International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Experimental Study on Torsion of Steel Fiber Reinforced Concrete Members

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Abstract: ***The study on the torsional behavior of concrete in which the effect of fiber reinforcement in resisting twisting of concrete beams and performance of concrete with ternary blends. Fly ash in the mix replaces Portland cement, producing big savings in concrete materials costs. Fly ash is an environmentally-friendly solution that enhances the performance of concrete. Hence, this work is carried out with different combination of fibers with the inclusion of two admixtures to form ternary blended concrete to find out maximum torsional carrying capacity and to achieve the optimum fiber combination for Ternary Blended Fiber Reinforced Concrete Beams. In the present experiment program standard cubes (150x150x150mm) standard beams (1200x150x150mm) long and (300x150x150) arms at both ends were casted and tested for finding the torsional strength property of plain cement concrete and ternary blended steel fiber reinforced concrete. The compressive strength of control concrete (ordinary concrete),Ternary concrete contain 3% GGBS, 5% Micro silica and 10% Fly ash and ternary blended fiber reinforced concrete with various percentages of fibers concrete specimens having W/C 0.467, were tested. Results obtained from experimental investigation to study the torsional strength of ternary blended fiber reinforced concrete are presented here for discussion; the torsional strength of ternary blended fiber reinforced concrete is compared with the ternary blended concrete. There is a considerable improvement in the compressive strength of concrete with 5% replacement of cement by micro silica and 10% replacement of fly ash along with addition of steel fibers, because of the high Pozzolanic nature of the condense GGBS, micro silica, fly ash and its void filling ability. The main objective of the study is experimenting and comparing the torsional Behaviour of conventional reinforced beam with reinforced beams having steel fibers in the volume fraction 0.5%, 1%, 1.5% and 2%.***

Keywords: crimped steel fiber, torsion, GGBS, deflection,

1. Introduction

If external loads act far away from the vertical plane of bending, the beam is subjected to twisting about its longitudinal axis, known as torsion.

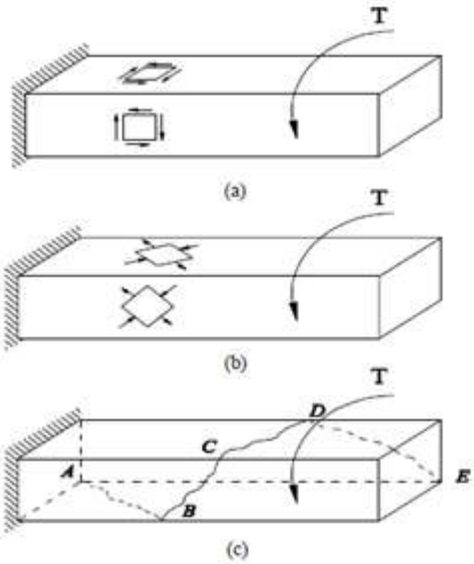

Figure 1 (a), (b), (c): Principal stresses and cracking due to pure torsion

When the beam shown inFigure 1.(a) is subjected to pure torsion, shearing stresses develop in the four faces as shown by the elements. The principal stresses on these elements are shown in Figure 1.(b). The principal tensile strength is equal to the principal compressive stress and both are equal to the shearing stress. Ultimately, when the principal tensile strength exceeds the maximum tensile strength of the beam, cracking will occur spiraling around the outside surface of the beam as shown in Figure 1.(c).

In a reinforced concrete member, such a crack would cause brittle failure unless torsional reinforcement is provided to limit the growth of this crack. Closed stirrups and longitudinal bars in the corners of the section are usually used as torsional reinforcement.

2. Technical Terms

1) **Torsion** – If external loads act far away from the vertical plane of bending, the beam is subjected to twisting about its longitudinal axis, known as torsion
2) **Crimped steel fiber** –**Crimped steel fiber** are low carbon, cold drawn steel wire fibers designed to provide concrete with temperature and shrinkage crack control, enhanced flexural reinforcement, improved shear strength and increase the crack resistance of concrete.
3) **GGBS-** Ground-granulated blast-furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.
4) **Deflection-** It is the degree to which a structural element is displaced under a load. It may refer to an angle or a distance.

3. Crimped Steel Fiber

Steel fibers have been given more and more attention for its better performance of crack controlling and preventing deadly flaws. Steel fiber reinforced concrete is a kind of uniform composite material. The big difference that the steel fibers create is that ductility and post-crack performance are significantly enhanced. In fact, mechanical properties of concrete matrix are mainly depended on the type and proportion of fiber used. Generally, smaller fibers with a high fiber count provide excellent first-crack strength and

superior fatigue endurance.
Nothing can entirely eliminate cracking including steel fibers. At present, steel fibers are superior to controlling cracks and substantially reduce the odds of cracking. In addition, there are other several elements will affect the cracking, including design and installation practices.

Figure 2: crimped steel fiber

3.1 Technical specifications

Table 1: Technical specifications of steel fibers

Length of fiber	10/20/30/35/40/50mm
Aspect ratio	45 to 80
Diameter	0.6-0.8mm (+- 0.05mm)
Width	2mm-2.5mm
Tensile strength	800-1000mpa
Apprearance form	Clear , bright and undulated along the length
Astm specs	Astm a820 m04 type1
Material type	Low carbon drawn flat wire

It is available in a variety of types and sizes and be used in diverse projects. However, SFRC can't deal with all purposes. It does great job in providing discrete, discontinuous reinforcement and effective crack control.

4. Reinforcement Details

Figure 3: Reinforcement details

The moulds are of size 150mm x 150mm for cubes and wooden moulds (1200x150x150mm) long and (300x150x150) arms at both ends for the beam specimens.
In these beams longitudinal reinforcement is 10mm and transverse reinforcement is 8 mm diameter of steel bars. Here reinforcement is taken only in the cantilever portion. The reinforcement details are shown in fig 3.After casting the specimens are as follows as shown in fig 4:

Figure 4: beam specimens

5. Test setup

The experimental setup is a commonly used torsional test rig and it is shown in fig 5. The total length of the specimens was 1.20 m. Beams were supported on one roller support at one end and the other end is fixed. These supports ensured that the beam was free to twist and to elongate longitudinally at free end directions during the test. The load was applied through a diagonally placed steel spreader beam on the end properly configured over reinforced concrete arms the end parts of the specimens, as shown in Fig. The end parts of the specimens were also heavily reinforced with volume of stirrups in order to bear without cracking the imposed torsional loading at the ends of the 300 mm long concrete arms. This way, the examined test region was the central part of the specimens. During the test procedure, torsional helical diagonal cracking and, finally, failure were localized within this test region. The heavily reinforced end parts and the over-reinforced concrete arms of the beams remained quite intact. The load was imposed consistently in low rate and measured by a load cell with accuracy equal to 0.05 KN. The beams were tested in monotonically increasing torque moment until the ultimate torsional strength and subsequently in increasing twist until the total failure of the specimen or the maximum twist capacity of the test apparatus.

Figure 5: Testing of beams

The failure of the beams are as shown in fig 6 below

Figure 6: Failure of beams

6. Result and Discussion

6.1 Compressive and tensile strength of the concrete

Table 2: Compressive and tensile strength of the concrete

percentage of fiber	compressive strength (N/mm2)		Split tensile strength (N/mm2)	
	7 days	28 days	7 days	28 days
0%	25.189	44.47	1.685	2.562
0.50%	33.43	50.89	2.72	4.135
1%	34.8	52.92	3.129	4.756
1.50%	35.73	54.83	4.77	5.75
2%	37.29	56.69	4.985	6.217

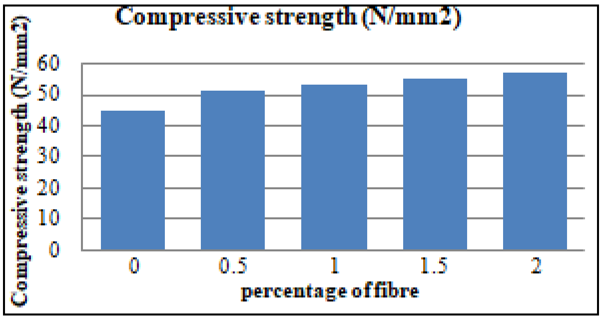

Figure 7: compressive strength of concrete

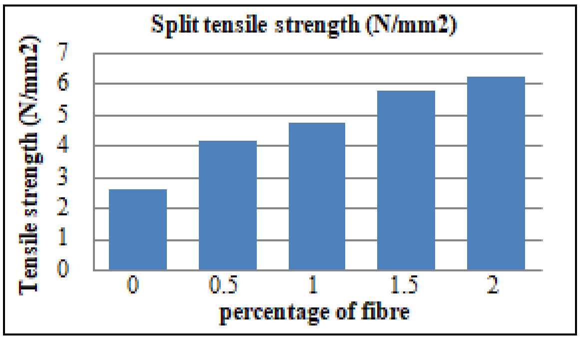

Figure 8: tensile strength of concrete

6.2. 0% CSFB

The specimens are removed from the curing pond just before testing on the specified due date and time and cleaned to wipe off the surface water. The cube specimen is placed on the lower platen such that the load is applied centrally on the faces other than top faces of casting. The top plate is brought in contact with the specimen by rotating the handle the oil pressure valve is closed and the machine is switched on a uniform rate of loading is maintained. The maximum load at failure at which the specimen breaks and pointer starts moving back is noted. The specimen is tested and the value is taken as mean strength.

Table 3: Values of 0% CSFB

Load KN	Deflection (mm)	Torque (KN.m)	Twist (rad/m)
1.5	0.42	0.45	0.0056
3	0.64	0.9	0.0085
4.5	0.98	1.35	0.0131
6	1.11	1.8	0.0148
7.5	1.45	2.25	0.0193
9	1.72	2.7	0.0229
10.5	1.89	3.15	0.0252

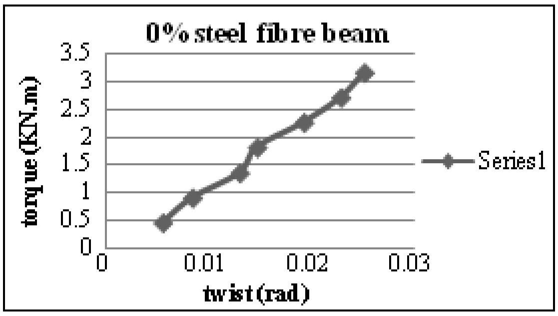

Figure 9: Torque v/s twist for 0% CSFB

6.3. 0.5% CSFB

Table 4: Values of 0.5% CSFB

Load KN	Deflection (mm)	Torque (KN.m)	Twist (rad/m)
2	0.43	0.6	0.00573
4	0.66	1.2	0.0088
6	0.87	1.8	0.0126
8	1.12	2.4	0.0149
10	1.43	3	0.0191
12	1.76	3.6	0.0235
14	2.221	4.2	0.0295

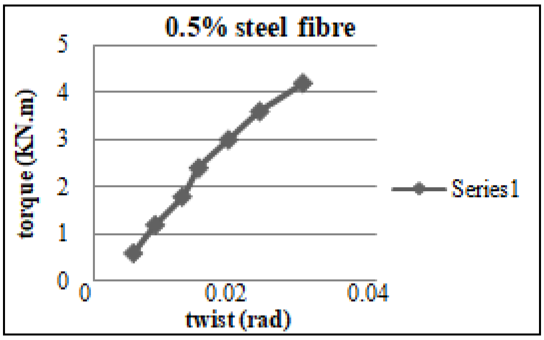

Figure 10: Torque v/s twist for 0.5% CSFB

6.4. 1% CSFB

Table 5: Values of 1% CSFB

Load KN	Deflection (mm)	Torque (KN.m)	Twist (rad/m)
2	0.41	0.6	0.0055
4	0.74	1.2	0.01
6	1.15	1.8	0.0153

8	1.65	2.4	0.022
10	1.82	3	0.0243
12	1.94	3.6	0.0259
14	2.29	4.2	0.0305
16	2.62	4.8	0.0349

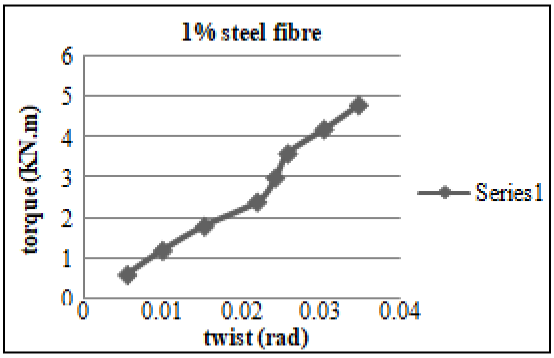

Figure 11: Torque v/s twist for 1% CSFB

6.5. 1.5% CSFB

Table 6: Values of 1.5% CSFB

Load KN	Deflection (mm)	Torque (KN.m)	Twist (rad/m)
2	0.68	0.6	0.0091
4	1.02	1.2	0.0136
6	1.45	1.8	0.0193
8	1.83	2.4	0.0244
10	2.65	3	0.0353
12	2.82	3.6	0.0376
14	3.12	4.2	0.0415
16	3.49	4.8	0.0465
18	3.73	5.4	0.0497
20	4.12	6	0.0549

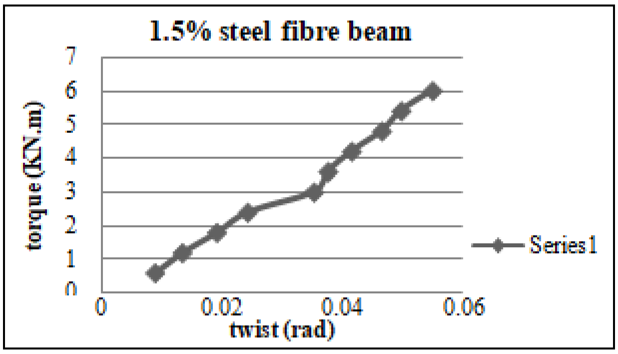

Figure 12: Torque v/s twist for 1.5% CSFB

6.6. 2% CSFB

Table 7: Values of 2% CSFB

Load KN	Deflection (mm)	Torque (KN.m)	Twist (rad/m)
2	0.33	0.6	0.0044
4	0.52	1.2	0.0082
6	0.75	1.8	0.0119
8	1.09	2.4	0.0145
10	1.48	3	0.0197
12	1.72	3.6	0.0229
14	2.18	4.2	0.029
16	2.43	4.8	0.0324
18	2.87	5.4	0.0383

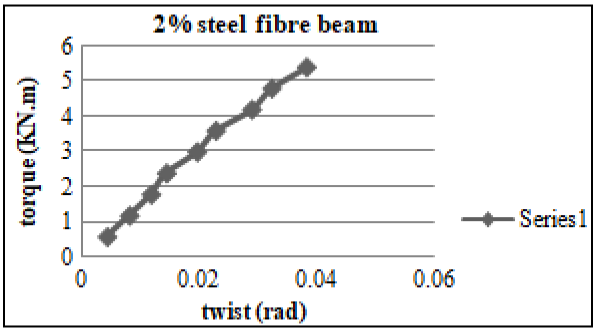

Figure 13: Torque v/s twist for 2% CSFB

7. Conclusion

1) The torsional response of reinforced beam is improved by using steel fiber in the concrete.
2) Steel fibers used in volume fraction of 1.5% and 2% exhibited the increased torque carrying capacity and angle of twist.
3) Steel fibers improve the cracking torque of the members to a noticeable extent, which improves the performance of the member in aggressive environments.
4) Addition of steel fibers is more beneficial in high strength concretes as they are brittle in nature.
5) The steel fiber reinforced beam also succeeded increase stiffness of the beam by decreasing angle of twist compared plain concrete beam.
6) The ultimate torsional strength is independent of the longitudinal reinforcement.
7) Failure pattern of all beams is torsion shear failure (cracks are about 450 to the axis of the beam).
8) Optimum percentage of micro silica, fly ash and GGBS as partial replacement of cement was found to be 5%,10% and 3% respectively. The addition of micro silica as second mineral admixture to form the ternary blended concrete improves the initial strength development.
9) GGBS improves the workability of concrete mix and also filled the voids to avoid the cracks.
10) The maximum increase in strength of concrete mix with the above said percentage of micro silica and fly ash is achieved at 1.5 % of crimped fiber content. The torsional strength of beams of ternary blended fiber reinforced concrete with 5% micro silica, 10 % fly ash , 3% GGBS and 1.5 % of crimped fiber was found to be increased by 35 % where as compressive strength of same concrete mix is increased by 12.6 % at the age of 28 days.
11) Steel fibers improve the cracking torque of the members to a noticeable extent, which improves the performance of the member. Addition of steel fiber consistently decreased crack spacing and sizes, increased deformation capacity and changed a brittle mode to a ductile one.

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