Experimental Investigation of Hybrid Fibre Reinforced Concrete Short Columns Using Micro Steel Fibre and E-Waste Fibre

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Abstract - *This paper present an experimental study on concrete short columns reinforced with hybrid fiber under axial loading condition. The strength and durability of concrete short column improve with the addition of fiber. Fibers added to the concrete at 0.6, 0.8 and 1% of e-waste and 0.5,1 and 1.5% of micro steel fiber with respect to the weight of concrete on the strength criteria of M30. In hybrid fiber concrete, the micro steel fiber delayed the development of macro cracks and e-waste fiber helps to improve the mechanical properties of concrete .When using e-waste fiber in concrete it reduces the amount of dumping e-plastic waste into nature. A total of eight column specimen consisting of one normal RCC column, four fiber reinforced column and three hybrid fiber reinforced column were tested. The experimental result reveals that the optimal percentage addition of fibers to the concrete was found to be 0.8% of e-waste and 1.5% of micro steel fiber with respect to the weight of concrete. Result show that a combination of micro steel and e-waste fibers can be efficiently used to optimize the behavior of concrete. Hybrid fiber reinforced short columns were capable of carrying large amounts of strain than normal RC column.*

Key Words: **Hybrid fiber reinforced concrete, short column, Micro steel fiber reinforced concrete (MS-FRC) , E-waste fiber reinforced concrete (EFRC)**

1. INTRODUCTION

In the recent years, the various fibers were developed and used in the construction industries. Steel is mainly used fiber in concrete for various applications. Also glass fiber polythene fibres, carbon fibres, polyamide fibres ,sisal fiber are now developed and also used in construction, industrial and infrastructure development. Some electronic waste fibres can also be used in concrete. Electronic waste is considered more toxic than municipal waste. When e-waste used in concrete, it reduces the environmental pollution and solid waste problem. E-waste in concrete is the new revolutionary concept of sustainable concrete. E-waste plastic type fiber of different length, a small size of e-waste plastic will show good result in properties of concrete as compared with the larger size. In this paper, the extracted outer casting of electronic wire was used for making e-waste fiber. Fiber reinforced concrete helps to reduce the crack propagation and increase the mechanical properties compared to the normal concrete. In hybrid concrete, the micro fibers delayed the development of macro cracks and greater strength and crack resistance. It also improve the mechanical properties of concrete. The strength and the corresponding deflection was increase linearly with increasing steel fiber content in concrete. Effect of two or more fibres used in concrete gives the benefits of individual fibres and also improve desired properties of concrete. Hybrid fiber has been shown to be applicable to many types of RC structural elements. Several studies carried out on testing reinforced concrete short columns with different types of fibers. From this studies, we can conclude that to investigate the behavior of hybrid fiber concrete short columns under axial loading condition.

2. LITERATURE REVIEW

Several reports on the design and construction reinforced concrete have been published which provide information on the use of e-waste and micro steel fiber materials. Arjun Ramakrishna Kurup and K. Senthil Kumar carried out experimentally investigated on fresh and hardened properties of varying percentage fiber reinforced concrete and normal concrete .To enhance the properties of concrete, silica powder added to the FRC with 10% replacement of cement. Hardened properties of both FRC and SFRC is linearly increased by increasing the fiber content compared to normal concrete. Ashwini Manjunath B(2016) conducted an experimental study on utilization of e-waste particle as coarse aggregate in concrete with a percentage replacement. Fibers added to the concrete ranging from 0%,10%,20% and 30%. Compared with conventional concrete, the strength is reduce:-coarse aggregate replaced by 20% of e-plastic waste. It is because of decreasing the adhesive strength between the materials. K.Senthil Kumar and K.Baskar(2015) experimentally investigated the engineering properties of e-waste concrete and compared with normal specimen. In this paper the Coarse aggregate was partially replaced with HIPS. High impact polystyrene plastic (HIPS) may be used in structural concrete, up to 20% replacement by volume was good and acceptable. Iftekar Gull and M.Balasubramanian (2014) experimentally investigated, the mechanical properties of concrete with different proportions of material. Different proportion of e-waste are used-0%,0.4%,0.6%,0.8%,and 1% with respect to volume of cement. Plastic material is shredded into small pieces of 5cm,4cm and 3cm are used. Small size of e-waste plastic will show good result in properties of concrete as compared with the larger size. Emdad K. Z Balanji ,M Neaz Sheikh and Muhammad N. S Hadi(2016**)** experimentally investigate behavior HSC with hybrid fiber steel under different loading condition.By the addition of steel fiber in concrete, **t**he strength and ductility of columns improves. The results shows that the specimens reinforced with HSF achieved higher strength and ductility compared to normal concrete. Specimens is tested under different loading conditions. Doo-Yeol Yoo, Hyun-Oh Shin and Young-Soo Yoon (2013) studied on the effect of fiber content on the material and interfacial bond properties of ultra high performance fiber reinforced concrete .Four different volume ratios of micro steel fiber (1%,2%,3%,4%) with respect to volume of concrete are used. 3% steel fiber by volume shows best performance compared to normal concrete.

3. MATERIAL USED

3.1.Cement

Ordinary Portland cement of Dalmiya brand of grade 53 conforming to IS 12269:1987 was used. The properties of cement are given in the table 1.

Table -1: Properties of Cement

Sl. No	Property	Result
1	Specific gravity	3.15
2	Standard consistency	33%
3	Initial setting time	98 minutes
4	Final setting time	308 minutes
5	Fineness of cement	1.82%
1	Specific gravity	3.15

3.2. Fine Aggregate and Coarse Aggregate

M-sand, free from organic impurities conform to IS 4031: 1988 and crushed stones of 20mm, 12.5mm and 6mm sizes conform to IS 2386: 1963 part 3 were used. Properties of fine and coarse aggregate are shown in Table 2 and gradation curve of fine aggregate are in Figure 2.

Table -2: Properties of Fine and Coarse Aggregate

Sl. No	Property	Result
1	Specific gravity of fine aggregate	2.60
2	Specific gravity of coarse aggregate	2.78
3	Water absorption	0.51%

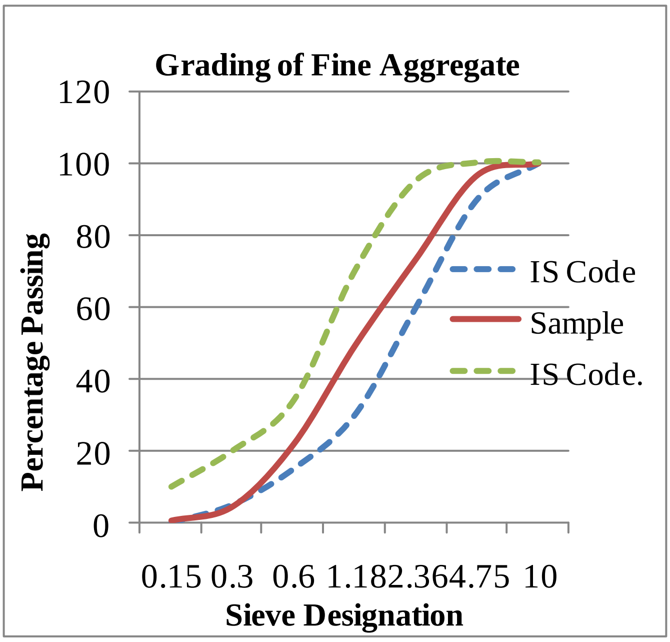

Figure -2: Gradation curve of fine aggregate

3.3. Super Plasticizer

Auromix 300 was used as Super plasticizer. Properties of Auromix 300 are shown in table 3.

Table- 3: Physical and Chemical Properties of Super Plasticizer

Sl. No	Property	Result
1	Appearance	Yellow coloured liquid
2	Ph	Minimum 6
3	Volumetric mass at 20°C	1.09kg/liter
4	Dosage	0.5-0.3 liter/100kg of cementatious material

3.4. Micro Steel Fiber

13 mm length size micro steel fiber was used. It helps to increases tensile strength and toughness of concrete.

Table- 4: Properties of Micro Steel Fiber

Property	Specification
Fiber Type	Brass Coated Straight Steel Type
Dimensions	Equivalent diameter 0.2mm and length 13mm
Aspect Ratio	33-35
Tensile Strength	2200-2850 N/mm^2

Figure- 3: Micro Steel Fiber

3.5. E-Waste Fiber

Extracted outer casing of electrical wire were used for making e- waste fiber in concrete. Diameter of fiber - 4mm and length-3 cm size fiber was used. E- plastic waste fiber are shown in figure 4.

Figure- 4: E-Waste fiber

4. EXPERIMENTAL INVESTIGATION

4.1.Concrete Mix Design

Concrete mix design was done as per IS 456:2000 and IS 10262:2009. The mix proportion for M30 mix is given in table 5.

Table -5: Mix Proportion

Sl No.	Material	Quantity(Kg/m^3)
1	Cement	350
2	Fine Aggregate	760
3	Coarse Aggregate	1220
4	Water	160
5	Super Plasticizer (0.4%mass of cement)	1.812
6	Water Cement Ratio	0.45
Mix Proportion (C:FA:CA:W)		**1:2.17:3.48:0.45**

4.2.Design of Column

Design of column was done as per IS 456:2000. As per the design, 4 numbers of 12mm diameter bars were provided as main reinforcement and 8mm diameter bars are used as transverse reinforcement. The cover provided is 20mm. The reinforcement detail for column is shown in figure 5.

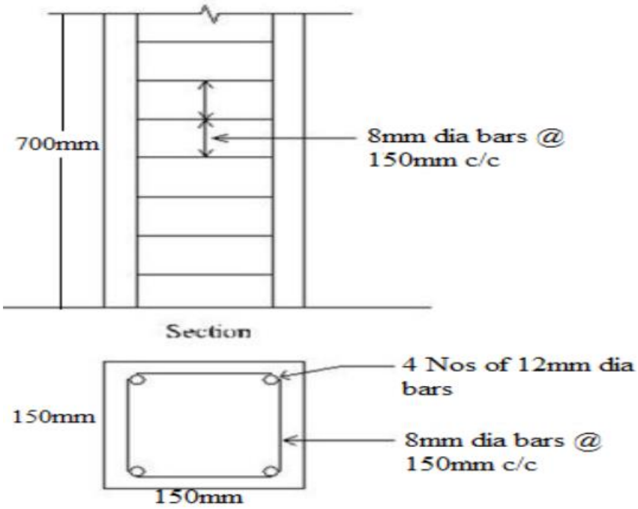

Figure -5: Reinforcement details of column

4.2. Test Specimen Details

An experimental research has been planned to study the behavior of short columns having 150 mm×150 mm×700 mm size in-filled with different types of concrete such as normal M30 mix and hybrid fiber reinforced concrete (HFRC). To obtain suitable hybrid fiber reinforced concrete mix for columns several trials was done by standard compression test, flexural test and slit tensile test on cube, beam and cylinder. From the test results the optimum dosages of different fibers was determined. Details of column specimens were given in table 6.

Table- 6: Details of Test Specimen

Specimen	Specimen Designation	Percent of Micro Steel Fibre	Percent of E- waste Fibre
RCC Column	C1	0	0
MS-FRC Column	C2	1.5	0
EFRC Column	C3	0	0.8
HFRC Column	C4	1.5	0.8

4.3. Test setup

Short column were tested on UTM (500kN) as shown in figure 6. The columns were cured for a period of 28 days and then the surface of columns cleaned and white wash were applied for the clear visibility of cracks. The load was applied on the column specimen until the failure took place. The load was applied until the failure took place. Axial strain of column noted at equal interval with help of strain gauge. Then ultimate load and corresponding strain was noted. The ultimate load or fracture load was taken at which the needle of load dial on the UTM returned back. The average of the few trials was taken and the stress-strain graph was plotted.

Figure -6: Test set up

5. RESULTS AND DISCUSSIONS

5.1. Standard Test Results

Compressive strength of concrete cubes for different HFRC mix, MS-FRC mix, EFRC and normal M30 are shown in table 7.

Table- 7: Compressive strength of cubes

Concrete mix	% of e-waste fibers	% of steel fiber	Average compressive stress in 28 days(N/mm2)
Normal Mix	0	0	35.76
MS-FRC	0	0.5	36.24
	0	1	38.88
	0	1.5	39.82
EFRC	0.6	0	35.05
	0.8	0	36.24
	1	0	34.03
HFRC	0.8	0.5	36.86
	0.8	1	39.82
	0.8	1.5	42.08

From the compression test results of HFRC cubes 1.5% micro steel fiber and 0.8% e-waste fiber were fixed as the optimum dosage. From the results of compressive strength, split tensile strength and flexural strength of cube, beam and cylinder for normal M30 mix concrete and finalized HFRC mix.

5.2. Short Column Test Result

Axially loaded columns are the one where load acts at the centroid of the column cross-section. The columns were EFRC, MS-FRC,HFRC and is compared with control specimen. Comparison of failure pattern and strain relationships are presented. The ultimate load carrying capacities are calculated and are plotted. Hybrid fiber reinforced column specimen shows increase in ultimate load carrying capacity compared to normal specimen. In micro steel fiber reinforced column 75.08% increase in ultimate load carrying capacity. Increase in load carrying capacity is due to the effect of fibers, they provide structural integrity to concrete and prevent the formation of micro cracks confinement effect provided by steel tube The ultimate load carrying capacities of each column specimens are graphically plotted and compared with the control specimens.

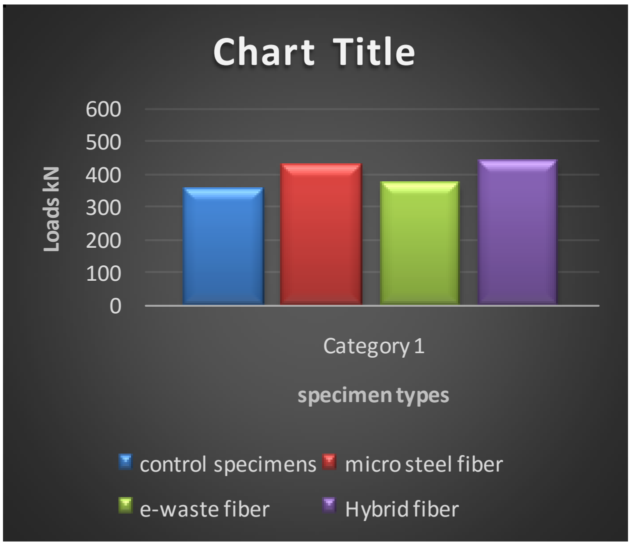

Figure -7 : ultimate load values

5.3.Failure Pattern

Test was continued until the failure of specimen took place. When the short columns are axially loaded, the reinforcement steel and concrete experience stress. Found that HFRC short column showed higher resistance compared with normal RC column. Failure mode of specimen divided into three types based on their material properties and geometric configuration. From the failure patterns of the normal RC specimens it is clear that the failure occurs mainly due to crushing. As long as it is a short column there is no chance of buckling. Due to crushing failure the cracks are mainly seen at the top and bottom of the column specimen. The ultimate load carrying capacities of each column specimens are graphically plotted and compared with the control specimens.

5.4.Stress-strain curves

In order to study the behavior of concrete columns, to plot appropriate analytic stress-strain graph. The better stress-strain graph results in reliable estimation of strength and deformation behavior of the structural members. The stress strain curve for normal specimen, EFRC, MS-FRC and hybrid fiber reinforced concrete short column were obtained. Figure 8 shows the stress strain curve for hybrid fiber reinforced concrete short column. Figure 8 shows the stress strain curve of normal specimen.

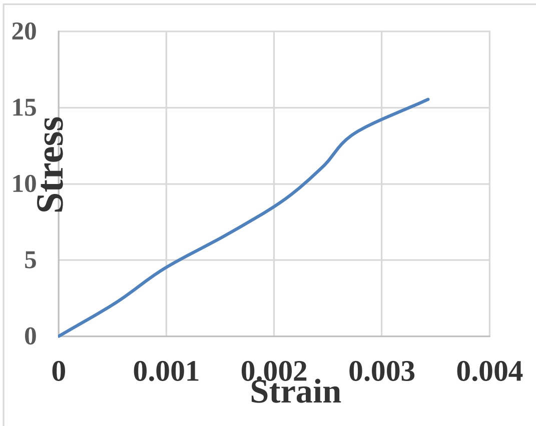

Figure -8: Stress train behavior of normal short column

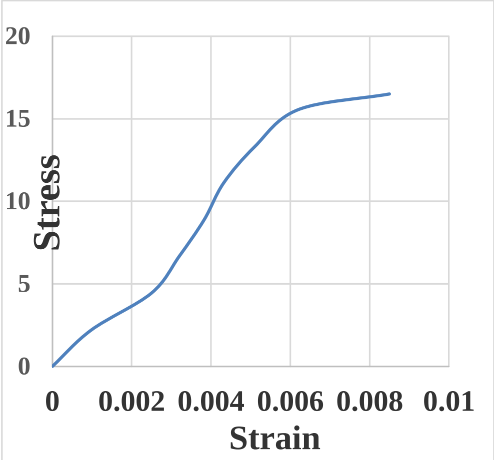

Figure- 9: Stress train behavior of HFRC short column

6. CONCLUSION

Concrete short columns with or without fiber content were tested under axial loading condition. The behavior of short columns was analyzed with respect to ultimate load carrying capacity, and failure modes. From the experimental study the following conclusions were drawn.

- Hybrid fiber reinforced columns have 81%increases in maximum load carrying capacity than that of the normal RC column.
- In micro steel fiber reinforced column 75.08% increase in ultimate load carrying capacity. Increase in load carrying capacity is due to the effect of fibers, they provide structural integrity to concrete and prevent the formation of micro cracks confinement effect provided by steel tube.
- In e-waste fibre reinforced concrete columns have 20.24 % increase in load compared to normal column.
- Hybrid fiber reinforced concrete short columns were capable of carrying large amounts of strain than normal RC column.

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