Mechanical and Bond Properties of Steel Fibre Reinforced SBR Modified Self Compacting Concrete

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Abstract - *The growth of Self Compacting Concrete(SCC) is revolutionary landmark in the history of construction industry. It has many advantages over normal concrete in terms of enhancement in productivity, reduction in labor, excellent finished product with excellent mechanical response and durability. Styrene-Butadiene Rubber (SBR) is widely used to improve adhesion and bond properties of cementitious-based repair materials. The main objective of this project is to evaluate the combined effect of steel fibres and polymers on stability of highly flowable self-consolidating concrete. Also, the bond properties to the steel bars are investigated. The results showed that the compressive strength reduces at later ages and there is a significant increase in the flexural, tensile strength and bond strength of the concrete.*

Key Words *Self- compacting concrete, Styrene butadie rubber latex, Ground granulated blast furnace slag, Fiber reinforced concrete,*

1. INTRODUCTION

The growth of Self Compacting Concrete is revolutionary landmark in the history of construction industry. It has many advantages over normal concrete in terms of enhancement in productivity, reduction in labor and overall cost, excellent finished product with excellent mechanical response and durability. The SCC in fresh form overcomes numerous difficulties related to the skill of workers, density of reinforcement, type and configuration of a structural section, pump-ability, segregation resistance and mostly compaction.

Fiber reinforced concrete pavements are more efficient than ordinary cement concrete pavement. "FRC is defined as composite material consisting of concrete reinforced discrete randomly but uniformly dispersed short length fibers. The fibers may be of steel, polymer or natural materials. FRC is considered to be a material of improved properties and not as reinforced cement concrete whereas reinforcement is provided for local strengthening of concrete in tension region. The primary role of fibers in hardened concrete is to modify the cracking mechanism. By modifying the cracking mechanism, the macro cracking becomes micro cracking. The cracks are smaller in width thus reducing the permeability of concrete and the ultimate cracking strain of the concrete is enhanced. The fibers are capable of carrying a load across the crack.

The newly developed "Polymer Concrete" possessing many superior properties over conventional cement renders itself as one of the most versatile construction materials. the addition of such polymers could remarkably alter cement hydration reactions including the aptitude to flow and development of strengths. In the hardened state, to a certain limit most studies converged that bond strength of polymer-modified materials increases with the increase in polymer-to-binder ratio (p/b).

Aliabdo and Elmoaty (2012) present an experimental investigation on the properties of polymer modified self-compacting concrete. Polymer modified SCC may be used successfully in repair of concrete elements or construct new concrete elements especially when concrete subjected to sever conditions. The effect of polymer content, polymer type, filler type and base of chemical admixtures were studied. Cube compressive strength, tensile strength, dynamic modulus of elasticity, bond strength between concrete and steel reinforcement, bond strength between self-compacting concrete and old concrete, thermo-gravimetric and X-ray diffraction analysis were used to evaluate the effect of studied parameters. From this work, styrene butadiene rubber and polyvinyl acetate can be used to produce polymer modified self-compacting concrete. Also, polymer self-compacting concrete has good mechanical properties especially tensile strength and bond strength. Finally, the use of polymer decreases the degree of hydration of cement [1].

Saldanha et al. (2013) Presents several tests available to evaluate the adhesion between concrete layers cast at different times. Among these, the Slant Shear Test (SST) has a wide spread use, mainly for being sensitive to the roughness of the interface surface, However, the major drawback of this test is the fact of being often obtained cohesive (monolithic) failures, therefore providing a lower bound of the interface strength, which is related with the concrete compressive strength. To definitely solve this issue, i.e., to enforce adhesive (interface debonding) failures in all situations, the 'Modified Slant Shear Test' (M-SST) was here in designed and developed [2].

Camille et al.(2017) Evaluate the effect of polymers on stability of highly flowable self-consolidating concrete during placement and until onset of hardening. Also, the bond properties to existing concrete substrate and steel bars where investigated and found that remarkable improvements in the concrete-bar bond stresses were noticed with PVA and SBR additions. This was attributed to improved concrete elasticity and tensile splitting strength that increased contribution of material bearing strength around the steel bars [3].

Singh and Kumar (2016) Polymer latex improves the workability significantly. The addition of 15% latex can produce a high strength polymer modified concrete. Compressive strength is increased as the steel fibre content in concrete is increased and shows maximum strength at 1% steel fibre content of total volume of cement after that it starts decreasing. To achieve necessary balance, suitable high water cement ratio is used. All the three types of strength value (flexural, compressive and split tensile) decreases for any further increase in the quantity of latex above 10% dosage. The best mix was found to be steel fibre reinforced polymer modified concrete, which showed high strength and strain hardening characteristics; this mix would be promising for structural application of PM-SFRC. The addition of fibre plays an important role in arresting, delaying and propagation of cracks [4].

2. EXPERIMENTAL PROGRAM

2.1 Test Specimens

A series of specimens are chosen for the investigation and all are having a unique nominal sectional dimensions for cubes150 X 150 mm and 100X100 mm, cylinders 150 mm dia. and 300mm height and prisms 100 X 100 X 500mm respectively. The parameters tested include concrete type (SCC, polymer modified SCC, steel fibre reinforced polymer modified SCC); optimum SBR percentage is found (5%, 10% and 15%);steel fiber volume percentage is 0.5.

2.2 Material Properties

A concrete mix of M30 was used in this study. The materials used in the experiment are cement, fine aggregate, coarse aggregate, GGBFS, SBR latex, steel fibres and super plasticizer. The fresh properties of SCC were tested and listed in Table 2.

Styrene butadiene rubber latex is bought from Sika India Pvt .Ltd, Kolkatta. It has a milky appearance. It consist of very small polymer particles (0.05–5 μm) formed by emulsion polymerization and stabilized in water with the aid of surfactants.

Hooked end steel fibers were used to make fiber reinforced SCC. The steel fibers had a length of 30mm, diameter of 0.5mm, aspect ratio of 60 and density of 7850kg/m^3. The steel fibers were distributed randomly into the concrete mixtures and the percentage used is 0.5% to the volume of concrete.

Table -2: Fresh Properties of SCC

Mix ID	Slump Flow (mm)	T500 (s)	V-funnel test s)	L-box test
SBR-0	650	3.8	10	0.81
SBR-5	695	3.1	9	0.86
SBR-10	700	2.9	8	0.9
SBR-15	730	2.5	6.5	0.95
SSBR-5	670	3.5	8	0.83

2.3 Specimen Preparation

The mixing sequence consisted of homogenizing the sand, aggregate, and around 50 % of mixing water before introducing the binder. After 1 min of mixing, the other 45 % water was added, followed by GGBFS, latex, and then Master Glenium sky 8022 diluted in 5 % of water. The concrete was mixed for two additional minutes. The ambient temperature during mixing and sampling hovered around 21 ± 3 _C. Curing is done by immersing the specimen in the curing tank.

2.4 Test Setup

The specimens were tested under comprossometer, flexural testing machine and Universal Testing Machine. Compression(a) and split tensile strength(b) is measured in compressometer. Flexure is measured in flexural testing machine(c) and pull out is done in Universal Testing Machine(d) The test setup is shown in Fig. 1.

(a)

(b)

(c)

(d)

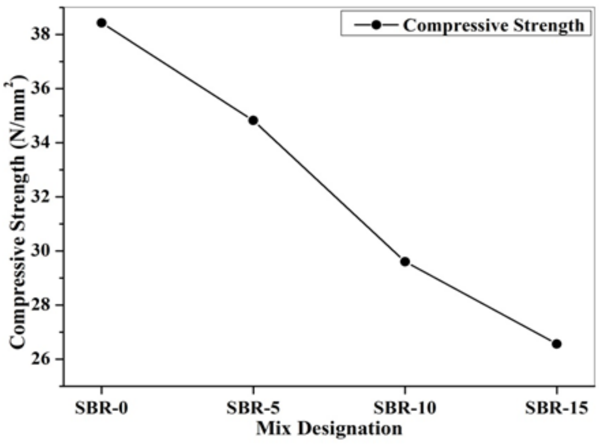
Fig -1: Experimental Test Setup

3. RESULTS AND DISCUSSIONS

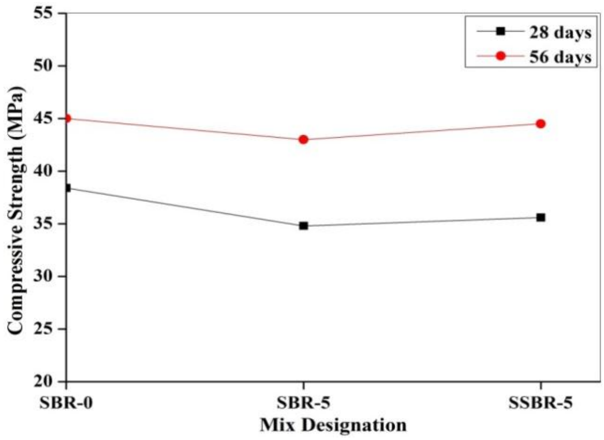
3.1 Mechanical properties

The hardened properties such as compressive strength, flexural strength and split tensile strength were tested in the laboratory.

3.1.1 Compressive Strength



(a)



(b)

Chart -1: Compressive strength of various mixes

Chart 1(a) shows the compressive strength at various percentages of SBR latex. As the SBR percentage is increasing the compressive strength is decreasing, therefore we take SBR-5 as the optimum percentage as the compressive strength value conforms M30 grade.

Chart 1(b) shows the compressive strength of various mixes at 28 and 56 days. Here we can see that the compressive strength has decreased for SBR-5 and then it is increased for SSBR-5, this is because of the polymer action on the atrophy of the growth in hydrated $Ca(OH)_2$ crystals which delays the cement hydration at earlier ages.

3.1.2 Flexural Strength

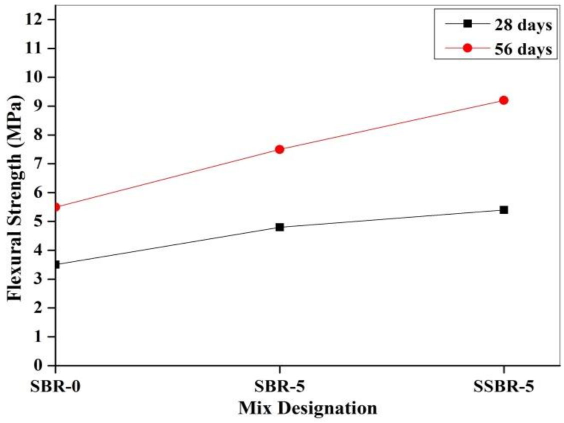


Chart -2: Flexural strength of various mixes

Chart 2 shows the flexural strength of various mixes at 28 and 56 days. It can be seen that flexural strength is increasing with the addition of SBR latex this is due to the Polymer action on the atrophy of the growth in hydrated $Ca(OH)_2$ crystals and on the reduction in the density of microcracks in the paste–aggregate interface, associated with the delay in the cement hydration and with the increase in the air content, leading to a significant increase in the flexural strength. The flexural strength is further increased in SSBR-5 due to its increase in interlocking and bond strength.

3.1.3 Split tensile Strength

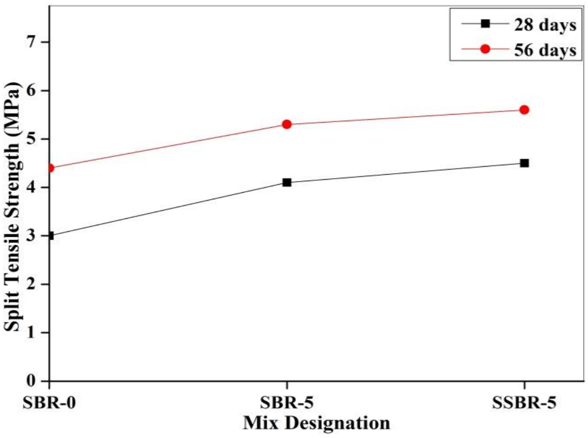


Chart -3: Split tensile strength of various mixes

Chart 3 shows the tensile strength of various mixes at 28and 56 days. It can be seen that the split tensile strength has increased with the addition of SBR-5 for both 28 and 56days of curing, this is due to the latex polymer films that provide increased elasticity through their high tensile strengths, thus bridging the micro cracks in hardened material and leading to stronger interfacial bond between cement paste and aggregate particles. Split tensile strength is further increased in SSBR-5 due to the compactness that is filling of voids in the matrix achieved due to latex and fiber filling in the concrete matrix.

3.2 Bond properties

The bond property such as pull out test where tested in the laboratory.

3.2.1 Pull out test

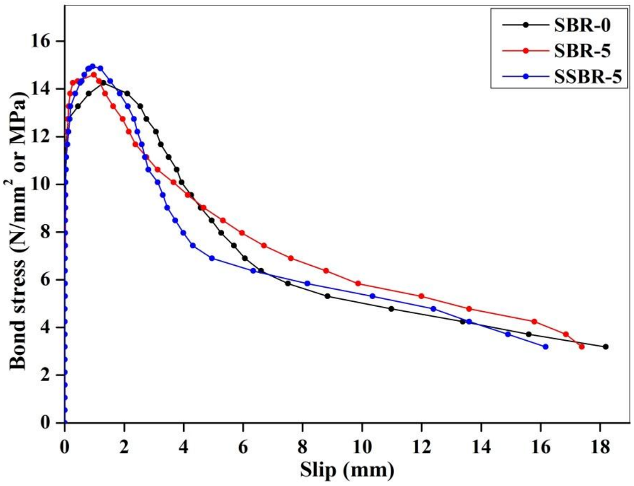


Chart -4: Bond Stress-Slip Curves

Chart -4 shows the bond stress slip curve, the bond strength between steel and self compacting concrete may be due to greater filling capacity of self compacting concrete, which covers the reinforcements completely without need of vibrators; while in traditional concrete the process depends on the vibration treatment being correct. The greater filling capacity of self compacting concrete and its smaller amount of bleeding also reduce the occurrence of voids between the steel and the concrete

The increase of bond strength between steel and polymer concrete may be due to the good adhesion of polymer and due to higher tensile strength of polymer modified self compacting concrete. Concrete tensile strength has a significant effect on bond strength between steel and concrete especially for deformed steel bars. For deformed steel bars embedded in concrete, bond failure occurred due to the resulting lateral forces as a result of the presence of ribs in deformed steel reinforcement. The increase of concrete tensile strength increases the bond strength.

In the SSBR-5 mix the bond strength is further increased due to the combined effect of steel fibres and polymer.

4. CONCLUSIONS

- The joining of SBR Latex increases the workability condition of the concrete, that resulting from the SBR latex plasticizing effect on the concrete.
- The maximum decrease in compressive strength was observed for 15% addition on SBR latex. This is due to the presence of polymer which act as small pores. As we are using M30 grade concrete, SBR-5 mix is used as optimum.
- Latex additions significantly decreases the compressive strength earlier but at later on very slight decrease is noticed, this is due to polymer action on the atrophy of the growth in hydrated Ca(OH)2 crystals which delays the cement hydration at earlier ages.
- By the addition of steel fibres to the SBR-5 mix compressive strength, flexural strength and tensile strength is increased.
- The Polymer action on the atrophy of the growth in hydrated $Ca(OH)_2$ crystals and on the reduction in the density of microcracks in the paste–aggregate interface, associated with the delay in the cement hydration and with the increase in the air content, leading to a significant increase in the flexural strength and tensile strength.
- With the addition of SBR latex the bond strength is increasing considerably due to the good adhesion of polymer and due to higher tensile strength of polymer modified self compacting concrete. Concrete tensile strength has a significant effect on bond strength between steel and concrete especially for deformed steel bars.

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