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PARAMETRIC STUDY ON FIBROUS CONCRETE MIXTURE MADE FROM E-WASTE PVC FIBRES

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Abstract-*Poly Vinyl Chloride (PVC) is one of the most important and extensively used plastics in the world, especially in electrical and electronic devices. Since it is extensively used, so are the waste produced, hazardous and tremendous in rate. Recycling of e-waste plastic has become a global concern. Recent researches show that concrete reinforced with short plastic fibreslike polypropylene, PET, etc. improves performance of concrete and negates its disadvantages such as low tensile strength and low ductility. In this paper, the outer insulation (PVC) from waste electrical cables are extracted and shredded into fibres keeping an aspect ratio of 30. The fibres were added to the concrete at 0.05, 0.10, 0.15, 0.20 and 0.25% volume fraction. Appropriate tests were performed to amountworkability and mechanical properties of the fibre reinforced concrete mixture. Results reveal volume fraction of 0.2% PVC fibres as the optimal dosage. The increased trend in fresh concrete properties and strength make PVC fibre reinforced concrete a new alternative high strength concrete and also reduces the amount of dumping e-wastes into the nature.*

Keywords*: E-waste plastic, PVC fibres, aspect ratio, concrete, tensile strength, ductility*

I. INTRODUCTION

Globally, a large amount of solid waste is produced every day. They include agricultural waste, municipal solid waste, electrical and electronic waste (e-waste) and many more. Among these, electrical and electronic waste is considered more toxic than the rest,since it contains more toxic materials and hence is a threat to our environment and nature. It has many ingredients like mercury, lead, cadmium, beryllium, poly vinyl chloride, printed circuit boards, plastic casings, cathode ray tubes, batteries, cable sheathing and so forth, which increase their complexity. In past few decades, several e-waste management systems have emerged, but not sufficient to meet the demands in e-waste management. Moreover, traditional methods like burning and dumping of e-waste onto the land are still in practice everywhere. In fact, the safe disposal of e-waste has become a challenging task for the world.

One possible solution is to incorporate e-waste with concrete. Plastic in e-waste are non-degradable and hazardous. Recycling of plastics like PVC from e-waste by using them in concrete to improve their structural properties is a better option. Even though concrete is recognized as a relatively brittle material, it is widely used as a structural material in construction industry due to its excellent engineering properties. Also, the tensile strength of concrete is only a fraction of its compressive strength. Tensile strength of concrete is typically 8 to 15% of its compressive strength. Hence, tensional strengthening is very much needed in modern concrete structural elements. Researches and studies are progressing in the field of tension strengthening and ductility enhancement of concrete. Many studies reveal development of e-waste concrete as a sustainable concrete by incorporating e-waste plastics and other kinds of e-waste like printed circuit boards, high impact polystyrene (HIPS) wastes etc. Concept of green concrete methodology was introduced by some researches by demonstrating incorporation of powdered e-waste incement mortar. The results reveal acceptable changes in basic properties of concrete and can be used as a sustainable method in construction technology. Though e-waste addition has proved to introduce more deformability to concrete, the fresh properties of concrete such as workability were seriously affected by the bad shape and surfacetexture of e-waste. E-waste concrete using e-waste fibres are a new innovation in green concrete methodology.Plastic fibres of appropriate aspect ratio have provenbetter results in properties of concrete. Fibre reinforcements primarily functions as crack arrestors and helps to reduce cracks and crack propagation by expansion. Fibre reinforcements can be used to increase certain properties of concrete like flexural behavior, ductility, cracking moment, impact resistance, thermal resistance etc.

In this research, fibres were extracted from PVC insulations of waste electrical wires of 4mm diameter, considering the plastic fiber aspect ratio. The e-waste PVC fibers used in this research are from rejected manufacturing defect pieces.

The scope of this study is toimprove the structural properties of concrete using fibre reinforcements made from e-waste PVC and also to reduce impacts of e-waste plastic in environment.The objective of present study includes:

- To study the effect of PVC fibres on workability of concrete.
- To study the effect of PVC fibreson mechanical properties of concrete.

II. EXPERIMENTAL DETAILS

2.1 Materials

OPC53 grade cement meeting the specifications of IS 12269-1987 was used in all concrete mixtures.The physical properties of the cement were obtained from laboratory testing, conducted in accordance with the standard tests given in IS 4031. The physical properties of cement are given in Table–1.

Table-1 Physical properties of cement

Particulars	Values
Fineness	3%
Specific gravity	3.13
Consistency	30.25%
Initial setting time	85minutes
Final setting time	260minutes
3rd day compressive strength	29.333N/mm^2
7th day compressive strength	39.036N/mm^2
28th day compressive strength	57.222N/mm^2

M-sand of 4.75mm maximum size and natural crushed stone of 20mm maximum size, both confirming to specifications given in IS 383-1970 were used as fine and coarse aggregates respectively. The properties of M-sand and coarse aggregates based on laboratory testing are shown in Table–2 and Table–3 respectively.

Table-2 Properties of M-sand

Particulars	Values
Fineness modulus	3.11
Specific gravity	2.6
Bulk density	1.65kg/m^3
Void ratio	0.57
Porosity	36.2%
Grade	Zone II

Table-3Properties of coarse aggregate

Particulars	Values
Fineness modulus	7.06
Specific gravity	2.74
Bulk density	1.58kg/m^3
Void ratio	0.73
Porosity	42.25%

For fibre reinforcements, fibres were extracted from PVC insulations of waste electrical cables of 4mm diameter.Based on literature review, an appropriate aspect ratio in the range of 30 was maintained. The extracted PVC fibres are shown in Fig-1.The fibres were added at 0.05, 0.10, 0.15, 0.20 and 0.25% volume fractions. The properties of PVC fibre are given in the Table-4.

Figure-1 Extracted PVC fibres

Table-4 Properties of PVC fibre

Particulars	Values
Length	30mm
Width	1mm
Thickness	0.8mm
Aspect ratio	30
Tensile strength	17N/mm^2
Specific gravity	1.4

2.2Mixture proportioning

The mix proportion for M30 grade was arrived through a number of trial mixes. Each mixture consisted of 425.733kg/m^3 cement, 646.464kg/m^3 fine aggregate, 1160.006kg/m^3 coarse aggregate and a W/C of 0.45. The mix was designed in accordance with IS 10262-2009. Table-5 shows the mix proportion used.

Table-5 Mix proportion

Material	Mix proportion
Cement	1
Fine aggregate	1.52
Coarse aggregate	2.72
W/C	0.45

2.3 Casting and curing of specimens

Specimens were prepared for both normal and fibre reinforced concrete. A total of 144 specimens were casted for the study. The specimen details are shown in Table-6.Fig-2 shows mixing of concrete in a laboratory type pan mixer. The mixes with fibres responded well, while placing and compacting. Care was taken during placing to avoid fibre free zones. Conventional methods were adopted in finishing of all the specimens. Care was taken to avoid fibres protruding out of the specimens. All specimens were water cured before testing. The casted specimens and specimens under curing are shown in Fig-3 and Fig-4.

Table-6 Specimen details

Sl. No.	Specimen	Size	Number
1	Cube	150 x 150 x 150mm	54
2	Cylinder	150mm diameter and 300mm height	54
3	Beam	500 x 100 x 100	36
Total specimen			144

Figure-2 Mixing of concrete

Figure-3 Casted specimens

Figure-4Specimens under curing

2.4Testing of specimens

Workability is one of the physical parameters that influencestrength and durability of concrete. For measuring the variations in workability of normal and fibre reinforced concrete, tests such as slump test and compaction factor test were conducted on freshly prepared concrete. Tests for measuring mechanical properties of concrete such as compressive strength (Fig-5), flexural strength (Fig-7)and modulus of elasticity (Fig-8) wereperformed after their respective curing period. These tests were conducted as per specifications given in IS 516-1959. Split tensile strength test (Fig-6) was conducted to indirectly measure the tensile property of concrete. The test was conducted after curing period of the respective specimens as per specifications given in IS 5816-1999.

Figure-5Compressive strength test

Figure-6Split tensile strength test

Figure-7 Flexural strength test

Figure-8 Test for modulus of elasticity

III. RESULT AND DISCUSSIONS

3.1 Slump

All the mixes with fibre reinforcement gave lesser slump value as compared to control mix, but it was found that all fibre reinforced mixes responded well in mechanical vibration and could be mixed, placed and compacted without much effort. The slump values for each mix is shown in Table-7 and the variation in slump values with fibre dosage are shown in Fig-9.

Table-7Slump value

Fibre(%)	Slump value(mm)	Degree of workability
0	70	Medium
0.05	69	Medium
0.10	68	Medium
0.15	67	Medium
0.20	66	Medium
0.25	64	Medium

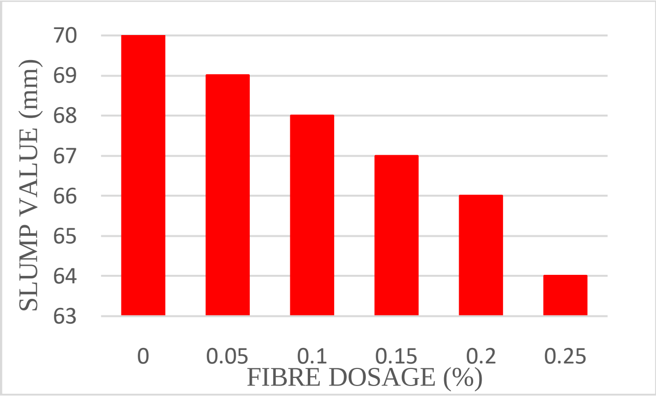

Figure-9 Slump variation with fibre dosage

The slump value for fibre reinforced concrete was reduced up to 6mm as compared to the normal concrete mix. But the slump values for all the mixes were within the designed slump 50 to 75mm. The normal concrete mix exhibited a higher slump value of 70mm. At 0.20% fibre addition, the slump value was dropped to 66mm and further at 0.25%, the slump value reached 64mm. The texture of the fibre is a reason for this reduction in workability. Distortion of fibres during mechanical compaction also restricts the flow ability of concrete, thereby affecting the concrete workability.

3.2 Compaction factor

Alinear reduction in compaction factor values was observed for the test. The mixes with fibre reinforcement gave reduced compaction factor value compared to control mix, but it was found that all fibre reinforced mixes were having a medium workability as of the control mix. The compaction factor values are provided in Table-8. The variation in compaction factor valueswith fibre dosage are shown in fig-10.

Table-8Compaction factor

Fibre(%)	Compaction factor	Workability description
0	0.913	Medium
0.05	0.897	Medium
0.10	0.885	Medium
0.15	0.873	Medium
0.20	0.866	Medium
0.25	0.852	Medium

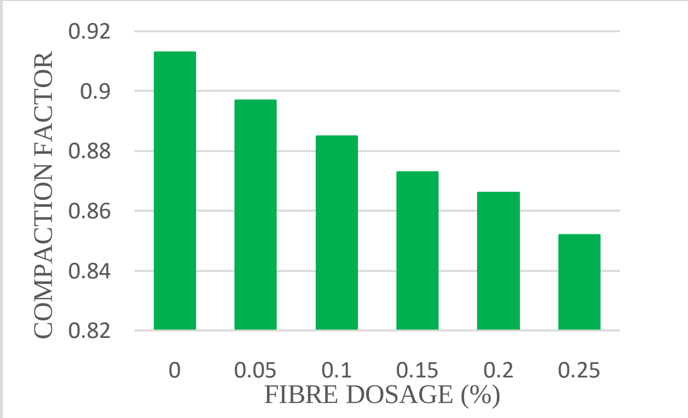

Figure-10Variation of compaction factor with fibre dosage

3.3 Compressive strength

Compressive strength is one of the most important properties of hardened concrete and in general it is the characteristic value for classification of concrete in various codes. A total of 54 cube specimens of size 150mm were tested as per specifications given in IS 516-1959. The results for compressive strength was based on the average of three test data for all mixes. The experimental strength values are presented in Table-9 and their variation with fibre dosage are presented in Fig-11.The results show an increase in compressive strength due to the texture and stiffness of fibre.At 0.20% fibre addition a maximum increase of 21.67% was observed for the 28th day compressive strength. The bridging action of fibres was found to be maximum at this fibre dosage. This lowers the stress concentration at crack tips.

Table-9Compressive strength values

Fibre(%)	3rd day strength (N/mm^2)	7th day strength (N/mm^2)	28th day strength (N/mm^2)
0	14.518	25.036	36.222
0.05	15.481	26.518	38.518
0.10	16.073	27.703	40.073
0.15	16.814	28.962	42.000
0.20	17.703	30.444	44.074
0.25	17.036	29.036	42.147

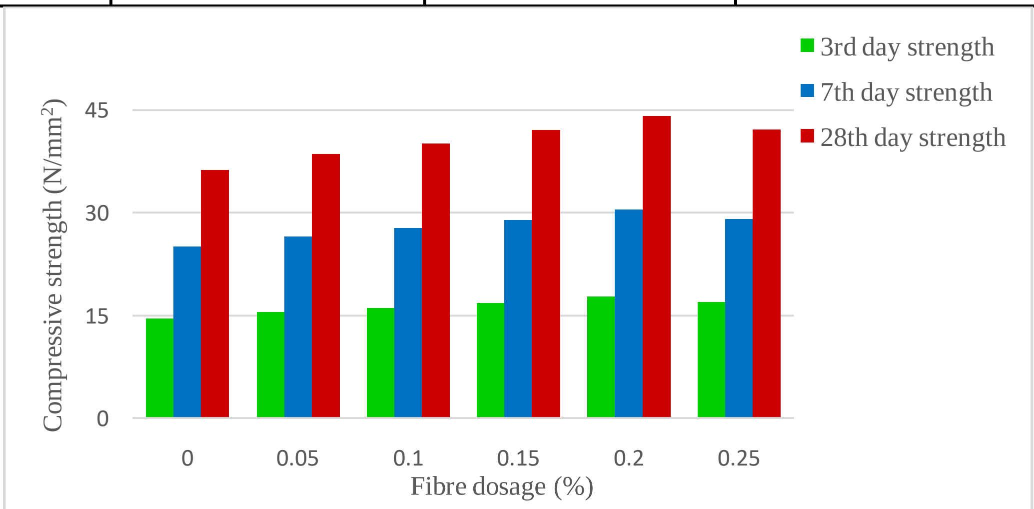

Figure-11Variation in compressive strength

3.4 Split tensile strength

A total of 36 cylinder specimens of 150mm diameter and 300mm height were tested as per specifications given in IS 5816-1999. Split tensile strength based on the average of three test data are presented in Table-10 and their variation with fibre dosage is shown in Fig-12. The split tensile strength values were increased in case of fibre addition as it gives an increased trend of post cracking effect. A maximum increase of 12.07% was observed at 0.20% fibre addition. The bridging action of fibre was found to be arresting the crack propagation by preventing further expansion of cracks. As for the fibre reinforcement specimens, unlike normal specimen brittle failure was not seen. The failure in normal concrete specimen and fibre reinforced specimen are shown in Fig-13 and Fig-14 respectively.

Table-10Split tensile strength values

Fibre(%)	7th day strength (N/mm^2)	28th day strength (N/mm^2)
0	2.499	3.513
0.05	2.522	3.607
0.10	2.616	3.725
0.15	2.73	3.89
0.20	2.758	3.937
0.25	2.687	3.842

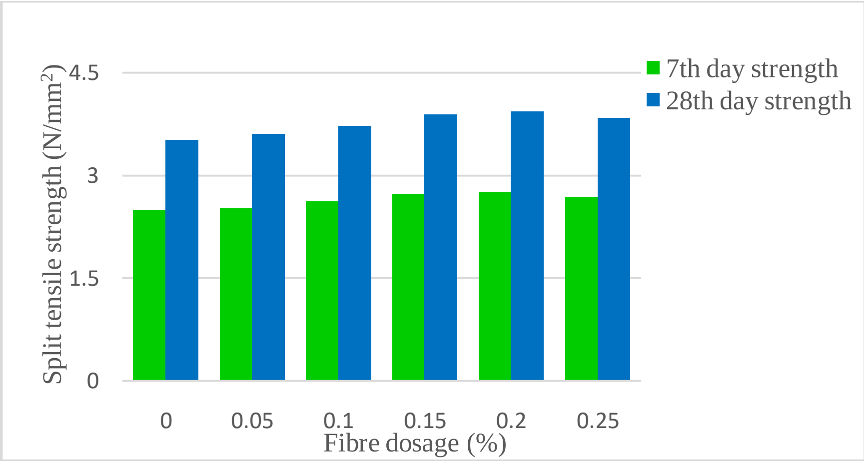

Figure-12Variation in split tensile strength

Figure-13Failure in normal specimen

Figure- 14 Failure in fibre reinforced specimen

3.5 Flexural strength

A total of 36 beam specimens of size 500 x 100 x 100mm were tested as per specifications given in IS 516-1959. Flexural strength based on theaverage of three test data are presented in Table-11 and their variation with fibre dosage are presented in Fig-15. The results show an increase in flexural strength with reference to the control mix specimens. A maximum increase of 15.86% was observed for the 28th day flexural strength at 0.20% fibre addition. Fibre addition increased the bending capacity of concrete as compared to normal concrete. The bridging action was found to be maximum at 0.20% fibre addition. The fibres were withstanding the tensile stress in the tension zone below the neutral axis. The failure in normal concrete specimen and fibre reinforced concrete specimen are shown in Fig-16 and Fig-17 respectively.

Table-11 Flexural strength values

Fibre(%)	7^{th} day strength (N/mm^2)	28^{th} day strength (N/mm^2)
0	2.866	4.2
0.05	3.066	4.333
0.10	3.133	4.533
0.15	3.266	4.73
0.20	3.4	4.866
0.25	3.2	4.6

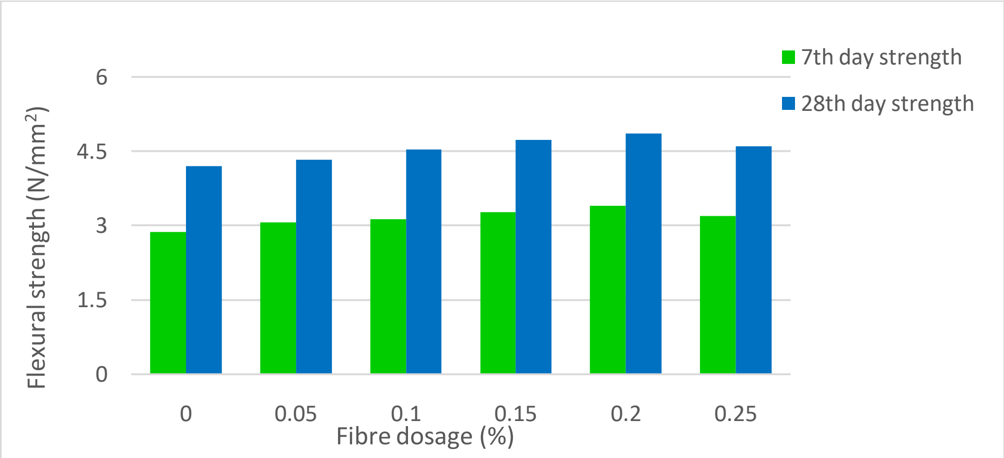

Figure-15Variation in flexural strength

Figure-16 Failure in normal specimen

Figure-17 Failure in fibre reinforced specimen

3.6 Modulus of elasticity

A total of 18 cylinder specimens of 150mm diameter and 300mm height were tested. The specimens were tested after a curing period 28 days as per the specifications given in IS 516-1959. The modulus of elasticity based on the average of the three test data are presented in Table-12 and their variations with fibre dosage are presented in Fig-18.As compared to the normal concrete the modulus of elasticity was found to be increased with fibre addition. A maximum increase of 16.91% was observed for the modulus of elasticity at 0.20% fibre addition. This was due to the increase in tension behavior of the fibres.

Table-12 Modulus of elasticity values

Fibre(%)	Modulus of elasticity (GPa)
0	29.596
0.05	31.463
0.10	33.167
0.15	33.968
0.20	34.601
0.25	33.528

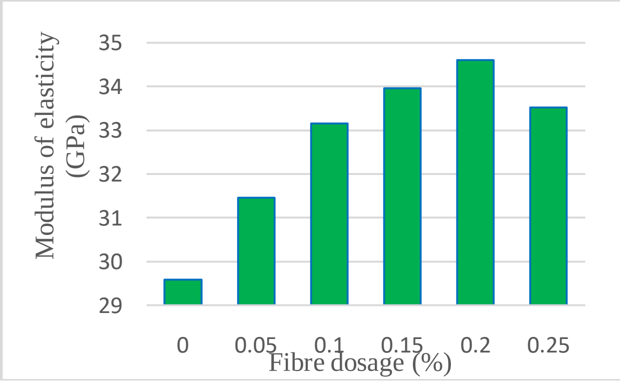

Figure-18 Variation in modulus of elasticity with fibre dosage

IV. CONCLUSIONS

PVC fibres extracted from insulations of waste electrical wirings were used in concrete at 0.05, 0.10, 0.15, 0.20 and 0.25% volume fractions. Following conclusions were reached based on the experimental results:

1. Though the slump values decreased with fibre addition, they remained in the designed slump range of medium workability 50 to 75mm. The texture and distortion of fibres during mechanical compaction were found to be restricting the flow ability of concrete, thereby decreasing the concrete workability.

2. The compaction factor values also decreased with fibre addition. But the degree of workability remained medium range as of the control mix. The reduction in workability was observed due to the texture of fibre

3. With the addition of 0.05, 0.10, 0.15 and 0.20% fibre addition in volume fraction, a notable increase in mechanical properties of concrete such as compressive strength, split tensile strength and flexural strength was observed. However, at 0.25% fibre addition in volume fraction the strength values started to decline.

4. The strength values were peak at 0.20% fibre addition. An increase of 21.67%, 12.07% and 15.86% was observed at 28th day compressive strength, split tensile strength and flexural strength of fibre reinforced concrete with reference to normal concrete. Hence, 0.2% fibre addition was determined as optimum.

5. The bridging action of fibres were found to be maximum at 0.2% fibre addition. This lowered the stress concentration at crack tips, thereby increasing the compression capacity. The texture and stiffness of fibre in the matrixwere taking maximum stress. This also increases the compressive strength.

6. The crack propagation was arrested by the bridging action of fibres by preventing further expansion of cracks. The post cracking effect was thus increased, thereby increasing the split tensile strength.

7. Fibre addition increased the bending capacity of concrete. The fibres were withstanding the tensile stresses in the tension zone below the neutral axis.

8. The modulus of elasticity increases due to the increase in tension behavior of fibre. At 0.20%, a maximum increase of 16.91% was observed.

9. On comparing with normal mix specimens, the mode failure was ductile for all fibre reinforced specimens.

10. The e-waste PVC fibre reinforced concrete is thus a sustainable concrete that has improved properties compared to the normal concrete. It also reduces the impact of e-waste in the environment and nature.

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