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A study of hybrid fibre reinforced concrete with E-plastic waste

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Abstract. Electronic waste, also known as electronic and electrical equipment waste, poses significant pollution issues for people and the environment. It's essential to think about new, efficient waste management methods, particularly those that emphasise recycling. Glass fibre and polypropylene fibre have the benefit of being lightweight, lowering the overall cost of building and promoting construction efficiency. The effectiveness of hybrid fibre-reinforced concrete using E plastic waste as coarse aggregate was investigated in the current study. The concept behind the research study is to replace 0% to 30% of the concrete's coarse aggregates with E-waste and 1% glass and 1% polypropylene fibres (each by weight of concrete). The results demonstrated that E-plastic aggregate may be successfully used in fibre-reinforced concrete, up to 20% of the weight of the coarse aggregate with hybrid fibre, leading to resource and waste depletion.

1 Introduction

Concrete is widely used in the construction sector, which is increasing quickly. Utilizing leftovers and by-products is a component of the answer to ecological and environmental issues [1,2]. Using these materials has several indirect benefits, such as lower landfill costs, energy savings, and environmental protection from potential pollution effects, in addition to ensuring that these materials are used in cement, concrete, and other building materials and reducing the cost of cement and concrete production [3-5]. The concrete industry has partially attempted to replace coarse particles with non-biodegradable parts of E-waste [6]. Every year, the world generates an estimated 30–35 tonnes of quarry dust and e-waste. To decrease the environmental impact of processing quarry dust and E-Waste for reuse in the building industry, a different workable solution is required [30,34].

Plain concrete's tensile strength, ductility, and crack resistance are relatively low. The concrete naturally contains internal micro cracks, and as a result of these microcracks spreading, the concrete has a poor tensile strength that finally results in brittle fracture [7]. The most frequently acknowledged solution for concrete's flexural weakness is high-strength steel for conventional reinforcement, despite the fact that these techniques improve the tensile strength of the material [13,16]. Additionally, if the concrete is of low workability, especially in the case of heavy concrete, the placement of reinforcement and efficient compaction of RCC are both exceedingly challenging [17]. Structure cracks can develop in plain concrete and other brittle materials even before they are loaded due to drying shrinkage or other factors of volume change.

Under loading microcracks spread and widen, and because of the effects of stress concentration, new cracks develop where there are minor flaws. Additional fractures develop with tiny flaws due to the attention of structural stress [19]. Because of several limitations, the structural cracks develop slowly. The growth of such microcracks is the primary factor in the inelastic deformation of concrete. It has long been understood that adding short, uniformly scattered fibres will significantly enhance concrete's static and dynamic properties while acting as crack arresters[20,21]. The term "fibre-reinforced concrete" refers to such concrete. The same result is achieved by glass fibres, which also outperform all other fibres. It has long been understood that adding tiny, uniformly scattered fibres will significantly enhance concrete's static and dynamic properties while acting as crack arresters [24,25].

Synthetic polypropylene fibres are a by-product of the textile industry. These are affordable and come in a variety of aspect ratios. Inexpensive specific gravity and low price are two characteristics of polypropylene fibres[27]. Using it, the material's inherent tensile and flexural strengths may be used effectively and reliably, and thermal cracking and plastic shrinkage cracking is significantly reduced. In the event of a fire, it offers reinforcement, protects against substantial structural damage, and prevents spalling. These dissertations compare the behaviour of reinforced concrete that has been supported using hybrid fibre to plain concrete.

2 Literature Survey

Chandramouli.K. [11] experimentally evaluated the rapid chloride permeability test for durability research on glass fibre reinforced concrete. Concrete cylinders were produced with varying additions of 0.03, 0.06%, and 0.1% glass fibre. The decreasing permeability of GFRC, which contains 0.1% glass fibres, was 17.59% at 90 days and 28.80% when the specimen was evaluated at 720 days. Using E plastic waste as the coarse aggregate, Lakshmi R and Nagan S [18] investigated the strength characteristics of concrete. With appropriate strength development characteristics and no negative long-term impacts, coarse aggregate could be replaced in concrete with 20% E-waste aggregate.

Addition of glass fibres increased the compressive strength, flexural strength, and split tensile strength of concrete of the M20, M30, and M40 grades by 20% to 30%, 25% to 30%, and 25% to 30%, respectively, at 28 days when compared to plain concrete reported by Avinash Gornale and Arabi Nourredine et al. [8, 9]. Deshmukh S.H. and Baaros et al. [10, 12] noted from the experimental findings and their analysis that adding glass fibre increases the concrete's compressive, flexural, and splitting tensile strengths. At the same time, they improved the concrete's mechanical characteristics and durability by 0.1% by adding glass fibre.

The impact of polypropylene fibre in various quantities and fibre lengths has been studied to enhance the concert features of lightweight cement composites recommended by Roohollah Bagherzadeh [26]. The mixture with two different fibre proportions (0.15% and 0.35%) by cement weight and fibres with two different sizes (6mm and 12mm). When compared to unreinforced LWC, Polypropylene (PP) reinforced Lightweight Cement Composites (LWC) with fibre proportioning were 0.35% of 12 mm fibre length had a 27% improvement in splitting tensile strength and a 30.1% increase in flexural strength. According to Yogesh Murthy et al. [29] adding glass fibres to concrete improves its performance and makes it easier to eliminate glass as industrial waste for the environment. According to the investigation, there is a 30% improvement in the flexural strength of the beam with 1.5% glass fibres. With more glass fibres present, the slump was shown to be reduced.

Gowri et al. [14] have conducted a study to better understand the performance of glass fibre reinforced concrete (GFRC) in both its fresh and hardened states. It has been noted that concrete with a more significant percentage of glass fibre may necessitate using superplasticizers to preserve its workability. Praveen Mathew et al. studied the influence of concrete's strength qualities when coarse aggregate was partially replaced by E plastic waste in 2013. They concluded that the concrete's compressive strength was improved when 22% of the average coarse aggregate was replaced with coarse plastic aggregate.

Milind V. Mohod [23] find the ideal polypropylene fibre content by experimenting with several levels of polypropylene content, such as 0%, 0.5%, 1%, 1.5%, and 2%. The compressive, tensile, and flexural strengths all showed a noticeable improvement. To learn more about the mechanical properties of fibre-reinforced concrete, however, more research was strongly encouraged. They used various percentages of ground glass fibre (GGF) as a pozzolanic (10%, 20%, and 30% by mass) in concrete. 2017 researchers Hassan Rashidian-Dezfouli and Prasad Rao Rangaraju observed the findings [15,25]. Because of this, the resistance of GGF-containing mixes to the alkali-silica reaction, sulphate attack, and drying shrinkage were assessed. The findings were compared to a two-year control combination with portland cement and a mixed variety containing 25% of class F fly ash. The outcome showed that the durability qualities were significantly improved when GGF was used in place of Portland cement.

Manoj Kumar et al. [22] experimentally examined the compressive, tensile, and flexural behaviour of concrete using glass fibres with a diameter of 14 microns, indifference percentages of 0%, 0.4%, 0.8%, 1.2%, and 1.6% by the weight of cement, and a water-cement ratio of 0.45. According to studies, adding 1.2% glass fibre by the weight of cement to concrete can boost its strength up to 17.36% compared to ordinary concrete. It can also raise its flexural strength to% and split tensile strength up to 40%. Teja V. P. et al. [28] investigated the effects of composite cement and glass fibre on concrete's strength and durability in specific applications. When combined with 50% regular Portland cement, 25% fly ash, and 25% ground granulated blast furnace slag, the compressive strength exhibits a specific development. Compared to glass fibre, there is hardly any difference in strength.

In this study is to determine behaviour adding hybrid fibre to concrete and replacing fine particles in different proportions with E-plastic waste affects the final product. The qualities of hardened concrete, including its compressive, split-tensile, and flexural strengths, were examined.

3 Method and Materials

3.1 Cement

The cement is OPC 53 grade was utilized and complies with IS: 8112-1989. The specific gravity, consistency, and setting test results for cement are listed in Table 1 together with information on the cement's physical properties.

Table 1. Characteristics of Cement

S.No	Characteristics	Value
1.	Specific gravity	3.14
2.	Standard consistency	29%
3.	Percentage of fineness	2%
4.	Specific Surface	2.24 m^2/kg
5.	Initial setting time	45 minutes

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6.	Final setting time	360 minutes

3.2 Fine aggregate

To screen out any larger than 4.75 mm particles, the sand was first run through that size screen. The fine aggregate was subjected to tests using IS: 383-1970. The physical parameters of the fine aggregate are listed in Table 2.

Table 2. Characteristics of fine aggregate

S.No	Characteristics	Value
1.	Nature	River sand
2.	Specific gravity	2.68
3.	Fineness modulus	2.6
4.	Grading zone	II
5.	Bulk Density	1693 kg/m^3

3.3 Coarse aggregate

According to IS: 383-1970, aggregates passing through a 20-mm sieve and remaining on a 16-mm sieve were sieved. Table 3 lists their physical characteristics.

Table 3. Characteristics of coarse aggregate

S.No	Characteristics	Value
1.	Nature	Crushed
2.	Specific gravity	2.74
3.	Impact value	16.26%
4.	Bulk Density	1527 kg/m^3

3.4 E-Plastic Waste

Utilising some of the current technology, the E-plastic waste that is created needs to be treated in the most efficient way possible. When it comes to planning waste management, having information on the characteristics of E-waste is absolutely necessary. This is because waste management technology is constantly evolving. E-waste from a plastic recycling facility in Madurai was used for the experimental program. Table 4 lists the physical characteristics of E-Plastic waste.

Table 4. Characteristics of E-Plastic Waste

S.No	Description	Value
1.	Specific gravity	1.01
2.	Absorption (%)	0.2%
3.	Colour	Dark
4.	Shape	Angular
5.	Crushing Value	2%
6.	Impact value	1.8%

3.5 Fibres

3.5.1 Glass Fibres

In this experiment, continuous glass fibres were employed to solve the issue of earlyage plastic shrinkage cracks and create suitable mechanical properties in the concrete.

3.5.2 Polypropylene Fibres

In this work, short-cut polypropylene fibres were used to increase concrete's elasticity, control cracks, and reduce water permeability. Table 5 lists their physical characteristics.

Table 5. Characteristics of Glass and Polypropylene fibre

S.No	Description	Glass fibre	Polypropylene fibre
1.	Length (mm)	6	12
2.	Diameter (μm)	0.014	0.05
3.	Aspect ratio	428	240
4.	Density (kg/m^3)	2680	980
5.	Modulus of Elasticity (GPa)	72	3.5
6	Tensile strength (Mpa)	1700	400

3.6 Super Plasticizer

In this study, Master Glenium SKY 8233, a high-performance superplasticizer based on polycarboxylic ether, was used. It has a pH of 6, a relative density of 1.08 at 25°C, and is a free-flowing liquid.

3.7 Mix compositions

Five different ratios for the concrete mixture were used in this investigation. The first mixture was the control mixture, while E-waste and hybrid fibre were included in the other four mixtures. By weight, E Plastic trash was used in place of coarse aggregate (typical sand). 10%, 20%, and 30% of the coarse aggregate were swapped out for other materials. The water cement ratio for the mix is 0.42. Power-driven rotating drum mixers with a 1 m^3 capacity were used to mix concrete. The test specimens were made using the same 1:1.87:3.28 concrete mix designed using IS: 10262:2009 procedures. Table 6 provides the mixture proportions.

Table 6. M30 Mixture proportions in kg/m^3

Mix Designation	Cement	Fine aggregate	Coarse aggregate	E Plastic waste	Fibre (GF + PP)	SP	Water
S1	380	712	1250	0	7.6	11.4	160
S2	380	712	1250	125	7.6	11.4	160
S3	380	712	1250	250	7.6	11.4	160
S4	380	712	1250	375	7.6	11.4	160
S5	380	712	1250	500	7.6	11.4	160

4 Experimental Investigation

4.1 Compressive strength test

The compressive strength of the concrete was assessed using conventional cube specimens that were 150 x 150 x 150 mm. Three samples were tested for 28 days with varying percentages of E plastic trash as 0%, 10%, 20%, 30%, and 40% while maintaining the proportion of fibres at 2% (each 1% of the weight of concrete). The usual concrete mix was contrasted with these. The components were weighed, and then hand mixing was used to combine the materials. Using a table vibrator, the mixtures were vibrated. Superplasticizers made up 0.5% of the binder's weight. After 24 hours, the specimens were taken out of the mould and allowed to cure for 28 days in water. Table 7 displays the test values and Figure 1 shows the variation of average compressive strength values of all mixes were presented.

Table 7. Compressive and Split tensile strength results

Mix/ Test (N/mm^2)	S1	S2	S3	S4	S5
Compressive Strength	36.67	42.12	52.41	47.23	45.13
Split tensile strength	3.04	3.36	3.94	3.52	3.42

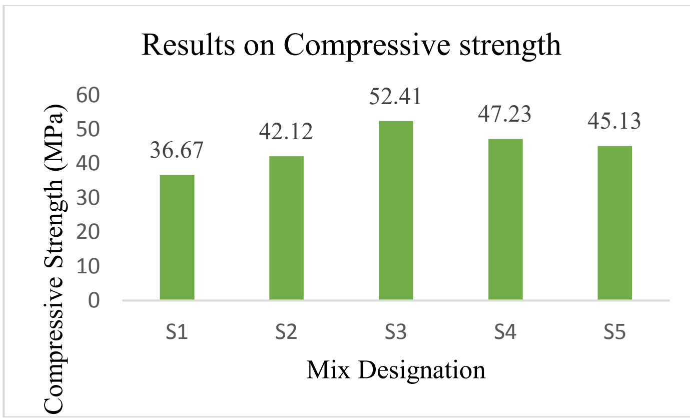

Fig. 1. Test Results on Compressive Strength at the age of 28 Days

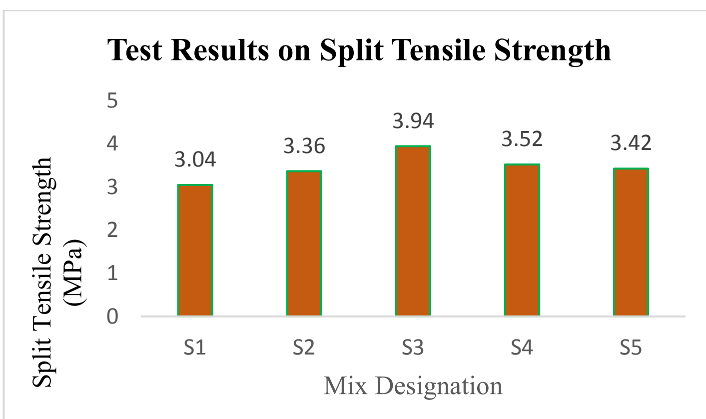

Fig. 2. Test Results on Split Tensile Strength at 28 Days

4.2 Split Tensile Strength

To test the split tensile strength, standard cylinder moulds 100 mm by 300 mm were manufactured. In this test, the specimen was broken by compression line stresses that were delivered in a vertical, symmetrical plane. According to BIS: 5816-1999, tests were conducted and the average split-tensile strength values were obtained. Fig. 2 display the splitting tensile strength test findings.

4.3 Two point load setup for RCC beams

To conduct the testing, a two-point loading technique was used. Two pedestals supported the beams, and 40-ton universal testing equipment delivered concentrated stresses on them (UTM). Utilizing LVDTs, which were positioned in the middle of the span and underneath the loading areas, the deflections were measured. The specimen failure load, kind of failure mechanism, and failure load for each beam were noted. In addition, the load at which concrete began to break was noted. Figure 3 specifics of the reinforcement for the RCC Beam and the Figure 4 depicts experimental configuration.

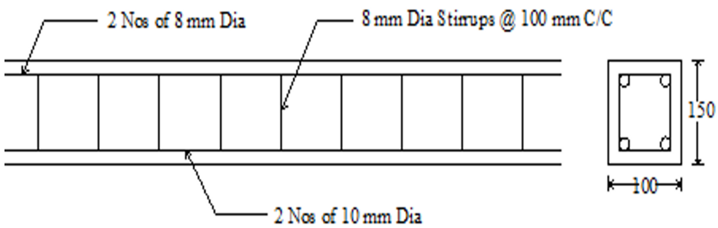

Fig. 3. Details of reinforcement for RCC beam

Fig. 4. Two-point loading setup

With increasing the percentages of E Plastic waste and hybrid fibre in R.C.C. members, the ultimate load-carrying capability of the R.C.C. beams under flexural loading is significantly increased. The equation is used to determine the beam's flexural strength.

Flexural strength (N/mm^2 or MPa) = PL/bd^2

Where,

P = load at failure

L = The support's distance from centre to centre = 1500 mm

b = breadth of specimen =100 mm,

d = depth of specimen= 150 mm

Compared to the standard concrete mix, the flexural strength of a hybrid fibre reinforced concrete (HFRC) beam with a 20% substitution of coarse material with E plastic waste performs better. Table 8 and Fig. 5 demonstrate their flexural strength findings for HFRC beams.

Table 8. Average flexural strength (N/mm^2) at 28 days

Mix Designation	**Average flexural strength (N/mm^2)**
S1	5.40
S2	5.45
S3	5.62
S4	5.23
S5	5.16

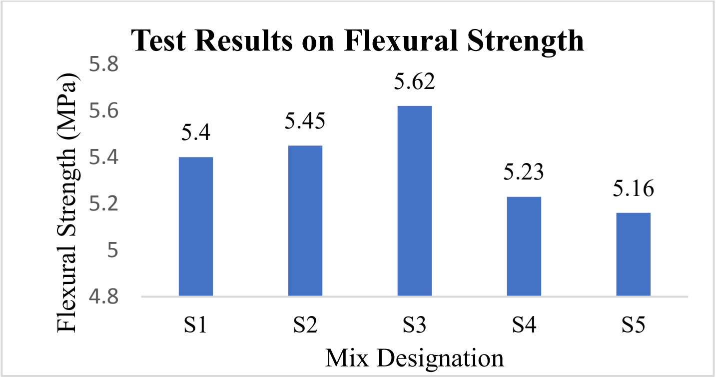

Fig. 5. Flexural strength of RC beam at 28 days

The load-deflection behaviour of different percentages of E-Plastic waste in HFRC beams is shown in Figure 6 in order to compare and more correctly portray the load against mid-span deflection curve for all the tested flexural beams. By substituting different percentages of E-waste, the ultimate load was raised, as seen in Table 9's comparison of load to midspan.

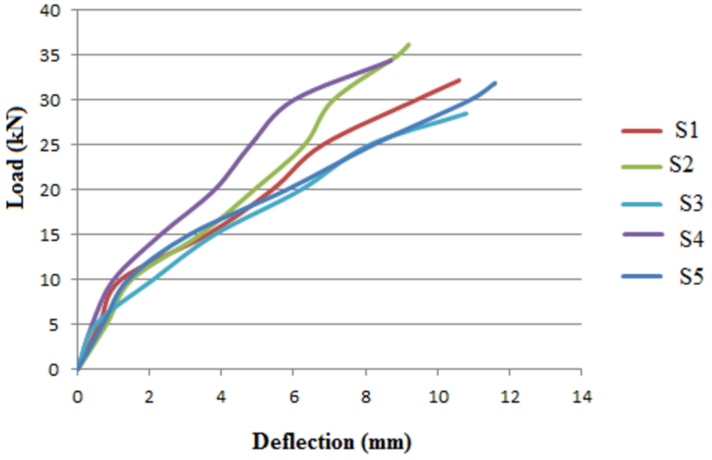

Fig. 6. Load-Displacement behaviour of beams

Table 9. Load Versus Mid Span Deflection for the Beams

S1		S2		S3		S4		S5	
Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
5	0.6	5	0.8	5	0.7	5	0.4	5	0.5
10	1.2	10	1.5	10	1.4	10	1	10	2.1
15	3.6	15	3.4	15	3.1	15	2.3	15	3.8
20	5.4	20	4.9	20	5.8	20	3.8	20	6.2
25	6.8	25	6.3	25	8.2	25	4.8	25	8.1
30	9.4	30	7.1	30	10.9	30	6	28.5	10.8
32.2	10.6	35	8.9	31.9	11.6	34.4	8.7	-	-
-	-	36.2	9.2	-	-	-	-	-	-

5 Conclusion

This study aimed to identify practical methods for recycling hard plastic trash into concrete aggregate. In general, from all the test results, it is clear that the concrete cast using the 20% replacement of coarse aggregate with e-plastic waste and 1% of each glass fibre and Polypropylene fibre gives better results than the conventional concrete. Because of this, the non-structural parts of a concrete construction can be prepared with this particular kind of concrete that is based on E-waste. E-waste aggregate improves the ductility of concrete as compared to conventional concrete, which indicates its ability to resist seismic loads. The incorporation of E-waste increases the durability and mechanical properties of concrete, which indicates that it has the potential to be used in the preparation of structural concrete. This also indicates that it has the potential to be used in the production of structural concrete.The findings of an analysis of concrete's strength properties, including recycled waste plastic and hybrid fibre, are as follows.

1. The electronic waste can be disposed of by utilising them as building materials in the construction industry.
2. The smooth surface texture of manufactured E-Waste plastic waste aggregates improves the workability of concrete. Hybrid Fibre-reinforced concrete can contain 20% of E-waste aggregate in place of coarse aggregate without any detrimental long-term effects and with acceptable strength development attributes.
3. Overall, it is evident from all the test findings that ordinary concrete does not perform as well as concrete which has had 20% of the coarse aggregate replaced with E-plastic waste and 1% of both glass fibre and polypropylene fibre.
4. Glass and polypropylene fibres significantly boost concrete's compressive strength and this strength rises as the fibre content does as well. Hybrid fibre is an excellent additive to reinforced concrete that meets all standards and may be utilised for all building purposes.
5. Due to the incorporation of hybrid fibres, the HFRC beams display widely dispersed and fewer cracks than control beams, increasing the toughness, ductility, and stiffness properties. The purpose of this project is to investigate in greater depth how to capitalise on the growing amount of e-waste around the world in future.

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