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Experimental Study on Torsion of Steel Fiber Reinforced Concrete Members with Ternary Blended Concrete

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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. When silica fume is added to fresh concrete it chemically reacts with the CH gel to produces additional CSH gel. The benefit of this reaction is twofold increased compressive strength and chemical resistance. The hydration (mixing with water) of Portland cement produces many compounds, including calcium silicate hydrates (CSH) and calcium hydroxide (CH). The CSH gel is known to be the source of strength in concrete. It is noted that the silica fume has better result when the cement replaced with it by 6% to 8% by weight. 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 programme standard cubes (150x150x150mm) standard beams (1300x100x100mm) long and (200x100x100) 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 6% Micro silica and 15% Fly ash and ternary blended fiber reinforced concrete with various percentages of fibers concrete specimens having W/C 0.40, 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 6% replacement of cement by micro silica and 15% replacement of fly ash along with 1.25% addition of steel fibers, because of the high Pozzolanic nature of the condense micro silica, fly ash and its void filling ability.

Keywords: Steel fiber reinforced concrete (SFRC), silica fume, Ternary blended, ultimate torsion strength, longitudinal reinforcement
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Introduction

Torsion occurs more frequently in most structures but rarely occurs alone. However, torsion forms one of the basic structural actions besides flexure, shear and axial compression/tension. Torsional failure of concrete members is initiated by the tensile stress developed due to a state of pure shear, which arises due to torsion. Inclusion of steel fibers principally may increase the tensile strength of the matrix to a moderate level but the toughness will be enhanced to a greater extent. This particular advantage of fiber reinforced concrete inspired the researchers to study its mechanical properties under different conditions of loading. But little information is available on the behavior of fiber reinforced concrete members under pure torsion. Earlier investigations indicated that the addition of fibers improves the torsional strength and ductility of member in this investigation an attempt has been made to quantify the effect of fibers in resisting torsional loads.

Effects of ternary cement system

The combination of micro silica and fly ash in a ternary cement system (i.e., Portland cement being the third component) should result in a number of synergistic effects, some of which are obvious or intuitive, as follows:

Micro silica compensates for low early strength of concrete with low CaO fly ash. Fly ash increases

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long-term strength development of micro silica concrete. Fly ash offsets increased water demand of micro silica. Micro silica reduces the normally high levels of high CaO fly ash required for sulphate resistance and ASR prevention. Very high resistance to chloride ion penetration can be obtained with ternary blends. Fly ash due to presence of spherical particles that easily rollovers one another reducing inter partial friction (call bearing effects) leads to improved workability and reduction in water demand.

Literature review

Jianguo Nie et al (2009) has conducted an experiment on eleven steel-concrete composite beams, four under pure torsion, and seven under combined bending and torsion were tested to study their torsional behaviors. Torsion-dominated and bending-dominated failure modes were observed, depending on the ratio between the applied bending and torsional moments. Testing results also showed that the reinforced concrete slab contributes mainly to the torsional resistance of composite beams and the contribution of steel joists to torsion is negligible. Based on the experimental observations, a three-dimensional behavioral truss model capable of analyzing composite beam sections subjected to the combined bending and torsion was presented. In this model, the section is subjected to one- and two-dimensional stresses separately. The former resists the longitudinal stresses due to bending and torsion while the latter resists the shear stresses due to torsion. The steel-concrete composite test beams exhibited two distinct failure behaviors, torsion-dominated and bending dominated failure modes, depending on the ratio between the applied bending and torsional moments.

Critical Appraisal of Literature Review:

The existing literature indicates that many researchers have studied the torsional strength of steel fiber reinforced concrete beams. Fibers are used for different percentages 0.5%, 1%, 1.5% and 2.0% with different section of beams and further conventional reinforcement is replaced with Steel fiber reinforcement. No literature is available on Ternary blended concrete. Also no comprehensive study was done on the effect of crimped fiber on the Torsional strength of ternary blended fiber reinforced concrete.

Experimental investigation

Preparation of Test Specimens

Mixing

Mixing of ingredients is done in a rotating drum. Thorough mixing by hand, using trowels is adopted. The cementitious materials are thoroughly blended with hand and then the aggregate is added and mixed followed by gradual addition of water and mixing in case of fiber reinforced concrete fiber was sprinkled evenly during mixing of the matrix. Wet mixing is done until a mixture of uniform colour and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found by slump test.

Casting of Specimens

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides before concrete is poured in the mould. The moulds are of size 150mm x 150mm for cubes and wooden moulds (1300x100x100mm) long and (200x100x100) arms at both ends for the beam specimens. The moulds are placed on a level platform. The well mixed concrete is filled in to the moulds by vibration with needle vibrator. Excess concrete was removed with trowel and top surface is finished level and smooth.

Curing of Specimens

The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the curing pond containing clean and fresh water.

Testing Arrangement

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 and bottom 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 test is repeated for the three specimens and the average value is taken as mean strength.

Tests Conducted

Compressive Strength of Concrete Specimens

The compressive strength of control concrete (ordinary concrete),Ternary concrete contain 6% Micro silica and 15% Fly ash and ternary blended fiber reinforced concrete with various percentages of fibers concrete specimens having W/C 0.40, were tested.

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Test setup

The experimental setup is a commonly used torsional test rig and it is shown in Fig.3.1.The total length of the specimens was 1.70 m. Beams were supported on two roller supports 1.20 m apart. These supports ensured that the beam was free to twist and to elongate longitudinally in both end directions during the test. The load was applied through a diagonally placed steel spreader beam on the ends of two properly configured over reinforced concrete arms at the end parts of the specimens, as shown in Fig3.1. The end parts of the specimens were also heavily reinforced with high volume of stirrups in order to bear without cracking the imposed torsional loading at the ends of the 200 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.

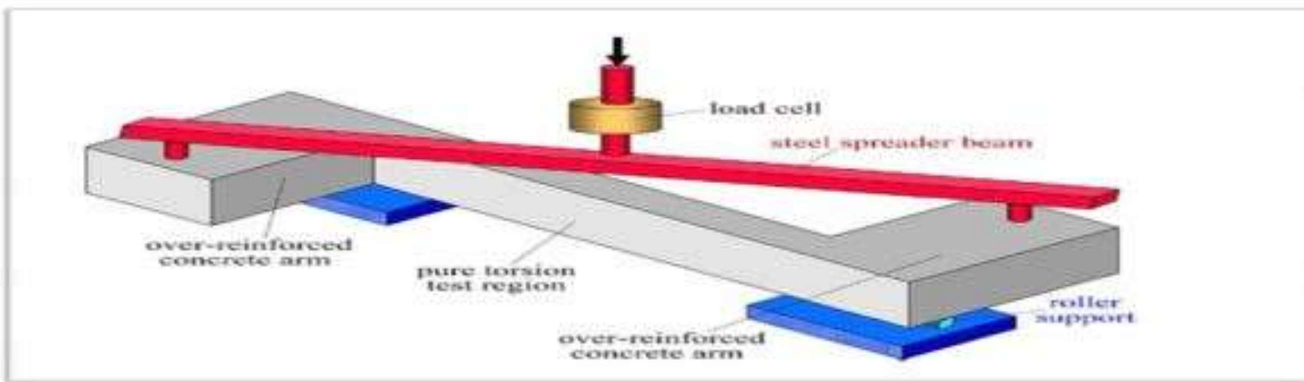

Figure3.1Testsetup

Discussion of test results

Workability

Addition of micro silica, fly ash and steel fiber into the concrete reduced the workability. The concrete mix was found to become strongly cohesive and stable compared to that of ordinary plain concrete. No bleeding was observed. This may be due to the void filling action of the superfine nature of micro silica and fly ash particles, which gives a high cohesion to the mix.

Mix with micro silica, fly ash and steel fiber tends to become harsh, sticky and stiff. However addition of super plasticizer to the concrete increased the workability at the same water cement ratio. By varying the dosage of super plasticizer workability is maintained i.e., maintaining the compaction factor 0.8 to 0.9. After application of vibration mixes were found to become mobile.

Compressive Strength

Preliminary Statement

Cube specimens were tested for compression and ultimate compressive strength was determined from failure load measured using compression testing machine. The average value of compressive strength of 3 specimens for each category at the age of 7days and 28 days are tabulated in the Table 4.1 and 4.2. The Table 4.3 shows the percentage increase in the compressive strength of ternary blended steel fiber reinforced concrete over ternary blended concrete.

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Table 4.1 Compressive Strength of Various Concrete Mixtures with Constant Micro Silica and Different Percentage of Fly Ash at Different Ages

S.No.	Mix ID	Compressive Strength (MPa)	
		7 days	28 days
1	S0F0	22.0	37.3
2	S6F10	22.2	38.2
3	S6F15	25.8	41.8
4	S6F20	24.4	39.3
5	S6F25	23.1	38.2

Table 4.2 Compressive Strength of Various Concrete Mixtures with Various Percentages

S.No.	Mix ID	Compressive Strength (MPa)	
		7 days	28 days
1	S0F0C0	22.0	32.3
2	S6F15C0	25.8	36.8
3	S6F15C0.5	27.5	37.6
4	S6F15C0.75	30.3	39.2
5	S6F15C1.0	31.8	41.4
6	S6F15C1.25	33.8	42.1
7	S6F15C1.50	31.4	39.7

Table 4.3 Percentage Increase in Compressive Strength of Various Concrete Mixtures over Ternary Blended Concrete at Different Ages

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S.NO.	MIX ID	Compressive strength (Mpa)	
		7 days	28 days
1	S6F15C0.50	6.0	2.1
2	S6F15C0.75	14.8	6.1
3	S6F15C1.0	18.8	11.1
4	S6F15C1.25	23.6	12.6
5	S6F15C1.50	17.8	7.3

Table 4.4 Torsional moment of Various Concrete Mixtures at age of 28 Days and Percentage Increase Over Ternary Blended Concrete

S.No.	Mix ID	Torsional Moment (KN-m)	Percentage increase over ternary blended mix
1	S0F0C0	0.82	-
4	S6F15C0	1.31	-
3	S6F15C0.5	1.6	13
4	S6F15C0.75	1.8	23
5	S6F15C1.0	2.15	35
6	S6F15C1.25	2.32	40
7	S6F15C1.50	2.09	34

Inference on test results

There is a considerable improvement in the compressive strength of concrete with 6% replacement of cement by micro silica and 15% replacement of fly ash along with 1.25% addition of steel fibers, because of the high Pozzolanic nature of the condense micro silica, fly ash and its void filling ability. It is observed that the compressive strength increased with increasing age of curing. The maximum 28 days cube compressive strength for a mix with 6%micro silica and 15% fly ash along with 1.25% of steel fiber is 42.1 MPa, i.e., 12.6 % increase over control mix.There is substantial improvement in the Torsional behavior of concrete with 6% of micro silica and 15% fly ash along with 1.25% addition of steel fibers. As expected plain concrete specimens showed no ductility resulting in brittle failure when the first crack forms. After the initial cracking in the fiber reinforced concrete the specimen exhibited a sudden drop in load carrying capacity but had some post peak resistance due to the presence of fiber that were bridging the cracks. This indicates that the addition of fiber to the concrete improves its ductility and energy absorption capacity. The maximum 28 days torsional moment for a mix with 6%silica and 15% fly ash along with 1.25% addition of steel fiber is 2.32 KN-m i.e., 40 % increase over control mix.

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Figure 4.1: Compressive Strength Vs Percentages Mixes with Different Percentage of Steel Fibers Silica

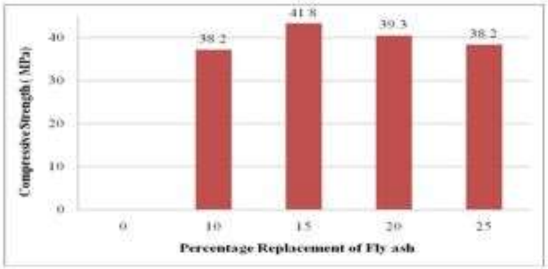


Figure 4.2: Compressive Strength Vs Age of Replacement of Fly ash and constant Micro

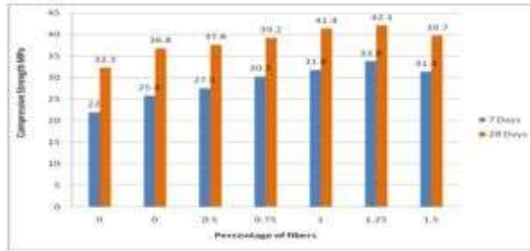


Figure 4.3: Percentage Increase in Compressive Strength overTernary Blended Mix Vs Percentage fiber

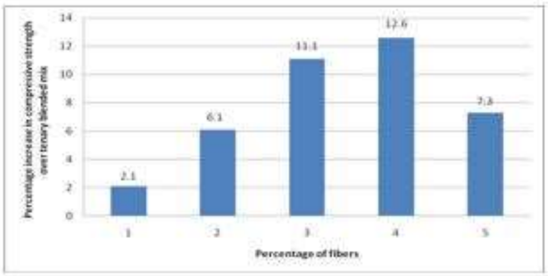
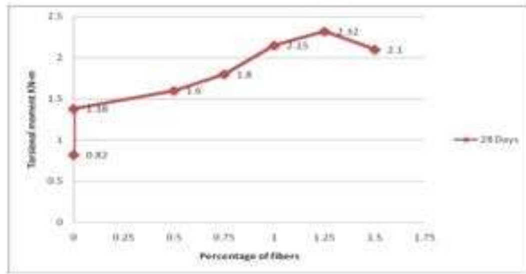


Figure 4.4 torsional moment Vs % of



Conclusions

Optimum percentage of micro silica and fly ash as partial replacement of cement was found to be 6% and 15% respectively. The addition of micro silica as second mineral admixture to form the ternary blended concrete improves the initial strength development. The maximum increase in strength of concrete mix with the above said percentage of micro silica and fly ash is achieved at 1.25 % of crimped fiber content. The torsional strength of beams of ternary blended fiber reinforced concrete with 6% micro silica, 15 % fly ash and 1.25 % of crimped fiber was found to be increased by 40 % where as compressive strength of same concrete mix is increased by 12.6 % at the age of 28 days. 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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