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Influence of steel fibre, electrical waste copper wire fibre and electrical waste glass fibre on mechanical properties of concrete

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Abstract. Fibre-reinforced concrete (FRC) contains fibrous material which increases its structural integrity. The application of irregular arrangement of fibres to concrete altogether upgrades its essential characteristics, for instance, static flexural strength, influence quality, elasticity and flexural stiffness. Filaments are added to cement to control breaking because of plastic shrinkage and to drying shrinkage. This paper exhibits the use of steel fibre, electrical waste copper wire fibre and electrical waste glass fibre of various percentages of volume fractions such as 0.25%, 0.5%,0.75%,1.0% and 1.25% incorporated in concrete. Mechanical properties such as compressive strength, splitting tensile strength and flexural strength tests were conducted for normal concrete and fibre reinforced concrete for a curing period of 7 days, 14 days and 28 days. In addition to that modulus of elasticity of concrete for various percentages of fibre content was investigated for a curing period of 28 days. The test results of fibre reinforced concrete were compared with normal concrete to determine the influence of fibres used.

1. Introduction

In the recent years, the various fibres were developed and used in the construction industries. Steel fibre is mainly used in concrete for various applications[1]. Other types of fibres such as polythene fibres, carbon fibres, polyamide fibres, sisal fibre are now developed and also used in construction, industrial and infrastructure development. Some electronic waste fibres can also be used in concrete[2]. Electronic waste (E-Waste) is considered more toxic than municipal waste. When E-waste used in concrete, it reduces the environmental pollution and reduces the solid waste problem[3]. E-waste in concrete is the new revolutionary concept of sustainable concrete. When E-waste plastic type fibre are used at small size the results obtained are good when compared with the larger size [4]. In this paper, the extracted outer casting of electronic wire was used for making E-waste fibre [5]. Fibre reinforced concrete helps to reduce the crack propagation and increase the mechanical properties compared to the normal concrete[6]. In hybrid concrete, the micro fibres delayed the development of macro cracks and shows greater strength and crack resistance [7]. It also improves the mechanical properties of concrete[8]. The strength and the corresponding deflection was increase linearly with increasing steel fibre content in concrete[9].This paper exhibits influenceof mechanical properties of concrete by use of steel fibre, electrical waste copper wire fibre and electrical waste glass fibre of various percentages of volume fractions in concrete.

2. Experimental investigation

2.1. Test materials

2.1.1. Cement
Ordinary Portland cement (OPC) of 53 Grade was used in entire program. Specific gravity was found to be 3.15 [10].Initial and final setting times of cement is found to be 200 and 280 minutes respectively. Properties of the cement as show in Table-1

2.1.2. Fine aggregates
Good quality locally available river sand was used as a fine aggregate. The sand was conforming to zone II [11]. Aggregate passing through 4.75 mm sieve and retained on the 75 µm sieve. Specific gravity of the fine aggregates is found to be 2.66. Properties of fine aggregates was show in Table -2

2.1.3. Coarse aggregates
The Crushed granite stone aggregate was used from the local quarry. In this experiment the aggregate was used of 20mm down and Specific gravity of the fine aggregates is found to be 2.58. Properties of coarse aggregates was show in Table -2

Table 1. Properties of cement.

Test	**Results**
Fineness	227 m^2/kg
Soundness	10 mm
Setting time	
1.initial	32 min
2.final	581min
Compressive strength	
1. 7days	27 N/mm^2
2. 14 days	37 N/mm^2
3. 28 days	53 N/mm^2

Table 2. Properties of aggregates**.**

Physical tests	**Coarse**	**Fine**
Specific gravity	2.58	2.66
Fineness modulus	4.32	2.32
Bulk density (kg/m^3)	1540	1780

2.1.4. Steel fibres (SF)
Steel fibres confirming to ASTM A 820/ A 820M – 04were used[12].Steel fibres improve ductility, flexural strength and toughness (shown in Figure 1)The properties of the steel fibres show in Table 3.

2.1.5. Electrical waste copper wire fibre

E-waste consists of all waste from electronic and electrical appliances. It includes computer and its accessories monitors, printers, internet cables, power supply cables, electrical machines windings, central processing units, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators and other household appliances. The length of the fibre used was 30mm(shown in Figure 2). Properties of the electrical waste copper wire fibre as shown in Table 3.

2.1.6. Electrical waste glass fibres

Electrical waste glass fibres confirming to ASTM D3517-14 were used [13]. The dried fibres were then cut to the required lengths to attain the desired aspect ratio of 30(shown in Figure 3). Properties of electrical waste glass fibres were shown in Table 3.

Figure 1. Steel fibres**.**

Figure 2. Electrical waste copper wire fibres.

Figure 3. Electrical waste glass fibres.

Table 3. Properties of fibres.

Fibre category	**Steel fibres**	**Electrical waste copper wire fibre**	**Electrical waste glass fibre**
Fibre shape	Straight	Straight	Straight
Fibre length [mm]	40	30	50
Fibre diameter [mm]	0.8	0.6	1
Aspect ratio	50	50	50
Tensile strength of fibres [N/mm^2]	1220	966	1950

2.2. Workability

The slump test was done for all the concrete mix to check the workability of concrete and is shown in Table 4. No admixture is used in the concrete mix to improve its workability [14].

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Table 4. Slump values.

Fibres used (%) by volume of concrete	Steel fibre reinforced concrete (mm)	Electrical waste copper wire fibre reinforced concrete (mm)	Electrical waste glass fibre reinforced concrete (mm)
0	61	61	61
0.25	59	57	60
0.5	58	55	59
0.75	55	54	56
1.00	54	52	55
1.25	53	51	53

2.3. Testing of specimens
Casting and testing of concrete cubes, cylinders, beams were done as per IS code recommendations. The concrete mix adopted was M20 concrete [15] with varying percentage of fibres ranging from 0%, 0.25%, 0.5% and 0.75%. Nominal concrete cubes (15 cm x 15 cm x 15 cm), concrete cylinders (15 cm diameter and 30 cm long)and prism (10 cm×10cm × 50cm)were used. A blend of fibres were mixed with the aggregate while casting the specimens, it was ensured that fibres were uniformly distributed throughout the mix. Tests were conducted on concrete cubes using different percentage of fibres to check for variations in compressive, splitting tensile and flexural strength. Three sets of nine cubes, nine cylinders and nine prisms of M20 mix were cast without fibres. Later, different sets of cubes, cylinders and prisms were cast with fibre content ratio as 0.25%, 0.5%, 0.75%, 1.0% and 1.25%. The specimens were then transferred to curing tank for the required period of curing and tested.

2.3.1. Compressive strength of concrete
Compressive strength of concrete cubes(15cm×15cm×15cm) were made according to IS516 [15]. No packing material was placed in between the cube and loading frame. The load was applied gradually without any shock. Compressive strength of cubes were determined at a curing age of 7,14 and 28 days. The results were tabulated in Table 5 and the graphical representation in Figure 4.

2.3.2. Splitting tensile test of concrete
The Splitting tensile strength of cylinders (15cm dia and 30cmlength) were made according to IS 5816 [16]. Diametric lines on each of cylinder were drawn to ensure that they were in the same plane. The splitting tensile strength was determined at curing periods of 7,14 and 28 days. The results were tabulated in Table 6 and the graphical representation in Figure 5.
The Splitting tensile strength (T) was determined from the equation-1.

$$T = 2P/\pi \mathrm{LD} \quad (1)$$

2.3.3. *Flexural strength of concrete*
Flexural strength of prisms (10cm×10cm×50cm) casted are determined at a curing age of 7,14 and 28 days respectively as per IS516 [15].The load is applied gradually without any shock or vibration. Flexural strength of prisms were determined at a curing age of 7,14 and 28 days [17]. The results were tabulated in Table7 and the graphical representation in Figure 6. The flexural strength of the specimen was determined from equation-2.

$$\mathrm{F_b} = \frac{\mathrm{Pl}}{\mathrm{Bd^2}} \quad (2)$$

Table 5. 28 days compressive strength of concrete cube with different fibres in N/mm^2.

% of mixing proportion by volume of concrete	Steel fibre reinforced concrete	Electrical waste copper wire fibre reinforced concrete	Electrical waste glass fibre reinforced
0.00	27.36	27.36	27.36
0.25	34.23	30.29	30.43
0.50	35.11	32.51	31.10
0.75	37.42	33.86	31.56
1.00	37.46	32.63	29.53
1.25	39.14	31.13	28.19

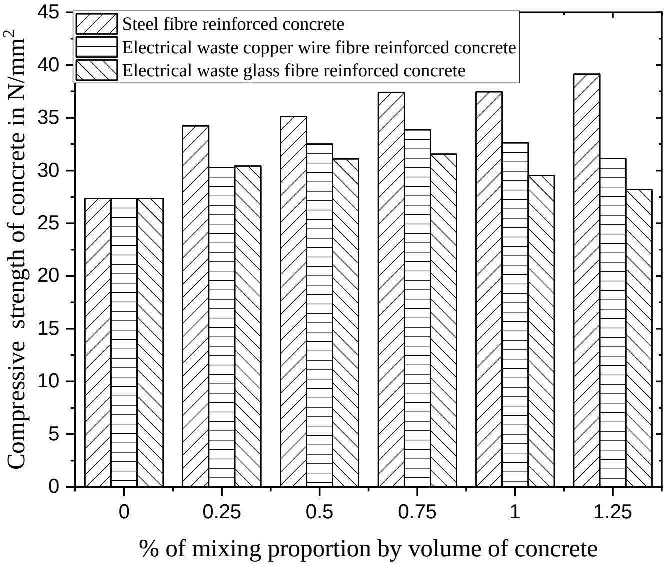

Figure 4. Compressive strength of concrete cube with different fibres.

Table 6. 28 days splitting tensile strength of cylinder with different fibres in N/mm^2.

% of mixing proportion by volume of concrete	Steel fibre reinforced concrete	Electrical waste copper wire fibre reinforced concrete	Electrical waste glass fibre reinforced concrete
0.00	2.67	2.67	2.67
0.25	3.10	2.79	3.25
0.50	3.34	3.12	4.05
0.75	3.83	3.41	4.78
1.00	4.20	3.64	5.03
1.25	4.85	3.91	5.10

Table 7. 28 days flexural strength of prism with different fibres in N/mm^2.

% of mixing proportion by volume of concrete	Steel fibre reinforced concrete	Electrical waste copper wire fibre reinforced concrete	Electrical waste glass fibre reinforced concrete
0.00	4.44	4.44	4.44
0.25	4.62	4.51	4.99
0.50	4.93	5.23	5.18
0.75	5.26	5.41	5.52
1.00	5.65	5.62	5.60
1.25	6.54	6.17	5.85

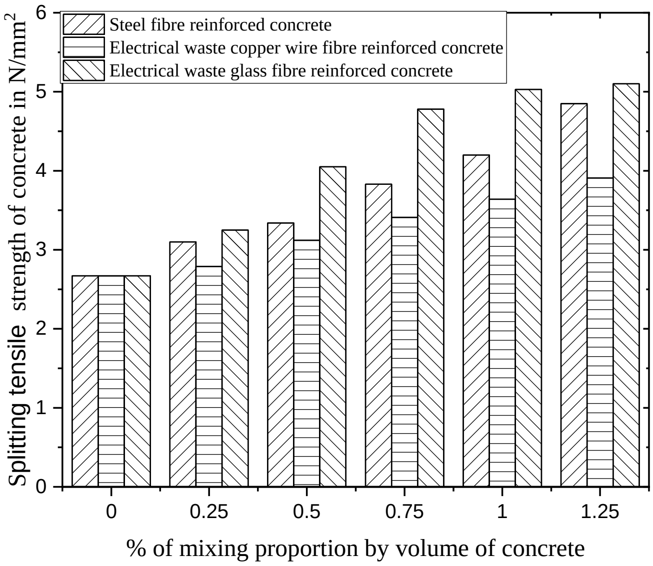

Figure 5. Splitting tensile strength of concrete with different fibres in N/mm^2.

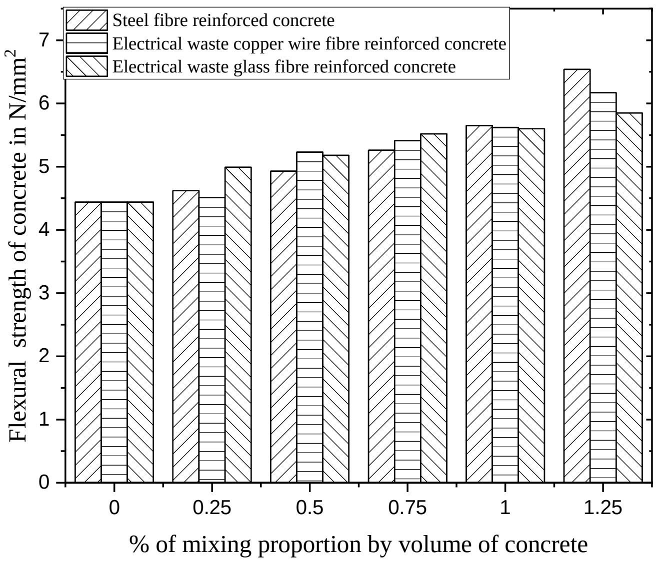

Figure 6. Flexural strengths of prism with different fibres in N/mm^2.

2.3.4. Elastic modulus of concrete

Elastic modulus was determined at 28 days of curing period on cylindrical specimen (150mm dia and 300mm height) under compression load as per ASTM C469-02 [18] and the deformation measured by means of dial gauge fixed between certain gauge lengths.The elastic modulus of the concrete incorporate with steel fibre and electrical waste copper wire fibres at various volumes is mentioned in Table 8. Figure 7 and 8 shows the stress-strain curve for the modulus of elasticity which has taken as the slope of the chord from the origin to some arbitrary point, the secant modulus calculated was for 40% of maximum stress.

Table 8. Elastic Modulus of concrete with different fibres.

% of mixing proportion by volume of concrete	Steel fibre reinforced concrete	Modulus of elasticity (GPa)	Electrical waste copper wire fibre reinforced concrete	Modulus of elasticity (GPa)
0.00	27.36	28.91	27.36	28.91
0.25	34.23	29.25	30.29	29.28
0.50	35.11	31.44	32.51	31.21
0.75	37.42	32.44	33.86	31.84
1.00	37.46	33.38	32.63	32.03
1.25	39.14	35.32	31.13	32.68

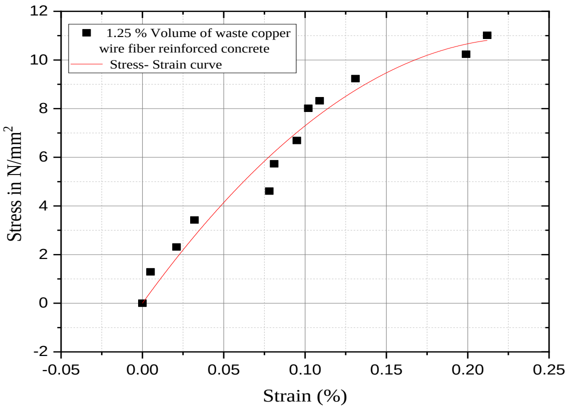

Figure 7. Stress –strain behavior of the electrical waste copper wire fibre reinforced concrete.

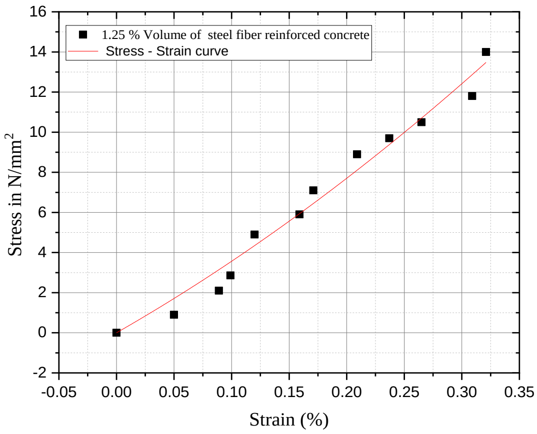

Figure 8. Stress –strain behavior of the steel fibre reinforced concrete specimen.

3. Conclusion
The following conclusions could be drawn from the present investigation.

- Compressive strength of concrete by using steel fibre, waste copper fibre and Electrical waste glass fibres were increased by 42.6%, 23.76 and 15.35% when compared to normal concrete.
- Splitting tensile strength of concrete by using steel fibre, waste copper fibre and Electrical waste glass were increased by 81.6%, 46.4% and 90.1% when compared to normal concrete.
- Flexural strength of concrete by using steel fibre, waste copper fibre and Electrical waste glass fibres were increased at 46.1%, 38.8% and 31.7% when compared to normal concrete.
- Elastic modulus of concrete by using steel fibre and waste copper fibre were increased at 21.1%and 13.04% when compared to normal concrete.

Hence this paper can be concluded that the addition of steel fibre, copper fibre and electrical waste glass fibre incorporated at 0.25,0.5%, 0.75 %, 1.0% and 1.25% by volume of concrete improve the compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of the concrete and it also reduces the crack width under different loading conditions that was observed in concrete testing conditions.

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