

Experimental Study on Mechanical Properties of Scrap Tyre Fibre Reinforced Concrete

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Abstract—Recyclates are widely being used in the construction industry as an input material for making concrete. A large inventory of used tyres piled over the globe creates environmental pollution. Unless these are disposed of safely, it remains a menace to the environment. In order to avoid environmental pollution during combustion of scrap tyres, it can added in small percentage during making of concrete. The scrap tyre fibre is a type of synthetic fibre. In the present study, the mechanical properties, namely, compressive strength, split tensile strength, flexural strength and ductility index with 0,2,4,6 and 8% of scrap tyre rubber fibre in concrete were determined. To evaluate the above properties, 24 cubes (150 X 150 X 150 mm), 24 cylinders (150 mm diameter and 300 mm height) and 5 concrete beams (150 mm x 150 mm x 1200mm) were cast and tested. The mechanical properties were found to increase with fibre content up to 4%.

Index Terms—fibre, scrap,tyre, concrete, recycle

1 INTRODUCTION

Fibre reinforced concrete is a composite obtained by adding a single type or a blend of fibres to the conventional concrete mix. Fibres can be in the form of glass fibres, steel fibres, natural fibres, synthetic fibres etc. Synthetic fibres are manmade fibres which possess long term durability. In this present study, synthetic fibres obtained as waste material during recycling of used tyres are used in concrete. Most commonly used form of scrap tyre derived products in civil engineering are crumb rubber, rubber powder, rubber fibres and steel wires. Civil Engineering applications of waste tyres include erosion control as barrier reefs, tyre shreds used in landfill and road construction, highway crash barriers, septic tank leach fields and others, tyre derived Aggregate (TDA) and rubberized Hot Mix Asphalt (RHMA). Tyre properties present additional benefits in their applications such as vibration and sound control, lightweight property for prevention of erosion and landsliding and drainage in leachate system.

The main objective of the study was to find the mechanical characteristics of concrete such as compressive strength, split tensile strength and flexural strength by varying the percentage of scrap tyre fibre content in concrete. The scope includes to investigate the effect of scrap tyre fibre (STF) on the strength characteristics of concrete also to find an alternative to the commercial synthetic fibre. The results showed improvement in concrete property.

2 LITERATURE REVIEW

Onuaguluchi and Banthia (2017) explored one of the byproducts derived from processing of used vehicle tyres in their study on cement based application for polymeric scrap tyre fibres (STF). Cement mortar with Polyethylene

terephthalate (PET) fibres is used for comparison with the cement mortar with STF fibres. STF characterization, alkaline stability of fibres, mortar mixture proportion, plastic shrinkage characteristics and long term durability are analysed. It was found that STF consists polyester fibres predominantly and the average length and width of the fibre is in the range of 3 to 5mm and 18 to 20 micrometer respectively. The plastic shrinkage cracking of cement mortar is reduced by addition of STF fibres. Also the optimum fibre content is concluded as 0.2% for PET and 0.4% for STF.

Li et al (2004) introduced waste tyre in concrete in the form of fibres and waste tyre modified concrete is developed. In the experiment, comparison of mechanical properties of tyre fibre modified concrete and tyre chip modified concrete is conducted. From the results, it was concluded that, waste tyre fibre reinforced concrete has higher strength and stiffness than waste tyre chip modified concrete. Also increasing the stiffness of the fibre and using thinner fibres increases the stiffness of concrete. It was found that stress concentration in the tyre fibre modified concrete is lower when compared to tyre chip modified concrete when a finite element analysis was conducted on a two- phase composite model.

Maryoto et al (2015) have conducted both experimental and numerical analysis aimed to investigate possibilities of using waste tyre reinforcement material for concrete. Flexural tests are conducted on prestressed and non- prestressed waste tyre reinforced concrete. From the results, it was concluded that reinforcement with 17% of tensioning increased 25% of flexural strength of concrete.

Thomas et al (2014) aimed to find an alternate to natural sand in concrete construction as fine aggregate and together with to dispose the waste tyre material. Experiments were done on mechanical behavior, abrasion resistance, water permeability and sorptivity in concrete specimens. It was observed that waste tyres can be utilized for partial replacement of natural fine aggregate upto 7.5% without enough reduction in its desired strength.

Thomas et al (2016) ensured the application of rubber

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particles in pavements, floors and concrete highways as they have more resistance to abrasion. In this study, they have partially replaced the fine aggregate by waste tire rubber particles in normal strength and high strength cement concrete and its abrasion resistance is measured. From the results, the rubberized concrete has more resistance to abrasion when compared to the control concrete without rubber. From the statistical analysis also, rubber particles have a positive effect on resistance against abrasion.

Gesoglu et al (2014) conducted a study on two types of scrap tyre rubber waste namely crumb rubber and tyre chips to obtain rubberised previous concrete. The concrete was obtained by partially replacing single sized natural coarse aggregate with equivalent volume of rubber. From the results, it was concluded that durability properties due to freezing and thawing can be reduced by utilization of rubber in pervious concrete without any reduction in flexural strength. Also it improves surface property of concrete by providing better abrasion resistance.

3 MATERIALS

The materials used in this experiment were scrap tyre fibre, cement, sand, fine and coarse aggregate. The tests were done as per the relevant IS codes for each material.

3.1 Scrap tyre Fibre

Scrap tyre fibres obtained by shredding of used tyres during its recycling process were used for this study. These fibres are obtained from a tyre recycling plant. These fibres are waste products obtained during the process of tyre recycling. The fibre used belongs to synthetic fibre.



3.2 Cement

Ordinary portland cement (OPC) of 43 grade was used for the study. The specific gravity of cement was 3.16 with a fineness 2.23.

3.3 Fine aggregate

Natural river sand with specific gravity of 2.58 and fineness modulus 2.28 was used for the experiment. The fine aggregate conforms to IS 383:1970 specifications, i.e. it lies within zone II.

3.4 Coarse aggregate

The tests on coarse aggregate is determined as per IS 383: 1970. The specific gravity and water absorption of the material was

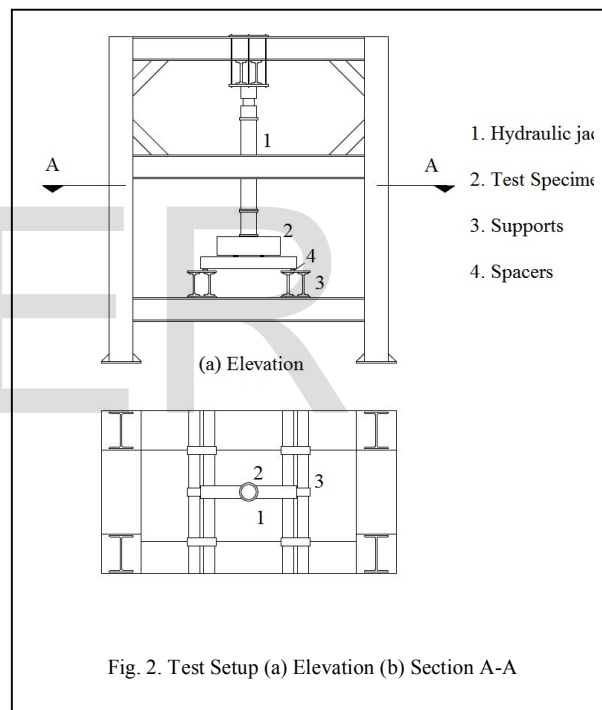
obtained as 2.88 and 0.15 respectively.

4 EXPERIMENTAL PROGRAMME

Casting of beam specimens were carried out in 5 batches. The moulds were filled in 3 layers. After placement of each layer, the concrete were compacted manually to ensure proper compaction. The specimens were demoulded after 24 hours of casting and then covered with wet gunny bags and applied water frequently.

4.1 Test Setup

The test was carried out at the structural Engineering laboratory of Government College of Engineering Kannur. A self equilibrating loading frame of capacity 750 kN was adopted as the loading equipment. The plan and elevation of loading setup is shown in the Fig.2 (a) and (b). To measure the displacement, two LVDT's were arranged at the mid span of the beam at its bottom.



4.2 Compressive strength test

The test was conducted as per IS 516: 1959. Cube specimens of size 150 mm was tested for compressive strength of concrete at 7 day and 28 day in compression testing machine of 3000 kN capacity with a loading rate of 14 N/mm² per minute. The compressive strength is found out by noting the maximum load applied. Three samples of each mix were tested and average compressive strength was found out.

4.3 Split tensile strength test

The tensile strength of concrete is determined by splitting tensile strength test. The experiment is conducted as per IS 5816: 1999. The strength were determined at 7th and 28th day of curing.

4.4 Flexure test

Reinforced concrete beams of cross-section 150 x 150 mm and length 1200 mm were cast. The beams were designed as per IS 456: 2000 with clear cover of 20 mm. The bars used are Fe 500 TMT bars. Beams are provided with two 12 mm diameter bars at bottom, two 10 mm diameter bars at top and thirteen 6 mm bars as shear reinforcement at a spacing of 90 mm c/c. The reinforcement detailing of the beam is shown in Fig. 3. The beam specimens were designated as STF0, STF2, STF4, STF6 and STF8 where STF indicates scrap tyre fibre and the number the percentage of fibre content.

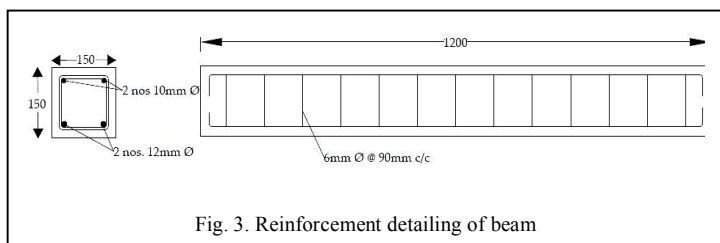


Fig. 3. Reinforcement detailing of beam

5 RESULTS AND DISCUSSIONS

5.1 Compressive strength

The compressive strength of cube specimens for different percentage of fibre are tabulated below. From the results it was found that both concrete with 2% and 4% fibre addition showed

TABLE 1
COMPRESSIVE STRENGTH TEST RESULT

Age	% fibre	Maximum load (kN)	Compressive strength (N/mm ²)
7 day	0	648.33	28.81
	2	728.33	32.37
	4	721.67	32.07
	6	568.33	25.25
28 day	0	880	39.11
	2	1023.33	45.48
	4	1023.33	45.48
	6	833.33	37.03

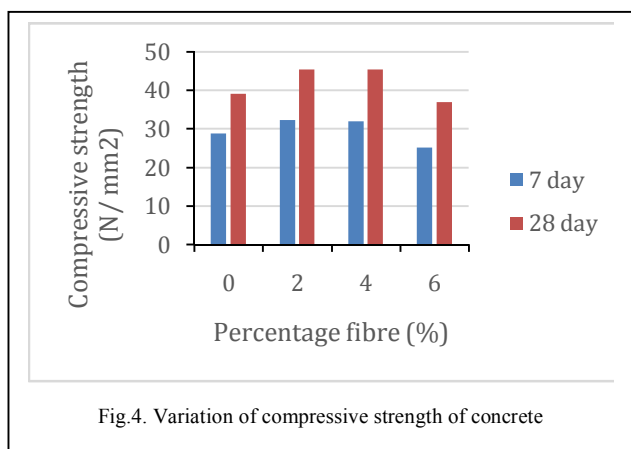


Fig. 4. Variation of compressive strength of concrete

similar behaviour. On addition of 2 and 4% of fibre, the compressive strength increased about 16 % than conventional concrete. Further addition of fibre decreased the compressive strength. The test result obtained after compression test is tabulated in Table.1. Also variation of compressive strength with different percentage of fibre is shown in Figure.4.

TABLE 2
SPLIT TENSILE STRENGTH TEST RESULT

Age	% fibre	Max load (kN)	Tensile strength (MPa)
7 day	0	256.67	3.63
	2	280	3.96
	4	270	3.81
	6	250	3.58
28 day	0	350	4.95
	2	380	5.37
	4	341.67	4.83
	6	306.67	4.33

5.2 Split tensile strength

The results obtained by split tensile strength tests are given in Table 2 and Figure 5 below. The split tensile strength of concrete was found to increase by addition of fibres up to 4%. The tensile strength decreases on further addition of fibres.

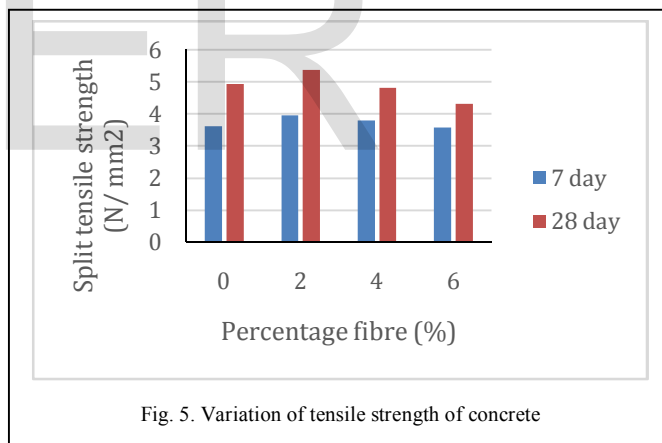


Fig. 5. Variation of tensile strength of concrete

5.3 Flexure Test

Influence of scrap tyre fibre on the load- displacement curves. The load- displacement relationships were obtained by plotting the curve between loading rate and its corresponding displacement values. Two LVDT's were used to measure the displacement. The average value of the displacement is calculated from the two LVDT readings. The load-displacement graphs plotted with the obtained data of beam with different percentage of scrap tyre fibre is shown in the Fig. 6 and compared with the control specimen of grade M35. From the figure, the curves were found to be slightly linear at the beginning and with the increase in load, it became non-linear. It was also founded that beam with 4 % fibre have higher loading capacity than the control specimen.

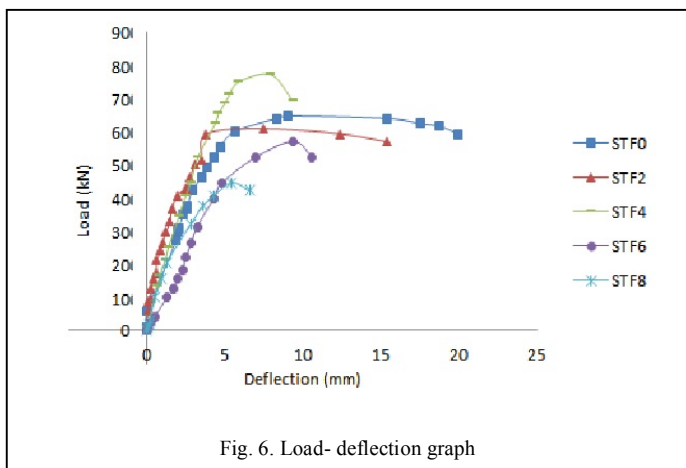


Fig. 6. Load- deflection graph

Influence of scrap tyre fibre on crack, ultimate and failure load. The first cracking load, ultimate load and failure load for different specimens were listed in the Table.3. The cracking load was found to increase as the percentage of fibre increases. This shows that propagation of crack in beams are reduced by addition fibre. The maximum crack widths of different specimens are also tabulated. It was observed that addition of fibres leads to shear failure. The crack pattern obtained after testing is shown in the Figure.7.

TABLE 3
CRACKING LOAD, ULTIMATE LOAD AND FAILURE LOAD

Specimen	First crack load (kN)	Ultimate load (kN)	Failure load (kN)	Flexural crack width (mm)	Shear crack width (mm)
STF0	18.5	64.5	59.1	1.5	0.2
STF2	20.5	60.7	55.2	1.3	0.1
STF4	27.5	76.9	68.4	0.1	0.5
STF6	30	56.7	52.1	0.05	1.2
STF8	31.5	44.3	42	0.05	1.4

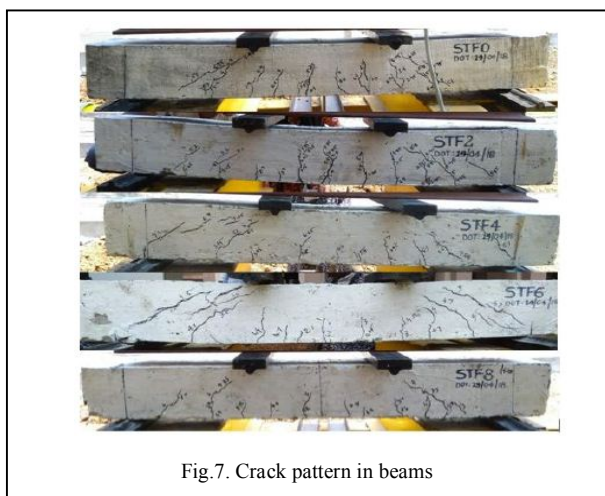


Fig.7. Crack pattern in beams

Flexural strength. Flexural strength for a rectangular beam under four point loading with loading span as one-third of the support span is given by the equation,

$$\sigma = \frac{WL}{bh^2}$$

Where,

- W = ultimate load
- L = length of beam
- b = width of beam
- h = depth of beam

The flexural strength of the beam with different percentage of fibre is tabulated in the Table 4. The maximum flexural strength is obtained for specimen with 4% of fibre. The strength for the beam is 19.14% more than the control specimen.

Ductility Index. The ability of a structure to undergo inelastic deformation is called as ductility. It is measured using ductility index. The ductility index is the ratio of deflection, rotation and

TABLE 4
FLEXURAL STRENGTH

Specimen	Ultimate load (kN)	Flexural strength (N/mm ²)
STF 0	64.5	9.56
STF 2	60.7	8.99
STF 4	76.9	11.39
STF 6	56.7	8.40
STF 8	44.3	6.56

curvature at the ultimate state to the deflection at yield point. Ductility index of the concrete is seem to be increased with addition of fibre. The results were given in Table.5.

6 CONCLUSION

Synthetic fibres are used extensively in construction industry

TABLE 5
DUCTILITY INDEX

Specimen	Ductility Index
STF0	0.99
STF2	1.10
STF4	1.30
STF6	3.34
STF8	3.74

to improve the ductility of concrete. In the present study an alternate material was used instead of synthetic fibres. Scrap tyre fibres extracted from used tyres are used to study the improvement in mechanical properties of concrete. From the studythe following conclusions were made:

- It was found that the compressive strength with addition of 2 and 4% of fibre increased about 16 % of the compressive strength of conventional concrete.

Both showed similar behaviour. But on addition of fibre percentage found to decrease the compressive strength.

- The split tensile strength of concrete increased by 8% upto 4% of fibre content.
- The specimen with 4% of fibre content improved the flexural strength by 19% when compared to the flexural strength of the control specimen.
- Ductility index of the concrete was increased with addition of fibre.

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