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Bond Characteristics of Steel Fiber Reinforced Concrete

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***Abstract*:** *Repair and rehabilitation of concrete structures is an important topic for the researchers as several concrete structures needs to be retrofitted or repaired and strengthened. Distress in concrete structures is noticed worldwide due to updating the code provisions or due to natural calamities. Bond characteristics of new concrete with old concrete assume importance in the repair strategies of concrete members to be repaired. Steel fiber reinforced concrete is a composite, whose usage improves the ductility of the concrete. When the steel fiber reinforced concrete is used as a repairing material on an old concrete, bond between the old concrete and repairing material assumes importance. In this investigation an attempt has been made to study the bond characteristics' of steel fiber reinforced with the substrate as conventional concrete. Slant shear tests were conducted to examine the influence of bond. Different Grade of conventional concrete (Substrate) are considered in this study they are M20 and M3. Different repairing medium (Steel fiber reinforced Concrete) are considered varying the fiber content in the concrete. Slant test indicates two types of failure modes. One of the failure mode is the failure of the interface while the other is the failure of the either repairing medium or the substrate. Test results indicated that increase in fiber content in the repairing medium increased the interfacial bond. For fiber content beyond 0.8%, a decrease in the interfacial bond strength is noticed.*

Keywords: *Interfacial bond, Steel Fiber reinforced Concrete, Slant Shear Test.*

1. Introduction

Now-a-days a large number of existing concrete structures worldwide are in urgent need of effective and durable repair. It has been estimated that almost half of all concrete repairs fail due to the lack of reliable and perfect bond. Good bonding between repair materials and existing concrete repair substrate is of vital importance in the concrete repairs. The strength and integrity of the bond depends not only upon the substrate concrete properties and the interface factors (such as surface roughness and soundness, bond adhesive, humidity conditions, …), but also physical and chemical characteristics of repair materials. In order to make these structures functional during the remaining years of service life, suitable repairs are made possible with the help of various repair techniques which utilizes the new generation concrete repair materials. Commercially available materials for concrete repair can be conveniently categorized as follows

- Resinous materials: epoxy mortar, polyester mortar, Acrylic mortar mixtures, polyurethane grouts.
- Polymer-modified cementitious materials: SBR (styrene butadiene rubber) modified, Magnesium phosphate modified ethyl vinyl acetate cementitious materials.
- Cementitious materials: OPC-Sand mortar, High Alumina Cement (HAC) mortar, HAC and OPC mixed mortar, expansion producing grout, flowing grouts.

Bond Strength of New (Over lay) and Old Concrete (Substrate)

The bond strength is the adhesion between overlay and substrate which can be the weakest link of a structural system. Good bond strength is an important factor to have a monolithic system. Bond can be expressed as the shear resistance.

Various factors that can influence the bond strength:

- Roughness of the old substrate.
- Bonding agent at the interface between old and new substrates.
- Mix proportions.
- Water to Cement ratio of the new substrate.
- Type of the modified overly concrete such as silica fume added, latex epoxy, fibre reinforced concrete.

In the present investigation interfacial bond strength of substrate and overlay (repairing medium) is taken up. the substrate is the conventional concrete and repairing medium is steel fiber reinforced concrete. Steel fiber reinforced concrete is one of the constructional materials which impart ductility to the structure. Randomly oriented discrete steel fibers are incorporated in concrete in its green state.

2. Review of Literature

Hugo COSTA, Pedro SANTOS, Eduardo JULIO (2011), conducted slant shear test and spilt tension test on the two different types of concrete viz., light weight aggregate concrete and normal weight concrete. It is concluded that roughness at the interface of two concretes influence the bond strength. 2D LRA method developed by them was used to find the roughness parameter.

H-C.Shin and Z.Wan (2010) conducted shear bond strength test on the interfacial region of old and new concrete elements for different surface conditions viz., wet interface and dry interface. Based on the experimental investigation it is concluded that saturated surface dry condition of interface exhibited better shear strength.

R. Abbasnia, M. Khanzadi & J. Ahmadi (2009) conducted slant shear test to identify the effect of mix proportion and free shrinkage effect on the interface of old concrete and new concrete. Based on the experimental results it is reported that increase in water to cement ratio and decrease in size of fine aggregate reduces the bond strength.

3. Slant Shear Test

This test was first presented in the form of “Arizona Slant Shear Test” (Kreigh, 1976) and later after some developments was standardized in British Standard, BS 6319: Part 4 for testing the repair materials. ASTM C882-99 also provides the procedure of bond measurement with the same test method. Wall and Shrive (1998) modified the test by using prism with the length three times the cross section dimension instead of the cylinder. As in many cases the real stresses in structures have the shear component, this test is representing the situation more close to the real world situation. In compressive test, concrete failure happens due to the shear cracks in the incline plane. The angle of failure plane with horizontal direction is theoretically between 50^{o} and 70^{o}, so 60^{o} could be a proper assumption. Therefore in this test method the interface is placed inclined with the same angle and a compressive force is applied to the system. A typical slant shear test arrangement is presented in Figure.1.

4. Experimental Program

The experimental program was designed to study the bond strength between old concrete and new concrete interface. The following cases are considered for experimentation. The substrate is taken as M20 grade concrete and M30 grade concrete. The repairing medium is SFRC with M20and M30 grades concrete with different fiber contents viz., 0.0%, 0.4%, 0.8% and 1.2%. For every case three identical specimens are tested. Thus a total of 24 specimens are cast and tested for slant shear test. The details of the test specimens are presented in Table.1.Each specimen is designated in such a manner that the first three letters indicate the grade of substrate and repairing medium and the last two letters indicate percentage fiber content present in the repairing medium e.g., F0-Plain Concrete, F1-0.4% fiber in the repairing medium, F2-0.8% fiber content in the repairing medium and F3-1.2%fiber content in the repairing medium. Table 1 shows the different substrates and repairing medium considered in this investigation and the corresponding designation


Fig. 1: Typical slant shear test arrangement

TABLE I: Different Test Specimens Tested in the Investigation and Their Designation

Designation	M20-F0	M20-F1	M20-F2	M20-F3	M30-F0	M30-F1	M30-F2	M30-F3
Substrate	M20	M20	M20	M20	M30	M30	M30	M30
Repairing Medium	M20-0.0% Fiber	M20-0.4% Fiber	M20-0.8% Fiber	M20-1.2% Fiber	M30-0% Fiber	M30-0.4% Fiber	M30-0.8% Fiber	M30-1.2% Fiber

4.1 Casting

The substrate concrete as per mix design is prepared in a rotary mixing unit and poured in a casting mould with a cast iron slant separator with required inclination of 30^0 with the longitudinal axis of the mould. The filled concrete in the mould in sufficiently compacted. After 24 hours of casting the concrete prism specimen is placed in the curing tank. The specimens cast in the initial stage are considered as substrate. After 28 days of curing, the substrate specimens are given indentation on the slant surface so as provide a rough surface to the interface. A typical roughened surface of the substrate specimen is presented in figure 2. The substrate specimen then placed in the prism mould and fresh repairing material (SFRC) is placed in the remaining portion of the prism mould. After 24 hours of casting the final specimen is removed from the mould and put for curing for 28days.

4.2 Test setup

The prism specimens of the concrete were tested on compression t**esting machi**ne (CTM) **of capacity** 3000kN. The bearing surface of the machine was wiped off clean and any loose sand or any other materials removed from the surface of the specimen the specimen was placed in the machine in such a manner that the load was applied to opposite vertical faces of the prism. The axis of the specimen was carefully aligned at the centre of the loading frame and the load applied was increased continuously at a constant rate until the failure of the specimen. Two dial gauges are attached on side faces of the prism to measure the slip. Atypical test setup is presented in Figure 1.

Fig. 2 Roughened surface of the interface

5. Test Results and Discussion

Slant test results for the two grades of concrete considered in this investigation for different percentage variations of fiber content in the repairing material is presented in Table.2. Toughness is estimated as the area load – slip diagram. From the test data it is clear that, increase in the fiber content in the repairing medium showed improved bond strength. The reason for this can be attributed to the fact that the fibers present in the repairing medium would have developed better interfacial friction. The roughness created on the surface of the substrate also added for the bond strength. In the case of M20 substrate, when the fiber content in the repairing medium is 0.8%, the increase in the bond strength is found to be 55% compared to plain repairing medium without fiber content. Beyond this percentage of fiber content in the repairing medium, the increase in bond strength is noticed to the tune of 65%. When the substrate is of M30 grade concrete and the repairing medium is having a fiber content of 0.8%, the increase in the bond strength is found to be around 21% when compared to the convention repairing medium without fiber content. The lesser increase in the bond strength with higher grade of concrete is due to the fact that lesser aggregate content in the matrix makes the concrete more smoother. Fiber content in the repairing medium increased the toughness, however higher dosages of fiber content in the repairing medium did not increase the toughness much beyond 0.8% fiber content in the repairing medium. From this experimental investigation it is clear that the fiber inclusion in the repairing medium enhances the interfacial bond strength. The variation bond strength with varying fiber content is presented in Figure 3.

TABLE II: Different Test Specimens Tested in the Investigation and Their Designation

Designation	M20-F0	M20-F1	M20-F2	M20-F3	M30-F0	M30-F1	M30-F2	M30-F3
Substrate	M20	M20	M20	M20	M30	M30	M30	M30
Repairing Medium	M20-0.0% Fiber	M20-0.4% Fiber	M20-0.8% Fiber	M20-1.2% Fiber	M30-0% Fiber	M30-0.4% Fiber	M30-0.8% Fiber	M30-1.2% Fiber
Bond Strength (N/mm^2)	7.221	8.593	11.192	11.915	11.626	13.648	14.081	14.659
Toughness in (kN.mm)	123.89	155.005	350.92	373.69	376.59	538.93	594.055	597.655

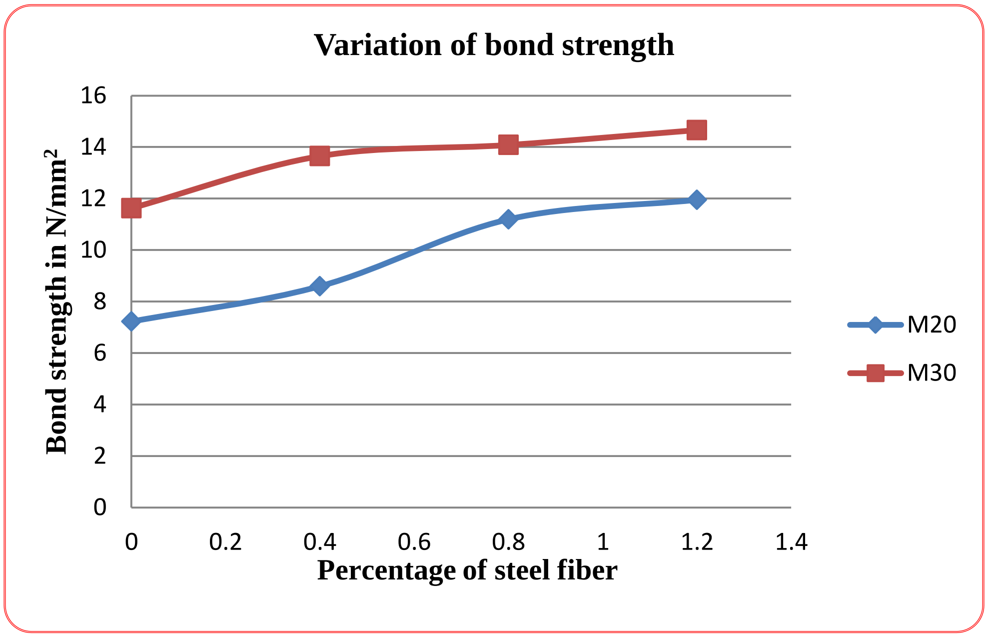

Fig. 3 Variation of bond strength for different percentage steel fiber content in the repairing medium

6. Conclusions

Based on the experimental investigation the following conclusions are drawn.

1. Increase in grade of concrete increases the bond strength.
2. Increase in fiber content in the repairing medium increases the bond strength.
3. The influence of fiber content is more in M20 grade concrete than in M30 grade of concrete.
4. Toughness increases with fiber content in the repairing medium, however the increase reduces beyond 0.8% fiber content.
5. Slant shear test represents the interfacial bond characteristics between old concrete and new concrete.

7. Acknowledgement

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8. Reference

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