INFLUENCE OF STEEL FIBERS EXTRACTED FROM WASTE TIRES ON SHEAR BEHAVIOR OF RC BEAMS

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ABSTRACT: *In this experimental work, influence of fibers on shear behavior of RC beams was investigated. Steel fibers were extracted from the used tires. Steel beads in tires were cut to the length of 38 mm, value of aspect ratio was 29 and added in concrete during casting. Four type of concrete mixtures were casted by varying the amount of fibers. Mixture without any fiber was the control mixture and other mixtures have 0.40, 0.65 and 1.00% fibers by volume. Five types of RC beams were prepared by using four type of mixtures. Control mixture have two types of beams, viz., one with stirrups and other without stirrups. Four point bending test was conducted on all types of beams to evaluate the shear behavior. It was observed that failure load, deflection, first shear crack and ultimate shear load were increased with the addition of fibers. Crack spacing and crack width were reduced by increasing amount of fibers. Workability of fiber reinforced concrete was lower than the conventional concrete.*

Keywords: Steel fibers; RC beams; Shear behavior; Deflection; Crack spacing and width

.1. INTRODUCTION

Concrete is considered as largest man made material on this planet and used to construct wide range of infrastructures of any region. Lot of supplementary materials were added in concrete to enhance it mechanical properties and durability. Concrete consumes natural resources and efforts have already been made to incorporate waste material in it for sustainable development, environment friendly and to avoid depletion of natural resources [1].

Utilization of fibers in concrete is the one technique to enhance the properties of concrete. Concrete is considered as brittle material but ductile behavior was observed after adding suitable amount of fibers. Properties of fiber reinforced concrete highly depend upon the type of fiber used and aspect ratio of fibers. Steel fiber, polymeric fiber, glass fiber, carbon fiber and natural fibers are mostly used in concrete. Addition of fiber improves the mechanical properties of concrete and especially in post cracking behavior [2]. Concrete spalling is one of the common failure of reinforced concrete structures, but fibers maintain the integrity of concrete matrix and resist the separation of concrete [3, 4]. Shear behavior of concrete highly improved by adding the desired amount of fibers. Shear capacity of RC beams was investigated by replacing stirrups with various amount of fibers. And improvement in shear capacity was observed [5-9].

From last few decades, volume of vehicles have increased rapidly and disposal of tires become a serious problem. Researcher incorporate rubber and fibers of tires in concrete to evaluate the ductility behavior of concrete [1, 10]. Properties of waste fibers vary significantly due to different exposure condition, usage of tires and extraction procedures, so the properties of fibers must be evaluated before using in concrete.

With such background, detailed experiments were conducted to evaluate the shear behavior of fiber reinforced concrete. RC beams were casted by varying the amount of fibers and influence of fibers on failure load, failure modes, mid span deflection, shear crack initiation, ultimate shear load, crack spacing and width were investigated.

2. EXPERIMENTAL METHODOLOGY

Experimentation was conducted in this research work for evaluating the shear behavior of fiber reinforced concrete beams. Materials used and their mix proportion along with preparation of specimens and testing are presented in following sub-sections.

2.1 MATERIALS

Concrete was casted by using local available materials. Cement in the concrete was ordinary Portland cement of ASTM type –I, physical properties of cement is presented in Table 1. Coarse and fine aggregate in concrete was Murgala crush and lawerencepur sand, respectively, which were locally available. Properties of both types of aggregates are mentioned in Table 2. The particle size distribution of both types of aggregates is presented in Figure 1, and both curves shows the well graded distribution of particle and acceptable for casting of concrete. Suitable amount of super plasticizer with commercial name Camride BA520 was used and meets the requirement of ASTM C494 [11]. Steel fibers used in this research were acquired by burning of used tires which is also known as pyrolysis process. Steel fibers obtained from this process were completely unspoiled (Figure 2.). Tensile strength of fiber was estimated by conducting tensile strength test on ten samples average value is reported as tensile strength of fiber. Length of fiber during testing was 100 mm and area of fiber was 1.32 mm^2 and obtained tensile strength was 780 MPa. Steel bars were used as the flexural and shear reinforcement. 10 mm and 12 mm deform bars were used of 400 MPa strength. Plain bar of 6 mm was used as shear reinforcement and its tensile strength was 275 MPa.

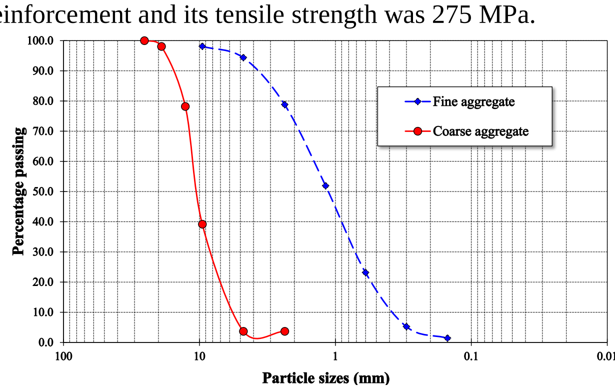


Figure 1. Particle size distribution of fine and coarse aggregate.

Table 1. Physical properties of ordinary Portland cement.

Physical property	Value
Standard consistency (%)	29
Initial setting time (Minute)	100
Final setting time (Minute)	205
Fineness (%)	7
Expansion (mm)	9

Table 2. Physical properties of aggregates used

Physical properties	Coarse	Fine
Source	Margalah	Lawrencepur
Specific gravity	2.65	2.7
Bulk Density (loose)	1390 kg/m^3	1440 kg/m^3
Bulk Density (compacted)	1560 kg/m^3	1632 kg/m^3
Fineness Modulus	6.62	2.64

Figure 2. Steel fibers used in this research work.

2.2. Mix Design

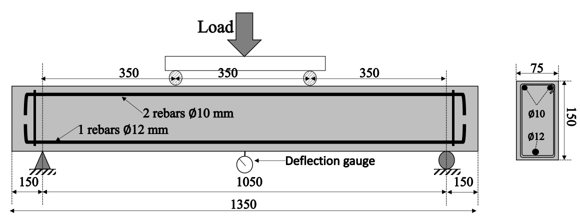
Concrete was casted in four different types. All constituents of concrete were kept constant only amount of fibers varies. Mixture without any fiber was the control mixture and other mixtures have 0.40, 0.65 and 1.00% steel fibers by volume. Admixture was used only in one mixture, having maximum amount of fibers, to maintain the workability of concrete. Concrete was mixed by following ACI 211.4R [12]. Cement, sand and crush were mixed by proportion of 1:1.7:3.80, respectively. Fibers were added cautiously during dry mixing of other constituents of concrete to circumvent the balling effect. Then desired amount of water was added and mixed further four to five minutes. Figure 3 presents the sprinkling of fibers during casting of concrete to avoid balling effect.

2.3. Preparation of specimen and testing

10 steel molds of size 75 x 150 x 1350 mm were prepared for casting of five types of beams. In all beam, one deform bar of 12 mm was used as flexural reinforcement, whereas, two hanger bars of size 10 mm was used. Shear reinforcement was used only in one type of beam throughout the span at distance of 150 mm center to center. In all other cases shear reinforcement was absent. By putting designed steel works in molds, concrete was casted in two layers. After casting of beams its upper surface was covered with polythene sheet to avoid the evaporation of moisture. After 24 hours of casting all beams were demolded and cured in wet condition for 28 days in laboratory. Along with the beams, cylinders were also casted to evaluate the compressive strength of different types of concrete. Three cylinders were used for one mixture and average value is reported as compressive strength.

Workability of all types of mixture were investigated by conducting slump and compacting factor test according to ASTM C143 [13] and BS 1881: Part 103 [14], respectively. Four point bending test was performed to evaluate the shear strength and mid-span deflection of beams. 150 mm spacing was maintained beyond the supports of the beam, shear span of 350 mm was fixed. And span between two loading point was also 350 mm. Deflection gauge was fixed at middle bottom size of the beam to measure the deflection at concerned loading points. Longitudinal and cross sectional detail of specimens along with loading set-up is mentioned in Figure 4.

Figure 3. Sprinkling fibers in dry mix.



(a) Longitudinal section (b) Cross-section

Figure 4. Testing set-up and geometrical detail of four point load test on beams (Unit: mm)

Table 3. Summary of test performed and number of specimens.

Fibers (%)	Workability test	Compressive strength	Beam test	Acronyms
0	----	----	2	F0S0
0	1	3	2	F0S1
0.4	1	3	2	F0.4S0
0.65	1	3	2	F0.65S0
1.00	1	3	2	F1S0

Control specimen without shear reinforcement is designated in this work as F0S0, amount of fiber (F) and shear reinforcement (S) is zero (0). Other control specimen is abbreviated as F0S1, where 1, present the presence of shear reinforcement. Table 3 presents the summary of whole research work. Amount of steel fibers and shear reinforcement and their influence on shear behavior of beam were investigated in this work. So, acronyms used were narrated by amount of fiber (F%) used and utilization of stirrups (S).

3. RESULT AND DATA DISCUSSION

Fresh and hardened properties of concrete with fibers were investigated and details discussion has been made in following sub-sections

3.1. Workability of fiber reinforced concrete

Workability was measured by slump test and compacting factor test and their values are mentioned in Figure 5. It was observed that workability decreases by the addition fibers [15]. Significant reduction in slump and compacting factor was observed just after addition of 0.4% and further decrease with addition of fibers. Almost similar values were observed at 0.65% and 1.00% addition of fiber because admixture were concrete with 1.00% fibers, to maintain the workability. It was also observed that the distribution of steel fibers was even enough and no balling effect was observed even at lowest slump and compacting factor value. Results of workability verifies the utilization of fibers in concrete but limited up to 1.00% only.

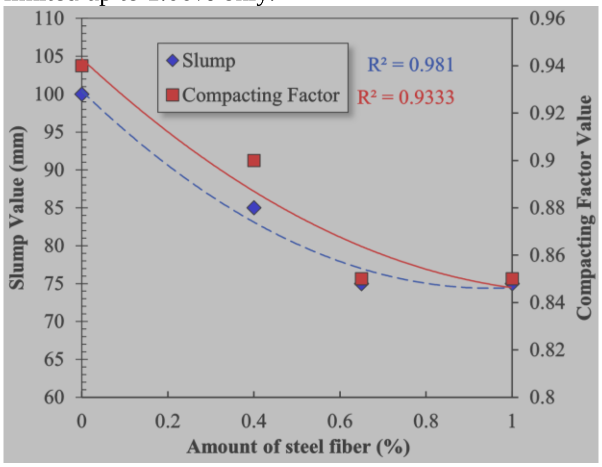


Figure 5. Influence of fibers on workability of concrete.

3.2. Behavior of beam with fiber reinforced concrete

3.2.1 Failure load and failure modes

Ultimate load of all types of beams were evaluated by conducting four point bending test. Schematic diagram of testing set-up is mentioned in Figure 4. Ultimate load or failure load was extracted for each beam and presented in Figure 6. It is clearly seen that failure load of all beams is lower than the calculated or theoretical ultimate flexural load. And observed faiulire mode was the shear failure, which verifies the above statement. Shear failure mode can be classified further, viz., diagonal tension failure, shear tension failure and shear compression failure [16]. For F0S0 (Figure 7(a)), observed failure mode was diagonal tension failure, in which shear crack appered in shear span and widened abruptly and causing sudden or brittle failure. This was the reason that failure load of this specimen was less among all. By the addition of fibers, ultimate load was increased by an amount of 17.86, 35.71 and 62.30% by addition of 0.40, 0.65 and 1.00% fibers, respectively, as comapred to zero % fiber without shear reinforcment specimen (F0S0). Whereas, by using stirriups, ultimate laod was increased by an maount of 26.79%, which is in between specimen F0.40S0 and 0.65S0 and give indication to the utilization of fibers. Failure modes was also shifted form diagonat tension to shear tension failure, which was due to reduction in bond between concrete and steel, some dowel action was also considered in such mode of failure [17].

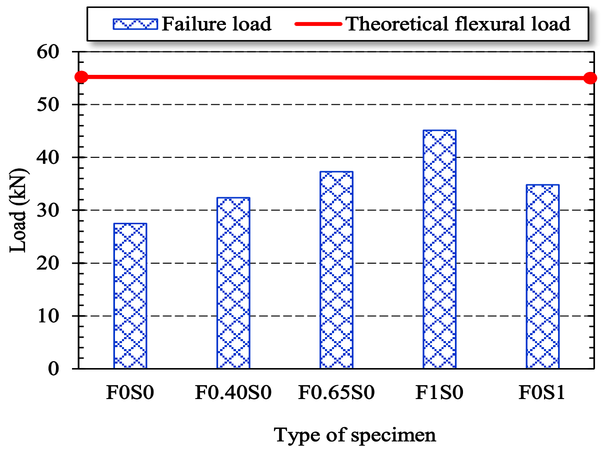
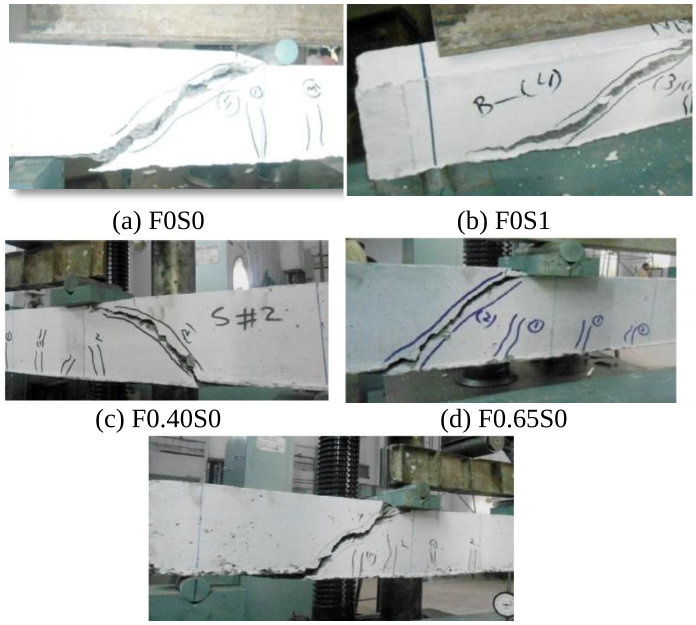


Figure 6. Failure load of all types of beams.



(a) F0S0 (b) F0S1

(c) F0.40S0 (d) F0.65S0

(e) F1S0

Figure 7. Failure modes of all types of beams.

3.2.2 Load deflection relationship

Figure 8 presents the load-deflection relationship of all type of beams. Mid-span deflection was continuously measured during testing versus small interval of load. Initial stiffness of all types of beams seems to be similar but it changes with the onset of cracking. It is clearly mentioned in highlighted portion in Figure 8. First of all, first shear crack was appeared in the specimen F0S0 among all specimen. All other specimen possesses some ductile behavior and resist the propagation of crack and bears further load. Least deflection was also observed in F0S0 specimen. Maximum deflection was observed in case of F1S0, which have higher amount of fibers. It was also observed from Figure 8 that yielding of bar is absent, so, all expected mode of failure must be shear failure which was verified by observed modes (Figure 7).

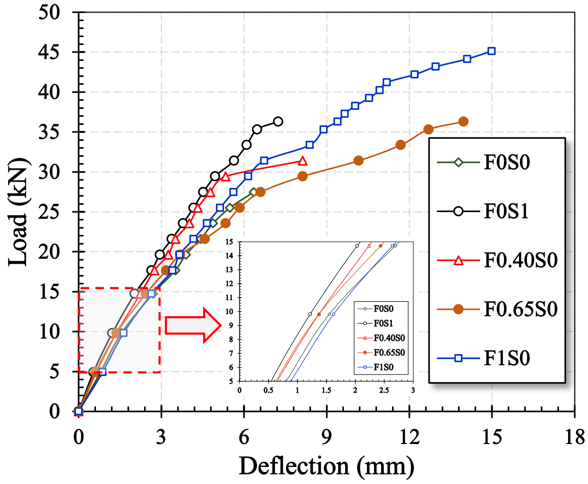


Figure 8. Load-deflection relationship of all types of beams.

3.2.3 Crack initiation and ultimate shear load

In this sub-section, discussion on crack initiation load in shear span and ultimate shear load were discussed in detail. Figure 9 shows the crack initiation and ultimate shear load along with the theoretical shear capacity of beams by ACI [18]. In SI unit ACI equation was modified to calculate the shear capacity provided by concrete (Eq. (1)) [18]. Further capacity was enhanced by providing stirrups and shear capacity provided by steel stirrups was evaluated by using following Eq. (2) [18].

$$V_c = \left(\frac{\lambda\sqrt{f_c'}}{6}\right) b_w d \tag{1}$$

$$V_s = \frac{A_v f_y d}{s} \tag{2}$$

where;

V_c and V_s are the shear capacities (N) of concrete and stirrups, respectively. b_w is the width of beam, d is depth of beam (mm), A_v is area of stirrups (mm^2), s is spacing (mm), f_y is the yield strength of stirrups and λ = 1 for normal weight concrete.

It was observed that first crack initiates in constant moment zone at tensile face of beam and with further application of load, cracks propagated towards compression side. With further application of load, more cracks appear on the surface of beam and distributed in constant moment zone as well as shear span. In shear span, crack is diagonal instead of vertical and also appeared at center of surface, where contribution of flexural reinforcement is negligible. In case of F0S0 specimen, crack initiated load is almost equal to the concrete capacity (V_c), and with further application of load crack propagated rapidly and sudden collapse was observed. By providing stirrups crack propagation can be resisted and it was observed in specimen F0S1. Ultimate shear load of specimen is almost equal to the capacity of concrete and capacity of steel with some factor of safety "Ø = 0.85". Utilization of fibers contribute more to enhance the shear capacity of concrete. It was observed that shear crack initiation load was increased by an amount of 31.03, 44.83 and 72.41% by using fiber by an amount of 0.40, 0.65 and 1.00%, respectively, as compared to F0S0 specimen. Whereas by using stirrups, crack initiation load was increased only by an amount of 17.24%. From Figure 9, crack initiation load of F0S1 is equal to the shear capacity provided by steel stirrups. Similar trend was observed in the ultimate shear load, ultimate shear load of F1S0 was more than F0S0 by an amount of 64.29%.

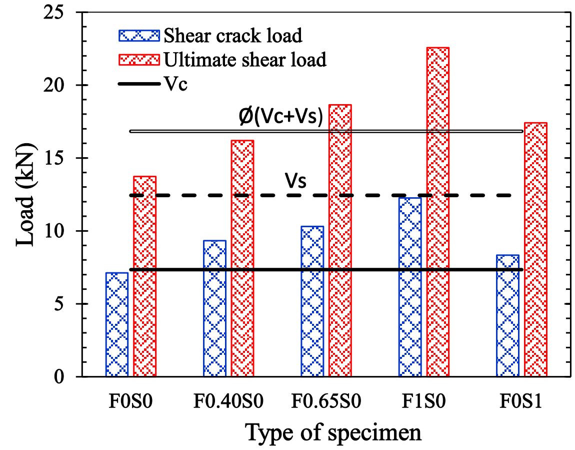


Figure 9. Crack initiation and ultimate shear load.

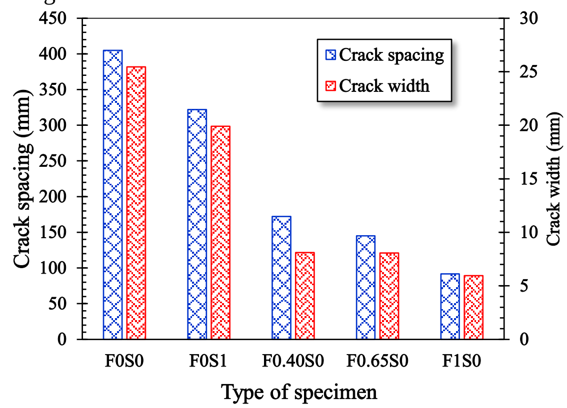


Figure 10. Crack spacing and width of all type of beams.

3.2.3 Crack spacing and crack width

Cracks were marked during testing of beams as shown in Figure 7. Cracks spacing depends upon the bond between steel and concrete. It is increased by increasing the amount of flexural reinforcement area and more specifically the perimeter of the flexural reinforcement [19-22]. In this work, flexural reinforcement for all beams were kept constant and only difference was the amount of fibers in the concrete. And significant reduction in the crack spacing was observed with the increase in the fibers amount as shown in Figure 10. Fibers assumed to strengthened the matrix of concrete and also resist crack propagation with application of load. It provides the good bond between concrete and steel and also among constituent of concrete. Crack width depends upon the crack spacing [19], and similar trend was observed in the crack width of shear crack and showed in Figure 10. Although, width was measured after failure of specimen and it was shear crack not the flexural crack but it provide the evidence of resisting crack opening with the increase in amount of fibers.

4. CONCLUSIONS

Detailed experimentation was conducted to investigate the properties of concrete with steel fibers in it. Fresh and hardened properties were investigated by conducting workability tests and four point bending test on RC beams, respectively, and following conclusions were extracted;

1. Fibers resist the flow ability of concrete and reduction in slump and compacted factor values were observed with the increase in amount of fibers.
2. Failure load and mid span deflection of RC beams were increased with the addition of fibers.
3. Fibers contributes to enhance the shear capacity of beams which results in the increase in ultimate shear and crack initiation load with fibers.
4. Fibers resist the crack propagation and reduction in crack spacing and crack width were observed with addition of fibers.

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