Study on Properties of Concrete Using E-Waste Copper, Aluminium and Steel Fibers

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Abstract— Electrical and electronic garbage that has reached the end of its useful lifespan is referred to as "e-waste." As technology develops, an immense quantity of e-waste is generated every day. Every year, several tones of e-waste must be disposed of. Thus, as it reduces solid waste issues and harm to the environment, e-waste in concrete is a concept of sustainable concrete. In this work, recycled copper, aluminum, and steel fibers from telecommunication and internet cables have been utilized to reinforce the fibers in M50 design mix concrete. Fiber's act as a crack arrester and could significantly improve the characteristics of concrete if added.[6] These fibers were added to the concrete at weights of 0.5%, 0.75%, 1.25 percent, and 1.5 percent. Additionally, different fibers—30, 50, and 80—had differing aspect ratios. At the appropriate curing age, the compressive strength, split tensile strength, and flexural strength of fiber-reinforced concrete with varied aspect ratios were calculated and compared with regular concrete. According to the experiment's findings, 1.0% of e-waste fibers should be added to concrete in order to achieve the best compressive strength. The steel fiber's strength was 66.89 N/mm². The best result for split tensile strength was 1.50%, with 10.62 N/mm² in copper fiber. And In copper fiber, the optimal result for flexural strength at 1.50% strength was 10.87 N/mm².[9]

Keywords— Fiber reinforcement, fibers, electronic waste, Compressive strength, Split tensile strength, Flexural Strength, Optimum percentage.

I. INTRODUCTION

Electronic equipment, appliances, and devices that have reached the end of their useful lives are referred to as electronic garbage, or E-waste. Because electronic items are used so widely and technology is advancing so quickly, the development of E-waste in India has become a major environmental and health hazard.[5]

India's increasing use of electronic products has led to the country being one of the world's top manufacturers of e-waste. Older electronic devices, computers, televisions, cell phones, and other electronic appliances are the main sources of e-waste in the nation. When these gadgets break down or become outdated, they are frequently disposed of incorrectly, which has negative effects on the environment and human health.[2]

The environment and public health are seriously threatened by the incorrect handling and disposal of e-waste. Hazardous compounds included in electronic equipment include lead, mercury, cadmium, and brominated flame retardants. If these materials are not handled appropriately, they can pollute soil, water, and air. Furthermore, informal recycling methods are widespread in India and frequently entail burning or disassembling electronic components without taking the necessary precautions, which releases pollutants and harmful chemicals into the atmosphere.[4]

Commonly found in electronic components are steel, copper, and aluminium. Recovering these elements from e-waste can offer a sustainable supply of materials for use in building. The problems of disposing of E-waste are addressed, and the mechanical and structural qualities of the resultant concrete composite are improved, by incorporating these metal threads into concrete.[6]

Recent years have seen an increase in interest in the use of E-waste Fibers in concrete as practitioners and researchers look for more ecologically acceptable substitutes for conventional building materials.[10] This method helps to generate more sustainable and environmentally friendly building techniques in addition to encouraging recycling and resource efficiency.[13]

Three distinct types of Fiber-reinforced concrete are examined in this study. 1. E-waste copper, aluminium, and steel Fibers are extracted from the E-waste Management plant and added to concrete at weight percentages of 0%, 0.5%, 0.75%, 1.25, and 1.50%, respectively. Additionally, determine the ideal values for the concrete's various mechanical properties, such as its flexural, split tensile, and compressive strengths.[7]

II. MATERIALS USED

A. M50 Design mix concrete

1. Cement

Ordinary Portland Cement (OPC 43 Grade) has a compressive strength of 43 Megapascals (MPa) following a 28-day curing period. In India's construction industry, it is one of the most widely utilized varieties of cement. The abbreviation "OPC" stands for Ordinary Portland Cement, a kind of hydraulic cement that sets chemically by reacting with water.[22]

2. Fine Aggregates

High-grade river sand that was widely available in the area was utilized as a fine aggregate. The sand was displaying Zone II compatibility. Retained aggregate after being passed through a 4.75 mm filter is placed on the 75µm sieve. It is found that the specific gravity for these fine aggregates is 2.44.[5]

3. Coarse Aggregate

The broken granite stone aggregate came from a nearby quarry. The specific gravity, or density, of the coarse aggregates in the experiment, which included 20 mm and 10 mm aggregates, was determined to be 2.75.[5]

4. Water

Water that is used to make concrete needs to be pure, uncontaminated, and safe to drink. It is generally advised to mix concrete with drinkable water. There shouldn't be any dangerous materials or excessive contaminants in the water that could compromise the concrete's qualities. The ratio of water to cement in concrete was 0.35.[9]

5. Super plasticizer Admixture

High-range water reducers, or super plasticizers, are a class of additive used in concrete to improve workability and performance. These substances are mixed into the concrete mixture to lower the water content needed to reach a particular workability level without sacrificing the concrete's strength or longevity.[23]

6. M50 design mix proportion

Table 1[4]

No.	Material	Quantity
1.	Cement	451 kg/m³
2.	Water	158 kg/m³
3.	Coarse Aggregate- 20mm	779 kg/m³
4.	Coarse Aggregate- 10mm	477 kg/m³
5.	Fine Aggregate	646 kg/m³
6.	Chemical Admixture	3.61 kg/m³
7.	W/C ratio	0.35

B. E-waste Fibers

1. Copper fiber

Copper's superior conductivity makes it a popular metal in electronics. It is present in connections, wiring, and other parts of electrical gadgets. Copper fiber made from e-waste collected from e-waste management plant. Chopped copper fiber into 1.0- and 0.6-mm diameter and 30-35 mm length. Other properties of e-waste fiber are given in table 2.[1][15]

Table 2[1]

Length of Fiber	Diameter of Fiber	Aspect ratio
30-35 mm	1.0mm	30
30 mm	0.6 mm	50

2. Aluminum Fiber

As aluminum is lightweight and conductive, it is frequently used as a component in electronic products. E-waste Aluminum fiber collected from E-waste management plant. Aluminum fiber cutted into 50 mm length and 1.0mm dia. Other properties of e-waste fiber are given in table 3.[18][1]

Table 3[1]

Length of Fiber	Diameter of Fiber	Aspect ratio
50 mm	1.0mm	50

3. Steel Fiber

Concrete is strengthened structurally by the addition of steel fibers, a sort of reinforcement. For improved performance in a variety of applications, these fibers, which are usually formed of steel, are added to concrete mixtures. Concrete strengthened by steel fibers has better toughness, greater resistance to cracking, and increased tensile strength.[17][1]

Table 4[1]

Length of Fiber	Diameter of Fiber	Aspect ratio
60 mm	0.75 mm	80

Fig. 1. Copper fiber

Fig. 2. Aluminum fiber

Fig. 3. Steel fiber

III. METHELODOGY

A. Test of specimens

The IS code standards were observed in the casting and testing of concrete cubes, cylinders, and beams. The percentage of fibres varied from 0% to 0.25%, 0.75%, 1.25%, and 1.50% in the M50 concrete mix. 150 mm diameter and 300 mm long concrete cylinders, 150 mm x 150 mm x 150 mm nominal concrete cubes, and 150 mm x 150 mm x 500 mm nominal concrete beams were used.[24] A combination of fibres was added to the aggregate after the specimens were cast, ensuring that the fibres distributed uniformly throughout the mixture. Flexural, splitting, tensile, and compressive strength differences were examined in concrete cubes with different fibre percentages. Three sets of nine fiberless cubes, nine cylinders, and nine prisms of M50 mix were cast. Then, in several sets of cubes, cylinders, and beams, various fibre content ratios of 0.25%, 0.75%, 1.25%, and 1.50% were cast. The specimens was placed in a curing tank and allowed to finish the required time of curing before being tested.[12]

1. Compressive strength of concrete

The compressive strength of the 150 mm x 150 mm x 150 mm concrete cubes was calculated using IS516. The empty space between the cube and the loading frame was filled with nothing. The load was put on gradually with no any shock. The cubes were cured for 7, 14, and 28 days before their compressive strength was tested. Table 6 provides the tabulated results, while Figure 4 shows a visual representation of the information.[24]

2. Splitting tensile test of concrete

For its splitting tensile strength, 300 mm long and 150 mm in diameter cylinders were built in accordance with IS 5816. Symmetric lines have been drawn on the cylinders to ensure that they were all in the same plane. The strength of splitting tensile was assessed following 7, 14, and 28 days of curing. Table 7 provides the tabulated results, while Figure 5 provides a visual representation of the data.[25]

3. Flexural Strength of concrete

A cast 150 mm x 150 mm x 500 mm beam's flexural strength is measured 7, 14, and 28 days after curing, in accordance with IS516, the standard. When the load is put on gradually, there is no disturbance and no vibration. We evaluated the flexural strength of the beams at 7, 14, and 28 days of curing. Figure 6 shows a graphical representation of the results, which were described in Table 8.[24][22]

IV. Results and Discussions

A. Compressive Strength test results

Table 5: Normal Concrete

M50 Concrete	Compressive Strength
7 days	43.02 N/mm²
28 days	58.82 /mm²

Table 6: Compressive result (N/mm²)[9]

Fibers	0.50%	0.75%	1.25%	1.50%
Copper- 1	61.3	62.21	65.55	61.25
Copper-2	48.23	53.25	57.85	63.85
Aluminium	46.99	43.12	45.55	32.78
Steel	53.52	51.2	66.89	63.5

For regular concrete, the 28-day compressive strength is about 58.82N/mm². It can be seen from the preceding table that for all e-waste Fibre percentages, The optimum result in steel Fiber at 1.25% Fibers add in concrete. And result was increase by 15.32% compressive strength with added 1.25% steel Fibers in concrete.

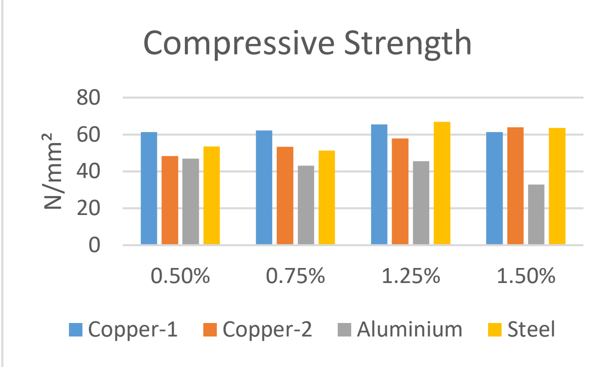

Figure 4[1]

B. Split tensile strength test result

Table 7: Split tensile result(N/mm²) [9]

Fibers	0.50%	0.75%	1.25%	1.50%
Copper- 1	7.62	7.80	9.20	10.62
Copper-2	8.20	8.34	9.50	10.36
Aluminium	6.95	7.38	6.70	8.80
Steel	7.80	8.95	10.05	9.32

For regular concrete, the 28-day split tensile strength is 7.30 N/mm². It is seen from the preceding table that for all e-waste Fibre percentages, The optimum result in copper fiber-1 at 1.50% Fibers add in concrete. And result was increase by 45.47% Split tensile strength with added 1.50% copper fibers-1 in concrete.

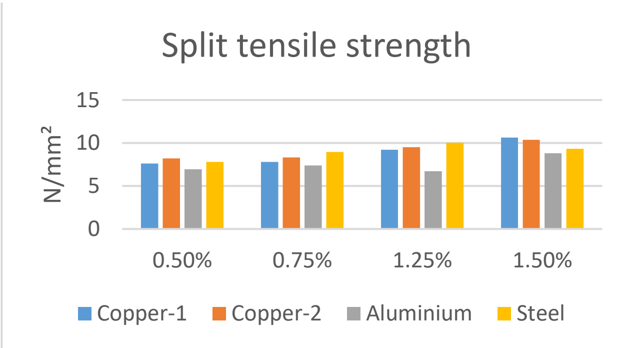

Figure 5[1]

C. Flexural strength test result

Table 8: Flexural Strength result(N/mm²)[9]

Fibers	0.50%	0.75%	1.25%	1.50%
Copper- 1	7.67	9.67	10.36	10.87
Copper-2	9.38	9.76	10.98	11.25
Aluminium	8.34	8.65	9.34	9.61
Steel	8.70	9.21	9.98	10.76

For regular concrete, the 28-day flexural strength is 9.5 N/mm². It is seen from the preceding table that for all e-waste fibre percentages, The optimum result in copper fiber-2 at

1.50% fibers add in concrete. And result was increase by 18.42% Flexural strength with added 1.50% copper fibers-1 in concrete.

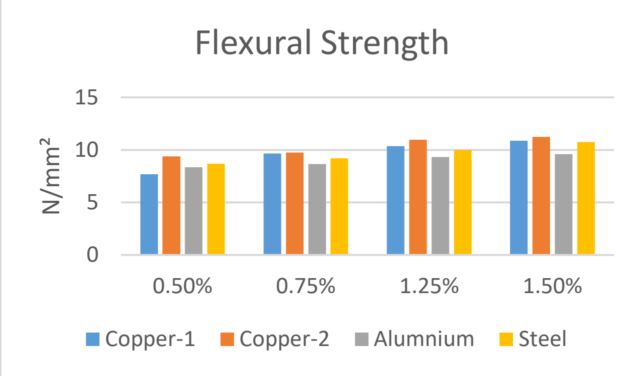

Figure 6[1]

D. Cost compairsion

If M60 Grade of concrete need at site than we suggest M50 fibours concrete with 1.25% steel or copper fiber. We achived 65 to 66 N/mm² Compressive strength in M50 grade concrete making cost. Because we are used E-waste fibers so it cost is 2-5% of its original cost. Then automaticaly M60 garde concrete cost is less. For example M60 grade market price is 9560/- per M³ and M50 fibours concrete cost is 7650/- per M³ but strength is given same as M60 mix in M50 cost. So at the end cost reduction 20% per M³.

V. Conclusions

The addition of waste Fiber to concrete is being researched. E-waste Fibers are added to concrete at amounts of 0.50%, 0.75%, 1.25%, and 1.50% with a ratio of water to cement of 0.35. Compression, split tensile, and flexural tests are performed. Following the addition of e-waste Copper, Steel, and Aluminium Fiber, the experimental study's primary results involve:[11]

- E-waste addition With a 1.25% improvement in compressive strength, Steel Fibers show a maximum strength increase of 66.89 N/mm², which is 15.32% greater than Normal concrete mix.[6]
- E-waste addition With a 1.25% improvement in compressive strength, Copper Fibers show a maximum strength increase of 65.55N/mm², which is 11.44% greater than Normal concrete mix.[6]
- E-waste addition With a 0.50% improvement in compressive strength, Aluminium Fibers show a maximum strength increase of 46.99N/mm², which is 20.09% lesser than Normal concrete mix.[6]
- The split tensile strength of concrete with E-waste Copper Fiber increased by 10.62 N/mm² at 1.50%, which is 45.47% higher than the typical concrete tensile result.[15]
- The split tensile strength of concrete with E-waste Steel Fiber increased by 10.05 N/mm² at 1.25%, which is 37.67% higher than the typical concrete tensile result.[15]
- The split tensile strength of concrete with E-waste Aluminium Fiber increased by 8.80 N/mm² at 1.50%, which is 20.54% higher than the typical concrete tensile result.[22]
- The flexural strength of concrete containing e-waste copper Fiber increased to 11.25N/mm² at 1.50%, and 18.42% more than the flexural result of regular concrete.[19]
- The flexural strength of concrete containing e-waste steel Fiber increased to 10.76N/mm² at 1.50%, which is 13.26% more than the flexural result of regular concrete.[16]
- The flexural strength of concrete containing e-waste aluminium Fiber increased by 9.61N/mm² at 1.50%, which is only 1.15 % more than the flexural result of regular concrete.[18]
- Based on research result 20% cost reduce with compare to normal concrete.

VI. Reference

[1] A. R. Bhat and A. Vikram, “Experimental Investigation on the Effect Polypropylene Fiber and E-Waste Fiber Embedded in Concrete,” International Journal of Innovative Research in Engineering & Management, vol. 9, no. 6, pp. 89–93, Dec. 2022, doi: 10.55524/ijirem.2022.9.6.15.

[2] G. N. Gopu and A. Sofi, “Electrical waste fibers impact on mechanical and durability properties of concrete,” Civil Engineering and Architecture, vol. 9, no. 6, pp. 1854–1868, Oct. 2021, doi: 10.13189/cea.2021.090618.

[3] G. Naidu Gopu and A. Sofi, “CORROSION-INDUCED BOND BEHAVIOUR OF STEEL, E-GLASS, AND E-WASTE COPPER WIRE FIBER REINFORCED CONCRETE.”

[4] A. Abubakar, A. Mohammed, S. Duna, and U. S. Yusuf, “Relationship between Compressive, Flexural and Split Tensile Strengths of Waste Copper Wire Fiber Reinforced Concrete,” Path of Science, vol. 8, no. 5, pp. 4001–4009, May 2022, doi: 10.22178/pos.81-5.

[5] A. Sofi and G. Naidu Gopu, “Influence of steel fiber, electrical waste copper wire fiber, and electrical waste glass fiber on mechanical properties of concrete,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Apr. 2019. doi: 10.1088/1757-899X/513/1/012023.

[6] V. M. Varghese and L. N. Boby, “Studies on the Effect of Fiber Size on Strength of Fibrous Concrete Mixture Made from Recycled Electronic Waste Fibers,” *International Research Journal of Engineering and Technology*, 2017, [Online]. Available: www.irjet.net

[7] D. Suhirkam, B. H. Fuady, L. Flaviana, and Suhadi, “The Copper Fiber on Compressive Strength and Elastic Modulus on Concrete Fc’25,” in *Journal of Physics: Conference Series*, Institute of Physics Publishing, May 2020. doi: 10.1088/1742-6596/1500/1/012085.

[8] H. Ndruru, R. M. Simanjuntak, and S. P. Tampubolon, “Utilization of copper fiber waste to increase compressive strength and split tensile strength of rigid pavement,” in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Nov. 2021. doi: 10.1088/1755-1315/878/1/012052.

[9] B. Shobana and B. N. Brinila Bright, “Experimental Investigation on High-Performance Concrete by Using Electric Copper Wire,” 2017, doi: 10.15680/IJIRSET.2017.0605041.

[10] Y. K. Sabapathy, S. Sabarish, C. N. A. Nithish, S. M. Ramasamy, and G. Krishna, “Experimental study on strength properties of aluminium fiber reinforced concrete,” *Journal of King Saud University - Engineering Sciences*, vol. 33, no. 1, pp. 23–29, Jan. 2021, doi: 10.1016/j.jksues.2019.12.004.

[11] J. Rajaraman, “Study on behaviour of Aluminium Fiber in Concrete,” in Journal of engineering and applied science 12(special Issue 11): 9182-9183, 2017 ISSN: 1616-949X.

[12] I. A. Channa and A. Saand, “Mechanical behavior of concrete reinforced with waste aluminium strips,” *Civil Engineering Journal (Iran)*, vol. 7, no. 7, pp. 1169–1182, Jul. 2021, doi: 10.28991/cej-2021-03091718.

[13] Md. Masuduzzaman UG Student, Dept. of Mechanical Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh.E-mail: zaman.masud37@gmail.com, Shishir Kumar Sikder Amit UG Student, Dept. of Civil Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh. E-mail: shishirce12@gmail.com, Md. Alauddin UG Student, Dept. of Civil Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh. E-mail: alauddince14@gmail.com.

[14] Basheer, E.S. and Antony, E.M., 2017. Experimental Investigation of Hybrid Fiber Reinforced Concrete Short Columns Using Micro Steel Fiber and E-Waste Fiber. International Research Journal of Engineering and Technology, 4(4).

[15] Amit Gupta, P. R.. Sharma, 2015. Investigation on Properties of Steel Fiber Reinforced Concrete. International Journal of Engineering Research & Technology, 9(12).

[16] N. Ganesan, R. Abraham, and S. Deepa Raj, “Durability characteristics of steel fiber reinforced geopolymer concrete,” Constr. Build. Mater., vol. 93, pp. 471–476, Sep. 2015, doi: 10.1016/J.CONBUILDMAT.2015.06.014.

[17] N. Ganesan, P. V. Indira, and A. Santhakumar, “Durability characteristics and compressive constitutive behaviour of steel fiber reinforced geopolymer concrete,” in Proceedings of the 3rd International Conference on the Durability of Concrete Structures, ICDCS 2012, 2012.

[18] C. G. Berrocal, I. Löfgren, and K. Lundgren, “The effect of fibers on steel bar corrosion and flexural behaviour of corroded RC beams,” Eng. Struct., 2018, 163, 409–

[19] Rao, K. K., & Rao, P. S. (2017). Comparative Study Of Normal Concrete With Partial Addition Of Copper Wire As Fiber For The Grade Of M40. International Journal of Engineering Technology Science and Research, 4(6), 613–618.

[20] Copper Development Association. (2022). Copper Building Wire Systems. Retrieved from https://www.copper.org/applications/electrical/building/wire_systems.html

[21] Arjun, R.K. and Senthil Kumar, K., Novel fibrous concrete mixture made from recycled PVC fibers from electronic waste, J. Hazard Toxic Waste 21 (2016).

[22] IS 8112 (1989): Specification for 43 grade ordinary Portland cement

[23] IS 10262, Indian Standard code for Mix Design of concrete mixes, 2009

[24] IS 516, Indian Standard Methods of test for strength of concrete, 1959

[25] IS 5816, Indian standard code for measurement of splitting tensile strength of concrete, 1959.

[26] Senthil Kumar, K., and Baskar, K. (2014a). Development of ecofriendly concrete incorporating recycled high-impact polystyrene from hazardous electronic waste. ASCE

[27] Kim, S. B., Yi, N. H., Kim, H. Y., Kim, J. H. J., and Song, Y. C. (2010). Material and structural performance evaluation of recycled PET fiber reinforced concrete. ASCE

[28] Balasubramanian, K., Bharathkumar, B.H., Parameswaran, V.S (1996) “Impact resistance of steel fiber reinforced Concrete”, The Indian concrete journal vol.70pp.257-268.

[29] Ramakrishna, V., (1987) “Materials and properties of fiber reinforced concrete”. Proceedings of the international symposium on fiber reinforced concrete, Chennai, pp. 2.3 -2.23

[30] Gao, J., Sun, W., Morino, K. Mechanical properties of steel fiber reinforced, high-strength, lightweight Concrete. Cement and Concrete Composites. 1997;19: 307-313.

[31] Wang, Youjiang, H. C. Wu, and Victor C. Li. “Concrete Reinforcement with Recycled Fibers.” Journal of Materials in Civil Engineering 12, no. 4 (November 2000): 314–319. doi:10.1061/(asce)0899 1561(2000)12:4(314).

[32] Hikmatullah Aziz1, Vipasha Rishi2, “Review paper on concrete using soft drink aluminum cans fiber”, International Research Journal of Engineering and Technology (IRJET) 7, no. 02, (February 2020): 348–352.