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# Mechanical Properties of Recycled Steel Fibre Reinforced Concrete with Partial Replacement of Cement with Saw Dust Ash

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**Abstract**- Saw dust ash is found to be a suitable material to replace cement in concrete as it has got high pozzolanic activity. But as the replacement percentage increases, the strength of concrete is found to be decreasing. The aim of this study is to enhance the strength of concrete in which cement is partially replaced with saw dust ash by reinforcing it with recycled steel fibres which is obtained from scrap tyres. Concrete reinforced with recycled steel fibres has got very good mechanical properties and the behaviour of such fibres in concrete is found to be almost similar to that of commercial fibres. In this study, cement is replaced with saw dust ash at three different percentages and each is reinforced with steel fibre by 1%, 2% and 3% volume of concrete. Compressive strength, split tensile strength and flexural strength was tested. From the test results, an optimum percentage at which the strength of concrete is maximum is found out.

**Index Terms**— recycled steel fibre reinforced concrete, saw dust ash

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## 1 Introduction

Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete. If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved. Appropriate utilization of these materials brings ecological and economical benefits. Saw dust is a waste material from the timber industry. It is produced as timber is sawn into planks at saw mills located in virtually all major towns in the country. This process is a daily activity causing heaps of saw dust to be generated after each day.

The every rising functional requirement of the structures and the capacity to resist aggressive elements has necessitated developing new cementations materials and concrete composites to meet the highest performance and durability criteria. The environmental factors and pressure of utilizing waste materials from industry have also been the major contributory factors in new developments in the field of concrete technology.

Approximately 70% of the wood ash generated is land filled; an additional 20% is applied on land as a soil supplement. The remaining 10% has been used for miscellaneous applications. Wood ash is used as a feedstock for cement production and road base material. Due to these reasons, many attempts are being made to develop high volume use technologies for wood ash, especially for use in construction materials.

Results of several researchers show the presence of significant silica in the ash specimens obtained from controlled incineration of saw dust and they claim that it can be used as a substituent for cement in concrete since it contains amorphous silica making it fit as cement replacing material due to its high pozzolanic activity. The strength of the concrete with saw dust ash shows significant value only up to small percentage of replacement and then the value decreases. Hence several means should be explored to use it as an effective cement replacement material at higher percentages also. However, use of saw dust ash in concrete helps to transform it from an environmental concern to a useful resource for the production of a highly effective alternative cementing material.

The use of recycled steel fibre as reinforcement in concrete will benefit the environment, since the fibres are currently a waste arising from the recycling of tires [14]. For the last few decades, the use of vehicles has increased tremendously and the disposal of the used tyres become a serious issue. Statistics show that four billion used tyres is generated each year across the world and the environmental issues caused by the landfills become a serious issue. By recycling the scrap tyres and reusing the rubber and steel wires inside the tyres is a solution for this problem even to a small extend. The steel fibres recovered from the tyres can be effectively utilised as a reinforcement in concrete and a lot of experimental studies had been conducted to evaluate the mechanical and other properties of recycled steel fibre reinforced concrete. Recent research is showing that the addition of recycled steel fibres from waste tyres can decrease significantly the brittle behaviour of cement based materials, by improving its toughness and post-cracking resistance. In this sense, Recycled Steel Fibre Reinforced Concrete seems to have the potential to constitute a sustainable material

for structural and non-structural applications [19].
Several processes can be used to recover recycled steel fibres from waste tyres: the shredding and cryogenic process for mechanical recovery, or the pyrolysis and microwave induced pyrolysis for recovery utilising thermal degradation [3].

## 2 Literature review

Youjiang Wang et al. (2000) reviewed the use of different type of recycled fibers such as tire cords/wires, carpet fibers, feather fibers, steel shavings, wood fibers from paper waste and high density polyethylene in concrete. In addition to the advantage that the fibers increase the toughness and durability, use of recycled fibers also helps to reduce the waste and resource conservation. Adding small fraction of fibers helps to resist the crack propagation and crack opening as well as it improves the tensile properties of concrete. Due to the above advantages, fiber reinforced concrete is mainly used in buildings, highway overlays, bridges and airport runways. The use of fiber reinforced concrete gained much importance since it has got properties like durability in cementitious environment, easily dispersed in concrete mix, good mechanical property and geometric configuration. There are different approaches in using recycled fibers such as recycling a product into its original form, processing the used product into a new type of product totally different in earlier appearance, pyrolysis and hydrolysis and finally converting waste into energy through incineration. Author also presents a review of different kind of recycled fibers such as fibers from carpet waste, used tyres, paper product and other recycled fibers and from the earlier studies conducted, they conclude that recovered material can provide similar reinforcement as original material although the quantity of fiber used may be higher to match the performance. Finally they suggest that the durability study of recycled fibers is an area which is not explored yet.

K. Neocleous et al. (2006) studied the design issues for concrete reinforced with steel fibres, including recycled steel fibres recovered from scrap tyres. This paper examined the suitability of existing guideline by RILEM for the flexural design of recycled steel fibre reinforced concrete. They found some fundamental design issues related to the tensile stress-strain behaviour of steel fibre reinforced concrete. On the basis of this, they developed a new model and it was applied for the flexural design of steel fibre reinforced concrete. It is concluded that the model proposed in this study is more conservative and accurate than the RILEM models.

G. Centonze et al.(2012) studied the mechanical properties of Steel Fiber Reinforced Concrete (SFRC) and compared it with that of Recycled Steel Fiber Reinforced Concrete (RSFRC). Also the post cracking behavior of concrete were evaluated by conducting four point flexural test. Experiments were conducted by taking same percentage of fibers in SFRC and RSFRC and the results were compared each other and also with that of plain concrete. As the fibers were recovered from different sources, the geometric variation in the diameter and length of the fibers was also taken into account. By conducting flexural test on specimen, the crack mouth opening displacement (CMOD) and crack tip opening displacement (CTOD) were measured. From the results obtained from the compressive, flexural and post cracking behavior of the recycled fiber reinforced concrete, it was clear that the use of recycled steel fiber is a promising application in the field of civil engineering. Authors also suggest to study the technological issues related to fiber production and concrete mix preparation.

Ziaaddin Zamanzadeh et al. (2015) was interested in conducting experimental and numerical studies on the use of RSFRC in elements failing in bending and beams failing in shear. In order to study the possibility of recycled steel fibers as shear reinforcement in RC beams, three point bending test was conducted and it also study the design and advanced modelling of RSFRC beams failing in shear. Also nonlinear simulation was carried performed using a computer program based on FEM.

Enzo Martinelli et al.(2015) studied the mechanical behavior of fiber reinforced concrete with both industrial fibers and recycled fibers. The strong motivation behind recycling tire was that it is an ecofriendly source of secondary raw material. After conducting compression and four point bending test, they concluded that compressive strength is almost unaffected by the presence of fibers and, then, no significant difference was detected between the FRC specimens with only industrial fibers and the ones made with an increasing proportion of recycled fibers. A significant decay in the post-peak cracking behaviour was observed as a result of the partial to total replacement of industrial fibers with an equal amount of recycled ones. The higher is the amount of recycled fibers, the more significant is the reduction in the post-cracking toughness (in terms of equivalent post-cracking strengths and/or ductility indices) observed in the four-point bending tests. They suggest that further investigations are still necessary to completely understand this and the other relevant aspects of the mechanical response

Antonio Caggiano et al. (2015) studied the experimental and numerical characterization of the bond behavior of steel fibers recovered from waste tires embedded in cementitious matrices. The results of an experimental investigation aimed at understanding the tensile response of the steel fibers and their bond behavior when embedded in cementitious matrices are reported and discussed. Then, an extensive comparison between numerical predictions and the corresponding experimental results of the pullout behavior of recycled steel fibers embedded in concrete is presented for validating and calibrat-


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ing the model and a satisfactory agreement was found between the both.

Ozkan Sengul (2016) studied the mechanical behavior of concrete containing recycled steel fibers from scrap tires and he determined the compressive strength, splitting strength and flexural strength and also the load-deflection behavior is monitored by using closed-loop bend deflection behavior. The main drawback of recycled steel fiber is that the variation in geometric properties, ie both length and diameter may vary unlike industrial steel fibers. From the results obtained, an optimization process was also performed to select the most suitable alternative from the solution.

M. Mastali and A. Dalvand (2016) replaced cement with silica fume in the reinforced self compacting concrete with recycled steel fibers and studied its mechanical properties and impact resistance. The combined effect of silica fume and recycled steel fibers improved the mechanical properties and impact resistance. From the results obtained, a linear equation was also developed. Experiment was performed with different percentage of silica fume replacing cement and reinforced with three different level of fiber volume fraction. Compression test, splitting tensile test, three point bending test and impact test was performed and after the analytical study, empirical equations was developed by regression analysis. Even though the replacement of cement with silica fume and adding recycled steel fibers reduced the workability of concrete, the combined effect of them improved impact resistance and mechanical properties.

## 3 Experimental Programme

As the preliminary part of the study, different raw materials used was tested. The experimental program starts by choosing the different materials that are to be used for the study and studying their properties to ensure that they possess the required characteristics. The materials used were cement, saw dust ash, fine aggregate, coarse aggregate and recycled steel fibre.. The properties of each of these materials contribute to the quality of produced geopolymer concrete. For the present study, the test for various materials were conducted as specified in the relevant IS codes for each materials.

### 3.1 Fine Aggregate

Fine aggregate used to conduct the experimental work was river sand passing through IS 4.75 mm sieve and from the sieve analysis, it was found that it conforms to zone II of IS 383:1970. The specific gravity and fineness modulus of fine aggregate was found to be 2.586 and 3.453 respectively.

### 3.2 Coarse Aggregate

Aggregates which occupy major percentage of volume of concrete substantially influence the properties and performance of the concrete. Crushed natural stone of maximum size 20 mm, with a specific gravity and water absorption of 2.688 and 0.15% respectively, were used as coarse aggregate for the work. Coarse aggregate used for this study confirms to IS 383:1970 specifications. Samples were tested as per IS 2386:1997 and was found to be confirming to IS 383:1970.

### 3.3 Cement

The cement used for this study is OPC 43 grade cement and the specific gravity, consistency and fineness was found to be 3.16, 33% and 2.23% respectively.

## 4 Casting of Specimens

Specimens were prepared by using cement, saw dust ash, sand, coarse aggregate and recycled steel fibre. The saw dust ash was obtained by controlled burning of wood waste at a constant temperature and it is used to replace cement partially. Concrete mix were prepared by following the above obtained mix proportions and were poured into moulds of standard size. The recycled steel fibres were mixed with the other raw materials during dry mixing and mixed thoroughly to get better workability. The moulds used for compression test and split tensile strength test were 150 x150 x 150 mm cubes and 150 x 300 mm cylinders.

## 5 Testing of Specimens

Specimens were casted to test the compressive strength, split tensile strength and flexural strength of concrete.

### 5.1 Compressive Strength Test

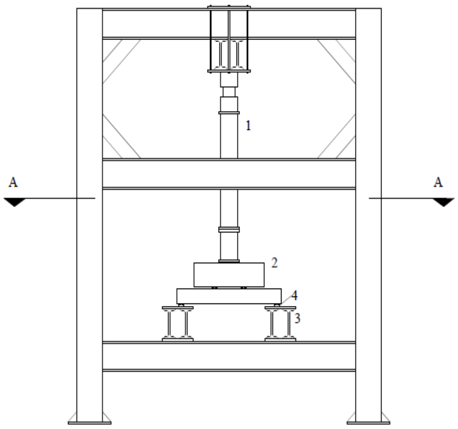
Cubic specimens were casted to test the compressive strength of concrete both with and without recycled steel fibres. In both the cases, the cement was replaced partially by 20% and the percentage of fibre varies as 0%, 1%, 2% and 3%. Test was done according to IS 516: 1959.

### 5.2 Split tensile Strength Test

Specimens of size 150 x 300 mm were tested in compression testing machine and the test was done according to IS 5816:1999.

### 5.3 Flexural Strength Test

Total of four beams of size 1000 x 150 x 150 mm were prepared with different recycled steel fibre content as 0%, 1%, 2% and 3% and designated as A0, A1, A2 and A3 respectively. The design of the beam was done as per IS 456:2000. Two numbers of 12 mm diameter and 10 mm diameter bars were provided as the bottom and top reinforcement respectively and a cover of 20 mm was provided at top and bottom. Stirrups were provided with 6 mm bars and the spacing adopted was 90 mm. The specimens were tested on loading frame of 750 kN capacity.. The test set up is shown in Fig.1. Load was increased and crack patterns were observed up to failure.




1. Hydraulic ram
2. Load cell
3. Supporting beam
4. Spacers

Fig. 1 Elevation of loading frame

## 6 Results and Discussion

### 6.1 Compressive Strength Test

The results of compressive strength is shown in Table 1 and their variation is shown in Figure 1. From the results, it can be seen that there is slight change in the value of compressive strength which implies that recycled steel fibres have negligible influence on compressive strength of concrete.

TABLE 1
COMPRESSIVE STRENGTH RESULTS

| Specimen | Compressive strength (N/ mm²) | |
|---|---|---|
| | 7 day | 28 day |
| S 0 | 23.81 | 37.61 |
| S 1 | 25.91 | 39.56 |
| S 2 | 8.13 | 41.87 |
| S 3 | 24.80 | 37.01 |

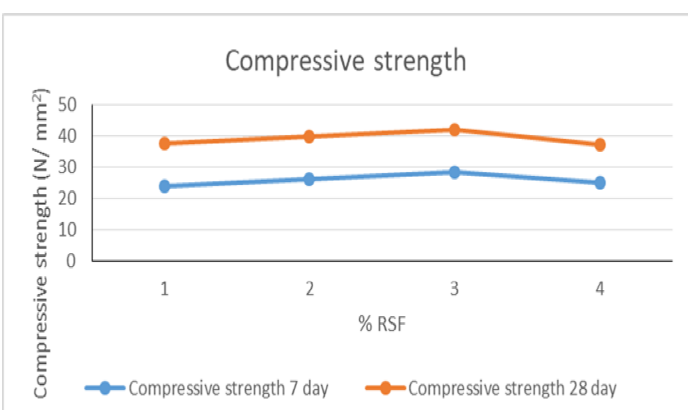



Fig. 2. Variation of compressive strength of concrete with % of steel fibre

- The compressive strengths of the cube specimens was found to increase up to 25.6%.
- The compressive strength of concrete was found to be increasing with the addition of recycled steel fibres upto 2% and then it started decreasing.

### 6.2 Tensile Strength Test

From the test results it has been found that split tensile strength is maximum when 2% fibre is added to the concrete. The percentage increase in split tensile strength when 2% fibre is incorporated in concrete is 32.92%.

TABLE 2
TENSILE STRENGTH RESULTS

| Percentage of Steel fibre | Average Split Tensile Strength (N/mm²) | |
|---|---|---|
| | 7 day | 28 day |
| 0 | 1.87 | 2.46 |
| 1 | 2.13 | 2.98 |
| 2 | 2.56 | 3.27 |
| 3 | 2.21 | 2.51 |

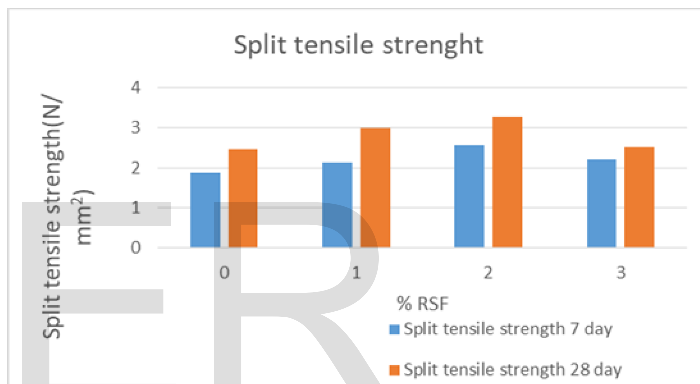



Fig. 3. Variation of tensile strength of concrete with % of steel fibre

### 6.3 Flexural Strength Test

In the post cracking zone, distinct behaviour in the different beams were observed. Regarding the post yield zone, the beams showed the ability to withstand higher load and to gain more deformability until failure with the increase in percentage of steel slag.

It is seen that the beam A2 is having maximum load carrying capacity compared to that of the other specimens. and it is about 3% more the control specimen A0. It is clear that, as the percentage of recycled steel fibre increases the initial cracking load and maximum deflection of the concrete beams increases.

**Load – deflection relations** The load - deflection curves of the different beams are shown in Fig. 5. At the initial zone of curves up to the first cracking point, linear be-haviour was observed and the beams stiffness shows almost identical values, as this stage is controlled mainly by the geopolymer concrete tensile strength. In the post cracking zone, distinct behaviour i.e. a non-linear behaviour with significant stiffness reduction up to yielding of tensile steel in the different beams were observed. The non – linear behaviour can be attributed to the non-linearity of the stress – strain relationship of the rebars.

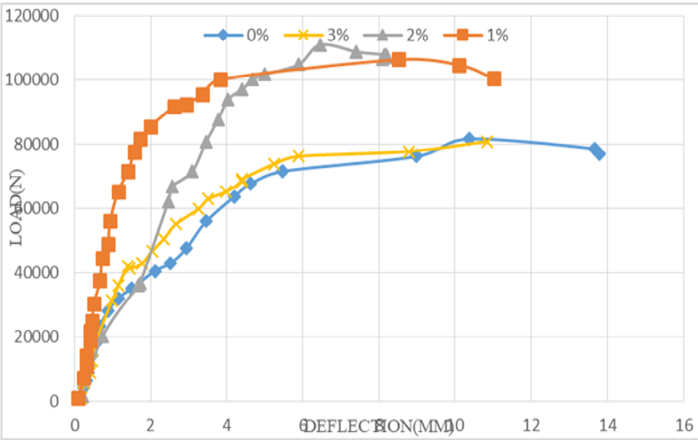



Fig. 5. Load vs. deflection graph

From Fig. 5, it is seen that the beam D30 is having maximum load carrying capacity compared to that of the other speci-mens and it is about 41.77% more the control spec-imen D0. It is clear that, as the percentage of steel slag increases the initial cracking load and maximum deflection of the flyash based geopolymer concrete beams increases.

From these data, the failure load and the corresponding deflection for each specimen is noted down and is shown in Table 3.

## 7 Conclusions

It has been found that saw dust ash can be used as an effective cement replacing material as it has got pozzolanic activity and chemical characteristics similar to cement. Incorporating re-cycled steel fibres into the concrete enhances the mechanical properties of concrete and hence it adds additional advantage of waste reduction.

From the compressive strength test and split tensile strength test, the following conclusions are arrived.

- Maximum strength of concrete is obtained when the cement is replaced by saw dust ash by 20%.
- Compressive strength of concrete was found to be maximum when the percentage of recycled steel fibre is 2%.
- Split tensile strength of concrete is found to be maxi-mum when 2% recycled steel fibre is incorporated in the concrete and the percentage increase is 32.92%.
- Flexural strength of concrete is maximum when the percentage of recycled steel fibre is 2% and the per-centage increase is 3%.
- The propagation of crack become less as the percent-age of fibre increases.

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