacement of coarse aggregate with manufactured E-waste plastic aggregates
S5 CCF	Control Specimen Cylinder for carbon fibres specimen 6" Diameter 12" Height

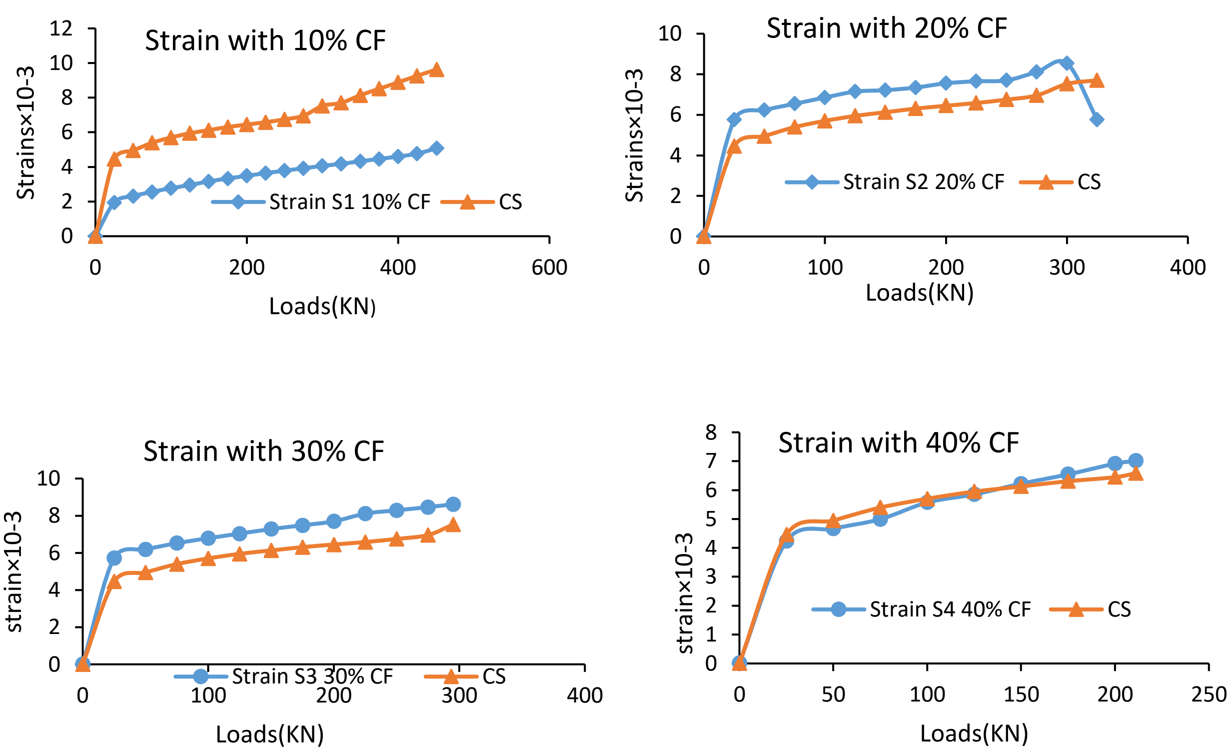

Figure 3 Loads vs Strain graphs with Carbon Fibres

4 Results and Discussions

4.1 Loads vs Strain Graphs with Carbon Fibres

The load vs strain graphs for E-waste concrete samples containing carbon fibers are shown in figure 6. The results are consistent for 20%. 30% and 40% ratios but in the case of 10% replacement sample the values of strain are quite low as compared to control specimen. If we compare these results with sample containing steel fibers, it is evident that the values of strain at same loading conditions are less.

4.2 Compressive Strength

Compressive Strength & Load vs Compressive Strength graphs is shown in Figure 7 which shows the compressive strength of both the sample sets. From the graph we can see that there is considerable reduction in compressive strength with the addition of plastic aggregates, in case of sample with steel fibers the maximus reduction in compressive strength is 32% at 40% substitution of natural aggregates with plastic aggregates. In the case of samples containing carbon fibers the loss in compressive strength is higher with maximum reduction of 55% as compared to control specimen.

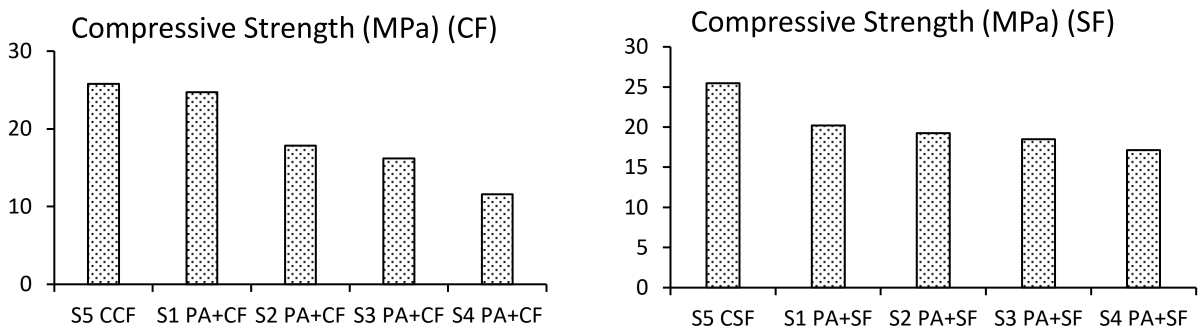

Figure 4 Compressive Strength

4.3 Splitting Tensile Strength Steel and Carbon fibres.

To check the effects of fibers on the tensile strength of concrete splitting, tensile tests were carried out. The addition of plastic aggregates decreased the tensile strength, but the percentage of tensile strength loss was less as compared to percentage of compressive strength loss. The overall tensile strength loss for steel fibers is 30% and for carbon fibers is 47%.

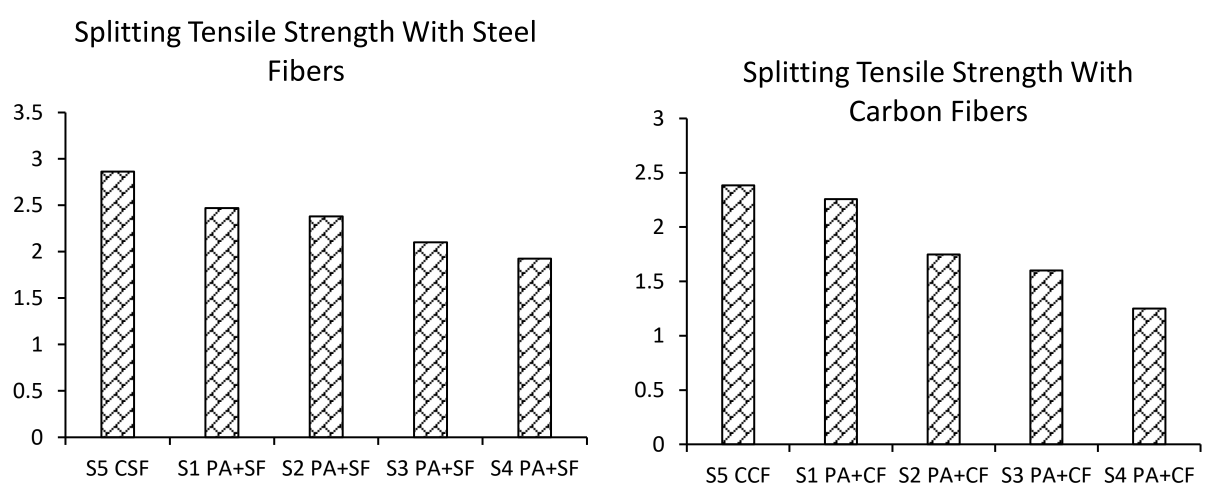

Figure 5 Splitting Tensile Strength

5 Relevance of Research

All the study related to use of electronic waste till this data is focused on using electronic waste as replacement material for coarse and fine aggregates as per literature very little research material is focused on improving the properties of E-waste concrete. In this research a new approach of using fibers for improving the mechanical properties is used. Research has indicated that use of fibers improves bond strength of aggregates, flexural properties, fracture toughness, ductility, and resistance to higher temperatures. If we are able to produce E-waste concrete with acceptable mechanical properties it will be a huge step forward in the direction of reuse of plastics in an effective manner. This research is also an effort to find ways to improve mechanical properties of E-waste concrete.

6 Conclusions

From the results of experiments carried out in this research following conclusions are made:

1. The compressive strength of E-waste concrete is directly proportional to the replacement ratio of plastic aggregate, higher the replacement more will be compressive strength loss. The addition of fibers has no significant effect in preventing compressive strength loss.
2. The tensile strength decreases with an increase in plastic aggregate, but addition of fibers helps reduce this strength loss. The splitting tensile strength was reduced in the range of 5-47% and 13-32% for e-waste concrete containing concrete and steel fibers respectively. Steel fibers performed better in reducing tensile strength loss.
3. The E-waste concrete with up to 20% replacement of natural aggregate can be used in non-structural applications.
4. Addition of fibers indicates a positive improvement in tensile strength of E-waste concrete.

The basic objective of this study was to study the effects of addition of carbon and steel fibers in E-waste concrete. As per above mentioned results it is quite evident that the tensile properties of E-waste concrete with fibers are improved as compared simple E-waste concrete. Further studies to optimize the concrete mix of E-waste concrete using cementitious materials to improve the compressive strength of concrete can be carried out.

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