Experimental Evaluation of Combined Effect of Flexure, Shear and Tension on SFRC Beams

Mohammad Israil, M S Jafiri, Pushpendra Kumar Sharma

Abstract*: *Short discrete fiber reinforcement is the right choice in the concrete matrix. De-bounding and pulling out of fibers requires more force, thereby increasing the durability and confrontation to repeat and dynamics loads. Fibers substantially decrease the fragility of concrete and advance its engineering characteristics, like load bearing capacity, resistance against impact load, flexural, tensile and fatigue etc. Behavior of SFRC in tension, compression, flexure and shear has already been studied separately but no or very little work has been done on combined state flexure, tension, shear, torsion etc. Present study involves the investigation of the behavior of SFRC composite M20 beams with varying percentage fiber content (0.0, 0.50, 0.75 & 1.0%) by volume under the combined state of tension and shear and flexure. The testing beam size was taken as100 mm × 100 mm × 500 mm. Straight fibers 28 mm long and 0.28 mm diameter were castoff. The specimen beams were tested applying direct tension of 0, 5, 7 and 10kN. For different fiber percent by weight beams were tested, all the direct tension values were applied to each of the three beams i.e. total of 48 beams were casted and tested accordingly. For the beam under combined effect of tension, flexure and shear, when tested it was observed that ultimate central deflection and ultimate bending stress were found to decrease for a particular percentage increment of fiber added along with increase of tension. It was also observed that for a specific tension value, deflection increases with increase of fiber percentage at ultimate load in beams. Bending stress increases at tension 10 KN for all percentages of fiber content.

Keywords*: *SFRC, Shotcrete, flexure, shear, deflection

I. INTRODUCTION

Concrete being stiff, durable, cheap with adequate compressive strength is used in construction and that is why it is a versatile construction material. Inappropriately, it is a moderately breakable and characteristically feeble in tension. To provide ductility and robustness, yarns are mixed in the concrete matrix to crop fiber reinforced concrete (FRC). Distinctive claims for FRC are; refractory concrete, highway, air strips, hydraulics constructions, tunnel linings, precast items and fibrous shot-crete. Fibers, amend the fracture development in concrete and bring the concrete to structural requirement; acting as crack arrestors. Fibers not only increase the essential energy for crack development but transmit tensile stress between the cracks also, even after the crack spanning ability by aggregates fails and hence provide structural steadiness. This fiber appliance intensifies the ductility characteristic of the concrete structure, so as to avoid the unexpected brittle disaster of un-reinforced plain concrete and enhance the bearing capacity of the structure. Under varying loading conditions, FRC beam initially, shows nearly straight line before getting its tensile strength. After cracks, it turns in to the load-deflection curve, depending on the fiber characteristics like geometry, number, the position with respect to the cracks direction and the pull out actions. This can be witnessed under uni-axial tests or flexural tests or closed-loop compression tests performed on fiber reinforced concrete beams. Adding steel as fiber reinforcement to concrete makes it SFRC. FRC primarily prevents the transmission of cracks and then sustains some amount of load bearing ability after the cracks developed. Though the conservative steel mesh reinforcement of bars offers burden bearing ability after cracking, yet show insignificant influence on crack arresting.

Revised Manuscript Received on July 20, 2020.

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II. LITERATURE REVIEW

From the beginning of the twentieth century, extensive investigations have been carried out on mixing of different type of fibers in concrete. And investigations were carried out to check the effects of fibers on individual properties of concrete. None investigations have been reported where the properties of SFRC were checked under combined state of stress. Niyogi and Dwarkanathan evaluated the effect of shear and moment on the performance of FRC beams. They observed that fiber volume portion, concrete mix proportions, shear span and quality of concrete ingredients were the main affecting parameters. It was found that shear capability falls as a shear span/depth fraction rises [1]. Gopalakrishna from Structural Engineering Research Centre (SERC), Chennai investigated toughness, resistance to impact load, flexural strength, ductility, shear strength, ductility and fatigue etc. like properties of steel fibers reinforced shotcrete (SFRS) and found that thickness of SFRS panels decreases as compared to that of we'd mesh concrete. They also observed that an Aspect Ratio of 65 for straight steel fibers could be efficaciously used in the field [2]. Bernando and Lopes experimentally studied the development of the depth failure of neutral axis along with the ductility characteristics at bending for high strength fiber reinforced concrete beams. A total of 9 simply supportedspecimen beams, were examined. Every specimen had been subjected to two balanced point loads at one third of span. Beam to beam, the strength of concrete and longitudinal tensile reinforcement ratio was found different. To study the nature of failure the ductility indices were analyzed [3]. Tan et al investigated the behavior of SFRC on the shear, testing six SFRC simply supported beams under 2-point loading hooking 30mm long and 0.5mm diameter steel fibers.

The researchers observed the behavior with varying percentage of fiber volume fraction right from 0.0% to 1.0% with an interval of increase by 0.25% [4]. Shende, et al studied the relationship between Aspect Ratio and the compressive, flexural and the split tensile strengths respectively and separately. The concrete grade M-40 of 1:1:4.3:3.04 mix proportions on SFRC having fibers volume fraction as 0,1, 2 and 3% were considered under this study [5].

III. LABORATORY SETUP

The laboratory set up for experimentation was programmed to ascertain the behaviour of SFRC in such a way that it gives insight into the combined state of flexure, tension and shear. For this SFRC specimens of 0%, 05%, 0.75% and 1.0% fibres by weight were *casted* and tested. Experiments were conducted such that the specimens could be tested in flexure under direct tension of 0, 5, 7 and 10 kN with shear.

A. Materials used

The properties of constituents were tested to ensure that the materials of the composite confirm the specified necessary requirement of performance standard. 43 grade of OPC was used in testing. Nearby obtainable coarse Sand was tested following IS: 383-1970. The specific gravity was 2.45 and the fineness modulus 2.83. Crushed stone aggregate was a mixture of 10 mm and 20 mm locally available with quartzite in mineralogical composition mainly. The fineness modulus and specific gravity of 10 and 20 mm aggregate was 2.60, 5.92 and 2.64 and 6.98 respectively as per IS code. Potable water free of impurities was utilized in preparing and curing the specimen cubes and cylinders of concrete. Commercially available steel wires 0.28 mm diameter and 100 aspect ratio and 2.8 mm length were used as steel fibres in proportion of 0.0.0.5.0.75 and 1.0% by weight, in concrete mixes.

B. Mixing, Casting And Curing of Specimens

M20 mix following IS: 10262 (1982) proportioning cement, fine aggregate, coarse aggregate as 372 kg, 579.6kg, 1159.85 kg per cubic meter respectively maintaining water cement ratio 0.5 was prepared. The same was applied in each percentage volume of fibers.

The fiber reinforced concrete cubes of 150mmx150mmx150mm cubes and 150mm dia and 300 mm length cylinders were casted to evaluate the compressive strength. While to assess the combined behaviour of SFRC, 48 beams of 100mmx1000mmx500mm were casted. For casting the cubes and beams mixing of the concrete was dons as per the guidelines of IS: 10262 using available laboratory equipment's.

The specimens casted were taken out of the mould after 24 hours and labeled. These specimens then put for 28 days curing. After 28 days well dried samples were tested under two point loads and direct tension for finding central deflection at room temperature.

After water curing of 28 days, the cubes and cylinders had been well dehydrated in the lab. The specimens were tasted in uniaxial compressive testing machine and load Vs deflection was observed with two dial testers located diametrically opposite face of specimen, along with load. Load versus deflection graphs were plotted to establish the stress-strain relation for different mixes and different weight percentage of fibers.

Compression Testing Machine was used to evaluate the splitting tensile strength of the FRC cylinders specimen beams. The specimen were positioned in laid down with cylinder axis perpendicular to axis of loading. For the evaluation of effect of the splitting tensile strength the FRC *cylinders* specimens were examined in compression testing machine in lay down position with longitudinal axis of the cylinders perpendicular to the longitudinal axis of the loading planed. At the two diametrically opposite faces by using dial gauges with 0.01mm least count, the deflections and mean distortion were observed.

C. Sample Testing

Under the two point loads, the steel fiber reinforced concrete (SFRC) beams were experimented for the central deflection measured by dial gauges supported on both faces of the plate. In case of pure bending samples were cautiously leveled, loading was exactly done at one-third of span on both direction from the central point of the sample beam. The deflection at center was noted in the clear bending zone. The dial gauges with 0.01 mm least count measured the deflection at center along with at one-third span. Loading pattern was achieved by hydraulic machine of 500kN capability. Figure 1 displays the experimental setup and position of dial gauges. Figure 2 displays the failed specimen beams after test.

Fig. 1. Test Setup

Fig. 2. Failed Specimens

IV. OUTCOMES AND DELIBERAIONS

A. Compression Effects on SFRC Cubes

150mmx150mmx150mm size cubes under uniaxial compression were tested. In this study the M20 grade SFRC cubes with varying percentage of fiber 0.0, 0.5, 0.75 and 1.0% by weight were tested to develop stress-strain diagram.

B. Splitting Tensile Strength Effect on SFRC Cylinders

150 mm dia and length 300 mm cylinders had been tested for splitting tensile strength. In this study the M20 grade SFRC cubes with varying fiber amount right from zero to 1.0 % with 0.0, 0.5, 0.75 and 1.0% by weights were tested and stress versus strain diagram was obtained.

C. 0.5 % Fiber Effect on SFRC Beams

The sample beams containing 0.5 % steel fibres were exposed to direct tension values 0, 5, 7 and 10 kN. When the beams were tested at 0kN tension the specimen beams went failed at 5.2N/mm^2 bending stress and 0.5 mm deflection. On raising the tension to 5 kN, the bending stress reduced by 7.7% with respect to 0 kN specimen and the beams failed at 4.8N/mm^2. A further reduction of 15.4% was registered when the specimens were tested in flexure under a constant tension of 7kN. The beams carried an ultimate load of 3.8N/mm^2 when the tension applied was 10kN, thereby indicating a decrement of 26.9% over the samples tested under pure flexure without any tension i.e. 0kN tension value with minor change in deflection. Figure 3 shows the load deflection curve for 05 fiber.

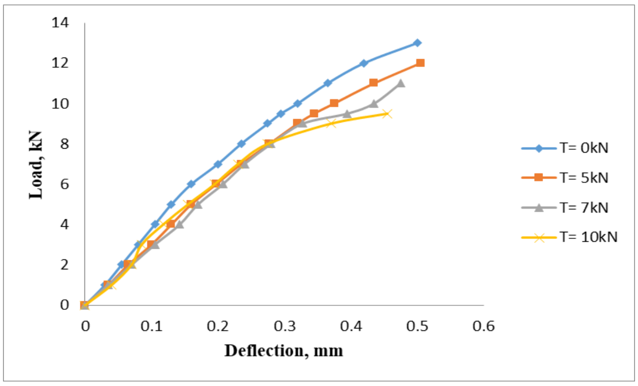

Fig. 3. Combined Load Deflection Curves for Fiber= 0.5% with different values of tension

V. INFERENCE

Following four inferences can be made from this experimental study

1. The central deflection (CD) and ultimate bending stress (UBS) decrease when tension rises to a specific amount of fiber for the beams tested under combined effect of tension, flexure and shear.
2. At ultimate load the central deflection increases with the increased amount of fibers for a specific amount of tension applied on specimen.
3. For applied tension value of 10kN the bending stress rises from 3.2 to 4.8 N/mm^2 by a maximum of 37.5% as the fiber content is raised from 0.0 to 1.00%.
4. For the beams without fiber, bending stress decreases from a maximum 4.8 to 3.2 N/mm^2 by a maximum value of 33.33%, as the tension increased from 0.0kN to 10kN.

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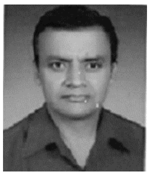

Dr. Pushpendra Kumar Sharma, born in December 1963, Graduated (1991), Post Graduated (1996) from Aligarh Muslim University, Aligarh, India in field of Civil Engineering in 1996 and with the same Research Centre completed PhD in Civil Engineering with Specialization in Environmental and Water Resources Engineering in 2016, is a Professor in School of Civil Engineering, Lovely Professional University, Phagwara, Punjab, India. He is having a total experience of more than 28 years; 9.5 years construction industry and 20 years of teaching. He is having his areas of interests like Environmental and Water Resources, Green Buildings, Capacity buildings, earthquake resistant buildings, energy efficient buildings, water and wastewater treatment technologies, environmental designs, sustainable construction project management, river pollution control and industrial wastewater treatment etc. In addition to teaching he has served and officiated many administrative designation like Dean Academics, Dean Students Welfare, Warden, Chairman Construction Committee HCST etc. He has been the author of more than 60 International/Journals and Conference research papers. He is reviewer of Cogent Engineering International Journal of Tailor and Francis, Journal of Environmental Chemical Engineering and has reviewed many papers of the same. He has successfully organized National and International Conferences in the working institutions. He is life time member of Indain Molecular Society (IMS), Indian Science Congress Association (ISCA) and Institution of Engineers, India (IEI). Currently he is guiding 10 PhDs in Civil Engineering on various topics @ LPU. He has guided one M.Tech and 4 more currently being guided in LPU. He has guided 150 B.Tech level projects on various topics of Civil Engineering. He has filed 8 patents out of which six published and rest in pipe line. He attended many workshops of international and national repute.

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