AN EXPERIMENTAL STUDY ON THE BOND STRENGTH OF TRIPLE BLENDED STEEL FIBRE SELF COMPACTING CONCRETE

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Abstract

The article deals with the experimental investigation on the bond strength for the triple blended steel fiber self-compacting concrete (TBSFSCC),and its variation with the percentage of the steel fiber content. Self-Compacting Concrete (SCC) is designed with the mineral admixtures such as micro silica, and flyash as supplementary cementitious materials(SCM's). These SCMS are used as the additives for SCC at 10 and 20 percentages respectively for the partial replacement of cement, to fulfil the norms of the SCC as per ACI specifications. The embedment length of steel bar of diameter 12mm, was fixed as 100mm length in all the standard specimens. The Fe-415 grade of the steel rebar is used in this experimentation. The bond strength of this triple blended Self-Compacting Concrete (TBSCC) is evaluated by pull-out test in the universal testing machine. Later, the ordinary steel fibres are added to the volume of the concrete at various percentages like 0.2, 0.4, 0.6,and 0.8. For each rebar the test results for the bond strength along with slip, and mode of the failure were recorded. The comparison of these results clearly indicates that the contribution of the steel fiber percentage on the bond strength of the TBSCC and the conclusions are drawn.

KEY WORDS: Self-Compacting Concrete, Triple Blended, Micro Silica, flyash, Steel fibers, Bond Strength, Pull-Out test, Slip of rebar.

I.INTRODUCTION

Wherever compaction of the concrete is not practically feasible, the concept of the Self-Compacting Concrete will be used. SCC was developed in Japan by Okamura and Ouchi [1], later Ozawa, and Nan-Su [2,3] have given very significant encouraging results in this type of concrete. Rebar slip is one of the main reasons for the failure of the concrete structural element. This may occur due to corrosion of the embedded steel rebar, or loss of the bond strength of the concrete with this rebar. The behaviour of the concrete structural elements like beam, columns is dependent upon the bond between the concrete and rebar used in it as reinforcement. The Bond strength is the resistance against the tangential shear developed between the concrete and rebar in it. The magnitude of this bond strength is dependent upon the denseness of the concrete (grade of the concrete), type of the rebar used in it as reinforcement. When fibers are used in this grade of the concrete; it will become more stiff and dense. Because of this in the concrete composite the bond strength is enhanced and this depends on the percentage of fiber, its geometrical and physical properties. Several researches have already used various types of fibers in the normal vibrated concrete (NVC), for evaluation of the bond behaviour, and mode of failure. The novelty of the present work is to study the behaviour of this bond strength for the triple blended Self-Compacting Concrete, in which the steel fiber of different percentages and optimum aspect ratio was adopted. The bond between the rebar of 12mm HYSD (high yield strength deformed), and the concrete in the structural elements influences in many aspects, such as the strength of the lap splices in beams, columns and other components of the concrete structures. The most commonly used test for evaluating the bond strength and the mode of failure is Pull-Test, which mainly depends upon the diameter, embedded length and grade of concrete and rebar. The failure mode of the specimen is usually either pull-out or splitting.

II.Literature Review

Ehsani et al (8) (1995) did the experimentation on the bond strength of the concrete composite with hooked glass fiber reinforced plastic (HGFRP) in the concrete, and the results of these experimentation is compared with the same concrete without the glass fibers. The results are very encouraging.Benmokrane et al (5)(1996) studied the effect of glass fiber reinforced polymer (GFRP) on the bond strength and load distribution of these composites in the concrete .Ioan Pop et al(12) (2013) were studied the bond strength in SCC and compared these results with the vibrated cement concrete (VCC) and concluded that SCC has better bond strength, and the authors also investigated the influence of the diameter of the bar on the embedded length.Nipun Verma,Anil Kumar Misra(13)(2015) did the laboratory experimentation on the bond strength of NCC and SCC, Their investigation concluded that SCC generated more bond to the reinforcing bars compared to the NCC, The relation between the bond strength and compressive strength in NCC is consistent compared to the SCC.A.Mohammed et al (7)(2016) adopted the approaches of near-surface mounted fibre reinforced polymer (NSMRF) for strengthening reinforced concrete elements which has become a very good technique. The authors investigated “the performance of NSM carbon FRP strengthening technique using single-lap shear tests with innovative high-strength self-compacting cementitious adhesive (IHSSC-CA) under high temperatures and this proved successful. Piotr Dybet(9) (2016) studied an importance on the bond issue in the concrete with the rebar, which is the main cause of the failure. A model was also given for the relation between bond and slip, which mainly depends upon the type of the rebar used in the concrete. The bond and slip correlation were presented separately for High performance self-compacting concrete and High performance concrete.Ahmed M. Diab et al(4)(2017) did the experimentation to record the performance of the bond strength between normal vibrated concrete and self-compacting concrete, The authors also highlighted the contribution of polypropylene fibers in enhancing slant the shear bond strength in SCC. Jinrui Zhang et al (6) (2017), investigated the surface adhesive properties of self-compacting concrete with different scattering gravel diameters (5–10 mm, 10–20 mm,and 5–20 mm). Splitting test and slant shear test were conducted and the failure characteristics of the bond interface” are observed through their examination of the specimens.Yiyan Lu et al(10) (2018) did the experimentation on pull-test on steel fiber self-compacting concrete filling in the steel tube column and arrived at the conclusion that the presence of the steel fibers significantly improved the bond strength. From the investigation, it was observed that initially the bond strength is decreased and later on it is increased and the authors also gave the predicted equations for the bond strength. Nelly Majain (11)(2020) did the experimental investigation on the pull test of 12mm,16mm and 20mm ribbed bars which are embedded in 200mm cube with, the steel fibers of hooked ends with 35mm length. Aspect ratio of 63 was adopted. The authors concluded that with the presence of steel fiber the failure mode is changed to pullout from the splitting.Adnan Al-Sibahy et al (14)(2020) studied degradation of the bond strength with the corrosion of steel bars embedded in the SCC and changes in the behavior of the bond strength.Giacomo Torelli et al (15)(2020) investigated the cement light weight concrete which can easily be placed in the forms in layers. Better interlayer bond can be arrived through fresh casting. The authors also concluded that wet casting of elements is an important achievement towards the light weight layered concrete with low energy.

III. Experiment and Result

MATERIAL USED:

Self-Compacting Concrete (SCC): As per the simple mix design concept as given by Nan Su[3], the ratio of fine aggregate to total aggregate of the concrete is arranged, It fulfils the norms of the ACI [18] for self-consolidating concrete. After various trials in the experimentation the ratio is fixed at 0.64. This ratio is varied from mix to mix, because of rheological parameters which depend upon the physical properties of the aggregates used like mineral, chemical admixtures, and size of the coarse aggregate adopted. The mix design proportions are given in table 1.

Table 1. M40 Grade of SCC Mix Proportions

CEMENT	Fine Aggregate	Coarse Aggregate	Water to cementitious ratio
1	2.32	1.38	0.45

Mineral admixtures: The basic supplementary cementatious materials (SCMs) used in this investigation is flyash (F-type) which is obtained from Vijayawada thermal power plant. Another admixture, micro silica is obtained from suppliers. The physical and chemical composition of these mineral admixtures are given in Table 3.The dosage of flyash and micro silica adopted are 20 and 10 percentage of replacement to 53 grade of Ordinary Portland Cement (OPC) conforming to IS 10269-2019[19].
Chemical admixtures: Glenium B 233 is used as a superplasticizer (SP) which is PCE based chemical, and Viscosity Modifying Agent (VMA) Glenium-2, are obtained from M/S.BASF India limited. The optimum dosage of these chemicals depends upon the percentage of steel fiber used in the concrete mix. In this experimentation,1% of SP and 0.15% of VMA was adopted.
Steel fibers: ordinary steel fiber of diameter 1mm is used, and aspect ratio is limited to 40, because beyond this aspect ratio flowability properties of the triple blended self-compacting concrete are affected. The rheological parameters were studied as per the guide lines of ACI, and the Typical results are shown in table 2 for 0.8% steel fiber with an aspect ratio of 40 in the SCC Mix.

Table 2.The rheological parameters of Typical Fiber Reinforced SCC.

Name of the test	Units	Experimental value*	Acceptance Value
Slump flow	Mm	680	650-800
V-Funnel	seconds	11	6-12
L-Box	ratio	0.82	0.80-1.00

15 numbers of standard cubes of size 150mm were cast for 5 different mixes which are shown in table 4, for evaluating the basic compressive strength of the SCC and 5 cubes were separately cast with 12mm diameter of ribbed Fe-415 inserted in the fresh concrete, such that embedded length is 90mm which is constant for the all mixes..The compressive strength and bond strength of these mixes are shown in table 5, along with the mode of failure of the specimen. The variation of the compressive strength with the percentage of steel fibers having aspect ratio 40, and the bond strength variations are also shown in fig 1 and 2. The typical cubes with embedded length are shown in fig 3.

Table 4. Mixes used for the experimentation and their abbreviations

Mix	Abbreviation of the Mix
M0 SF	Mix with 0.0 percentage of the steel fiber
M2 SF	Mix with 0.2 percentage of the steel fiber
M4 SF	Mix with 0.4 percentage of the steel fiber
M6 SF	Mix with 0.6 percentage of the steel fiber
M8 SF	Mix with 0.8 percentage of the steel fiber

Table 5.The 28 day compressive and bond strength values for the mixes

Mix	The compressive strength in MPa	The bond strength in kN/mm	Mode of failure
M0 SF	44.5	1.32	splitting
M2 SF	49.82	1.59	Pull-out
M4 SF	54.15	1.85	Pull-out
M6 SF	60.74	2.38	Pull-out
M8 SF	68.50	2.65	Pull-out

The embedded length is 7.5 times diameter of the steel bar. All the steel bars are 700mm length, such that it is easily tested in the Universal testing Machine by applying pull-out test as per the standard procedure. The experimental setup for finding the bond strength of the critical fiber content in triple blended SCC cube is as shown in fig 4.The best fit curve for the compressive strength is $f_{cc,}$

$$\mathbf{f_{cc}.=5.31\ (x) + 40}$$

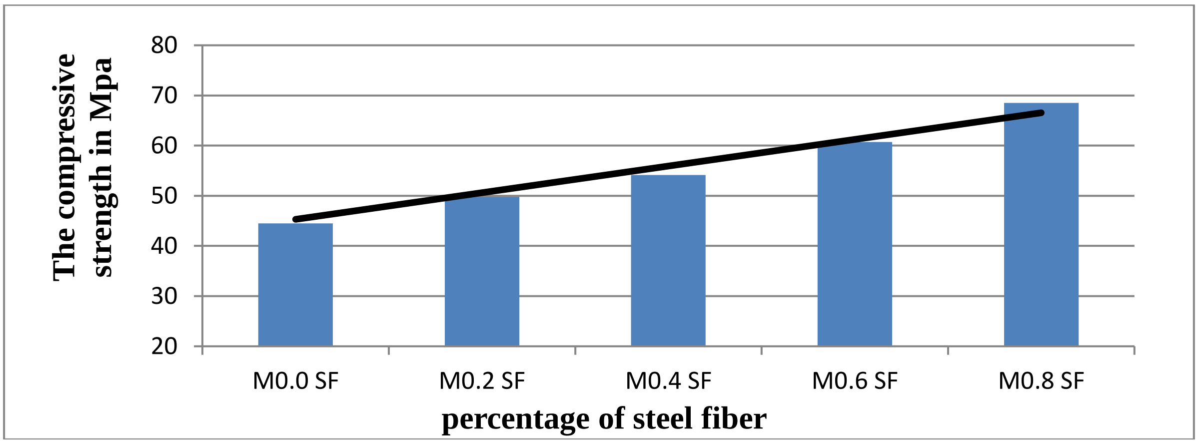

Fig 1. The variation of the Compressive strength with the percentage of steel fibers (aspect ratio 40)

The best fit curve for the Bond strength(τ),from the experimental data is

$$\boldsymbol{\tau = 0.367(x)+1.2}$$

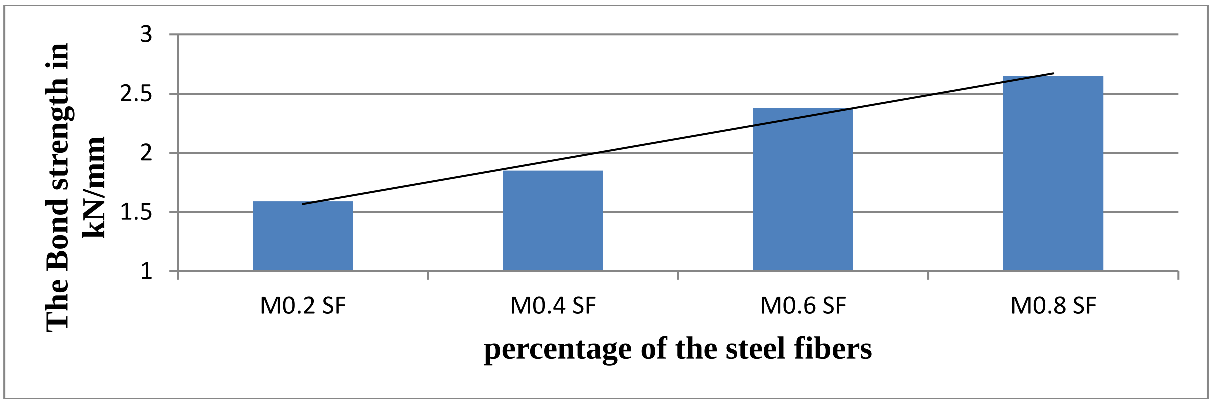

Fig 2.The variation of the Bond strength with the percentage of the steel fibers (aspect ratio 40)

The slip of the 12mm steel rod is calculated by δ is given by

$$\delta = \delta_l - \delta_p$$

$\delta_1$is deflection reading in the dial gauge placed between the platens of the universal testing machine

δ_p is deformation of the 700mm steel rod, δ_p =PL/ AE

P is the applied load at the corresponding dial gauge reading,

L is gauge length of the steel rod (700mm)

A cross sectional area of the steel road (diameter is 12mm)

E_s young's modulus of the steel; E=2.1 x 10^6 MPa

Fig 3. typical cubes with the embedded length of 12mm steel bar

THE BOND STRENGTH:

The average bond strength (τ) between the steel rebar to the concrete is given by the equation,

$$\boldsymbol{\tau} = \frac{\boldsymbol{P}}{\boldsymbol{\pi\, d\, l}}$$

P -The pull strength on the steel rod,

d- Diameter of the steel rod (12mm),

l-Length of the embedment (90mm).

Fig 4. Experimental setup for finding the bond strength of the critical fiber content in triple blended SCC cube.

The contact between the steel bar 12mm diameter and concrete along the deboned length was broken using a soft plastic hollow tube to minimize the influence of bearing plate.Mode of failure of the samples are classified into splitting failure of the concrete, and pull-out failure of the steel rod. In this experimentation for the mix M0 SF, concrete has failed due to splitting, where as in all other mixes failure has occurred through pull-out. The relationship developed between the bond strength-slip is shown in fig 5 for various steel percentages.

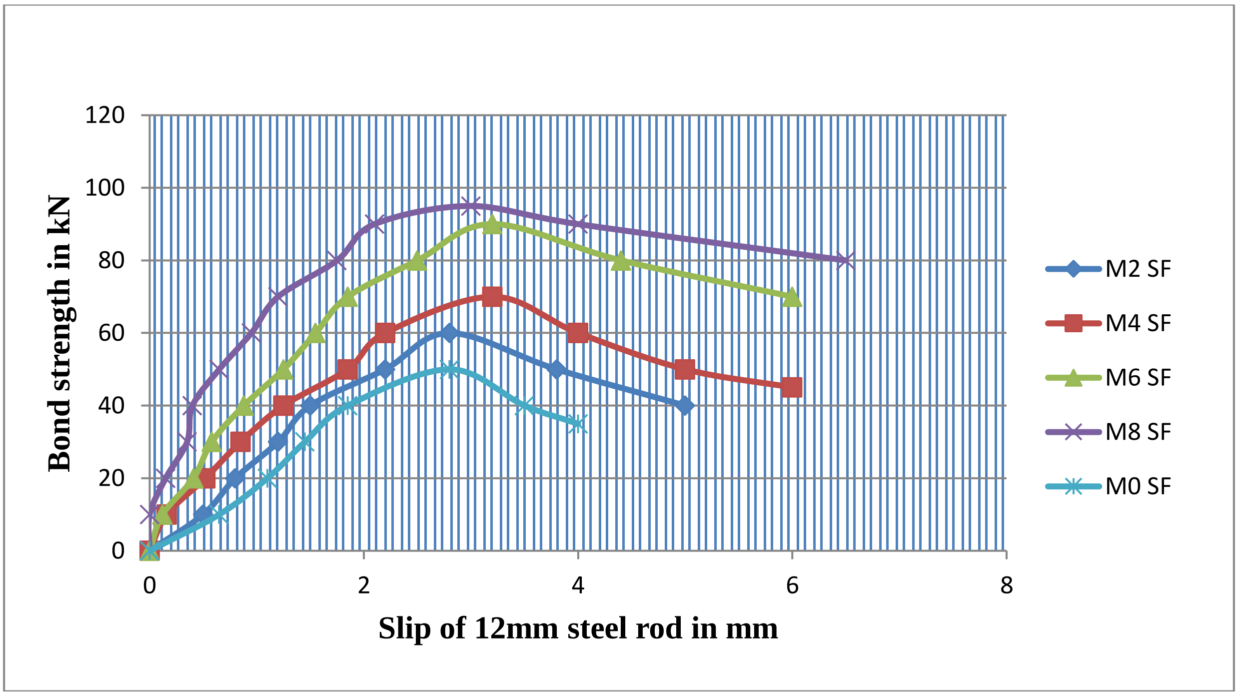

Fig 5. Relation between bond strength-slip for different percentage of steel fibers in TBSCC.

IV. CONCLUTION

From the above experimental investigation related to bond strength-slip of the steel fiber triple blended self-compacting concrete (SFTBSCC), the following conclusions are drawn,

1) As percentage of steel fibers is increased the compressive and bond strengths of the SCC specimens are increased due to confinement of the fibers around the concrete, this is also influenced by the mineral admixtures. It is noted that the bond strength is also affected due to the presence of mineral admixtures.
2) As per the percentage of steel fibre is increased, the compressive strength is increased from 44.5Mpa to 68.50Mpa where as the bond strength (kN/mm^2) is enhanced from 1.32 to 2.65. It is clear that the steel fiber's contribution is more for the increase of the bond strength rather than the compressive strength.
3) The failure mode of the SCC without steel fibre is observed as splitting. As the percentage of the fiber content is increased, the mode of failure is changed to pull-out failure.
4) The mode of failure of the specimen is mainly depends upon the concrete compressive strength and percentage of the steel fiber and its confining effect.
5) The magnitude of the pull-out strength is enhanced in SCC from no fiber to 0.8 percentage of the steel fiber from 50kN to 90kN.The percentage of pull-out is increased by 80%.
6) The slip between the bar and the surrounding concrete depends upon the steel fibre content in the TBSCC.

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