

Influence of Glass Fiber on Fresh and Hardened Properties of Self Compacting Concrete

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Abstract. The practical need of self-compacting concrete (SCC) is increasing due to increase in the infrastructure competence all over the world. The effective way of increasing the strength of concrete and enhance the behaviour under extreme loading (fire) is the keen interest. Glass fibers were added for five different of volume fractions (0%, 0.1%, 0.3%, 0.5% and 0.6%) to determine the optimum percentage of glass fiber without compensating the fresh properties and enhanced hardened properties of SCC concrete. The fresh state of concrete is characterized by slump flow, T-50cm slump flow, and V-funnel and L- box tests. The results obtained in fresh state are compared with the acceptance criteria of EFNARC specification. Concrete specimens were casted to evaluate the hardened properties such as compressive strength, split tensile strength, flexural strength and modulus of elasticity. Incorporation the glass fiber into SCC reduces the workability but within the standard specification. The hardened properties of SCC glass fiber reinforced concrete were enhanced, due to bridging the pre-existing micro cracks in concrete by glass fiber addition.

1. Introduction

Professor Okamura of Kochi university of Technology, Japan in 1986 insisted the need of SCC. Before the first prototype innovation, multi-particle physics was chiefly investigated to clarify the dynamic segregation of the liquid matrix - particle suspension system [1 & 2]. The fresh SCC considered as multi-sized particle and understood by T. C. Powers [3]. The development SCC improved the superiority of concrete and opened up its application in all the areas of construction industry [4]. The cost reduction and environment friendly SCC can be obtained by using the industrial wastes which has binding properties [5–10]. In another study, the cement was replaced with low calcium F fly ash from 40 to 60% in SCC. The characteristic compressive strength varied between 26 and 48 MPa. The possibility of developing economical SCC mixes was by using Industrial waste which is rich in binding properties [11 & 12]. The Interfacial transition zone (ITZ) plays a very important role to ensure quality and strength aspect of the concrete. Generally the ITZ consist of water film, calcium hydroxide layer and a porous cement matrix which affects the mechanical and transport properties hence the reduction in the ITZ results in good strength between aggregate to binder. [13-15].



The aim of current research is to examine the performance of Self compacting concrete with the addition of glass fiber (SCFC). The study focused on influence of various percentage of glass fiber on the fresh and hardened properties of SCC.

2. Experimental Program

2.1 Materials and their Proportions

The cement used in this study were ordinary Portland cement of 53 grade conforming to BIS 12269 [16] and Class F fly ash was taken from Vijayawada Thermal Power Station, Andhra Pradesh. The fly-ash collected was tested for physical and chemical and the test results were in compliance with ASTM C 618 – 78 [17], BIS 3812 [18] and satisfies all the properties of Class F fly-ash. River sand was used as fine aggregates and the properties was confirming to Zone II specifications [19] and 12.5 mm downgraded metal was used as coarse aggregate. Coarse aggregate of size 12.5 mm downgraded was used in a mix proportion. The coarse aggregate with specific gravity of 2.6, fineness modulus of 6.23 and moisture content of 0.4% were used. Table 1 provides the various mix proportions considered in the study. The fly ash was used in this study for partial replacement of cement by 30% of its weight. A sulphonated naphthalene polymer based super-plasticizer was used. The glass fiber used in the study has a Specific Gravity 2.67, aspect ratio of 859.0, Elastic modulus 71GPa and Anti – Crack HD fibers.

Table 1 Mix proportions of SCC (per m³)

| Mix | Glass Fiber in % | Water/binder ratio | Cement (kg) | FA (kg) | Sand (kg) | Aggregate (kg) 12.5 mm | VMA % | Super – Plasticizer (%) |
|----------|------------------|--------------------|-------------|---------|-----------|---------------------------|-------|-------------------------|
| SCC-0.0 | 0.0% | | | | | | | |
| SCC -0.1 | 0.1% | | | | | | | |
| SCC-0.3 | 0.3% | 0.40 | 350 | 142 | 707.7 | 1138.2 | 0.5 | 2.15 |
| SCC-0.5 | 0.5% | | | | | | | |
| SCC-0.6 | 0.6% | | | | | | | |

3. Testing Methods and Methodology

The fresh properties of SCC with and without glass fiber was carried out as per EFNARC specification [20,21]. To assess filling ability, rheology factors of the SCC slump flow test are performed. The slump flow value has to be in the range of 650 to 800 mm. T 50cm slump flow test is used along with slump flow test to assess the flow ability. V-Funnel test is used to determine the filling ability, flow ability and segregation resistance. The flow of the concrete in the congested junctions like beam column joint was assessed by the L-box test

According to BIS 516 [22] the compressive strength test, split tensile strength test, and Young's modulus tests were performed at concrete specimen after 7 and 28 days of curing. Similarly the flexural strength test was performed based on BIS 1199-1959 [23]. The cube specimens were tested upto failure in compressive strength using uniaxial compression testing machine of capacity 2,000 kN at constant loading rate of 140 kg/cm²/min. A flexural strength test was carried out using a prism specimen of size 150 x 150x 700 mm and were tested under universal testing machine of capacity 1,000 kN at a constant loading rate 180 kg/min. Split tensile strength and Young's modulus

were tested using cylindrical specimens of size 150 mm x 300 mm under uniaxial compression testing machine of capacity 3,000 kN.

4. Results and Discussion

4.1 Fresh Properties of SCC

Table 2 shows the various flow test done for varying percentage of glass fibre and the results are well within the permissible limits specified in EFNARC [20 & 21]. The table clearly depict that as the percentage of fiber content is increased the various fresh properties were slowly reaching the permissible limit.

The slump flow was varying from 692 mm for SCC to 661 mm for SCC – 0.6, it states values were well within the permissible limit of 600mm to 800mm. The passing ability of SCC through reinforcing bars was indicated by relation between the J-ring test to slump flow [20]. The passing ability of SCC was tested by using L-box, U-box, and J-ring as recommended by international standards [20, 24]. The devices were designed to assess the passing ability of SCC, in consideration with common reinforcing patterns used in the construction industry and for aggregate size of 20 mm for SCC [25]. The test result of J-Ring was found to decrease in the flow of concrete as the percentage of fiber content was increased but the results are well within the permissible value of the standards. Similar observation was observed with L-Box test, the values from 0.81 to 0.99 for SCC-0.0 and SCC-0.6 respectively. The filling ability of the SCC was measured using V-funnel test and the detail apparatus set up was made as per details of EFNARC[20]. The flow time required for SCC is 9 seconds, in the case of SCC 0.6 the flow time required was 11 seconds. It was clear from results that the flow time was increasing as the percentage of fiber content was increased. The research study consists of respondents in the construction companies specifically in South India.

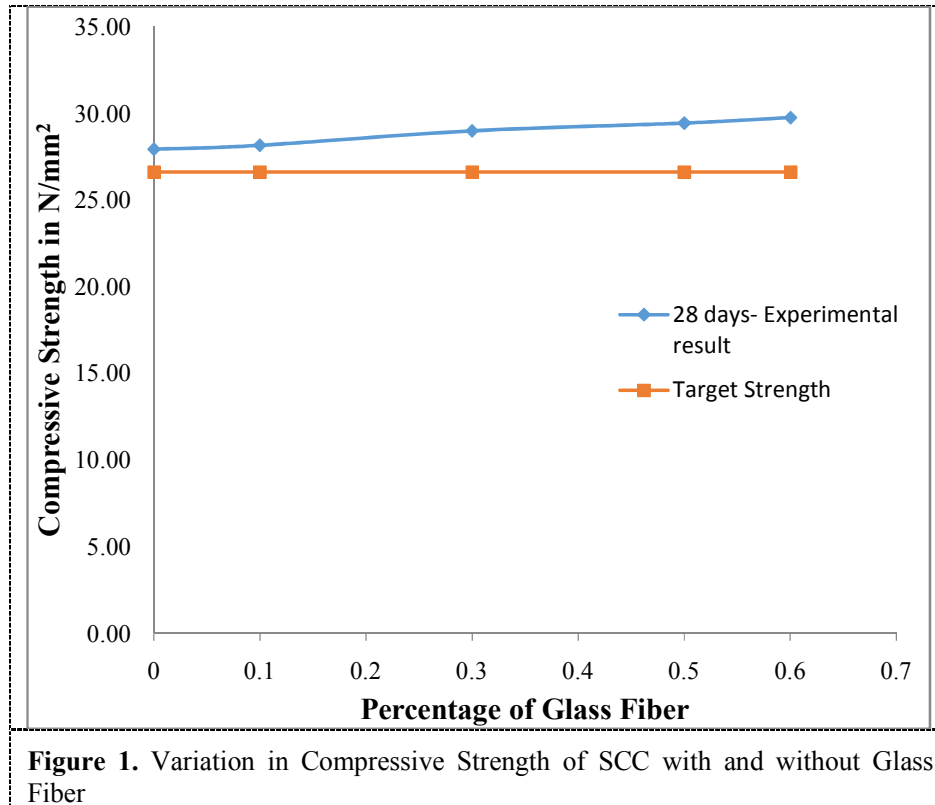
Table 2. Fresh properties of SCC with and without glass fiber.

| Specimen ID | Slump Flow (mm) | J-Ring (mm) | Slump for 500 mm Spread (s) | V-funnel time (s) | L- Box ratio |
|-------------|-----------------|-------------|-----------------------------|-------------------|--------------|
| SCC-0.0 | 692 | 632 | 2.92 | 9 | 0.81 |
| SCC-0.1 | 685 | 624 | 3.28 | 9 | 0.84 |
| SCC-0.3 | 679 | 609 | 3.73 | 10 | 0.89 |
| SCC-0.5 | 675 | 596 | 4.57 | 10 | 0.96 |
| SCC-0.6 | 662 | 581 | 5.89 | 11 | 0.99 |

4.2 Hardened Properties of SCC

The hardened properties of concrete were studied for various percentage (0.1%, 0.3%, 0.5% and 0.6%) of glass fiber of the cement content. In this study, the values presented were average of six samples for each series of experiments.

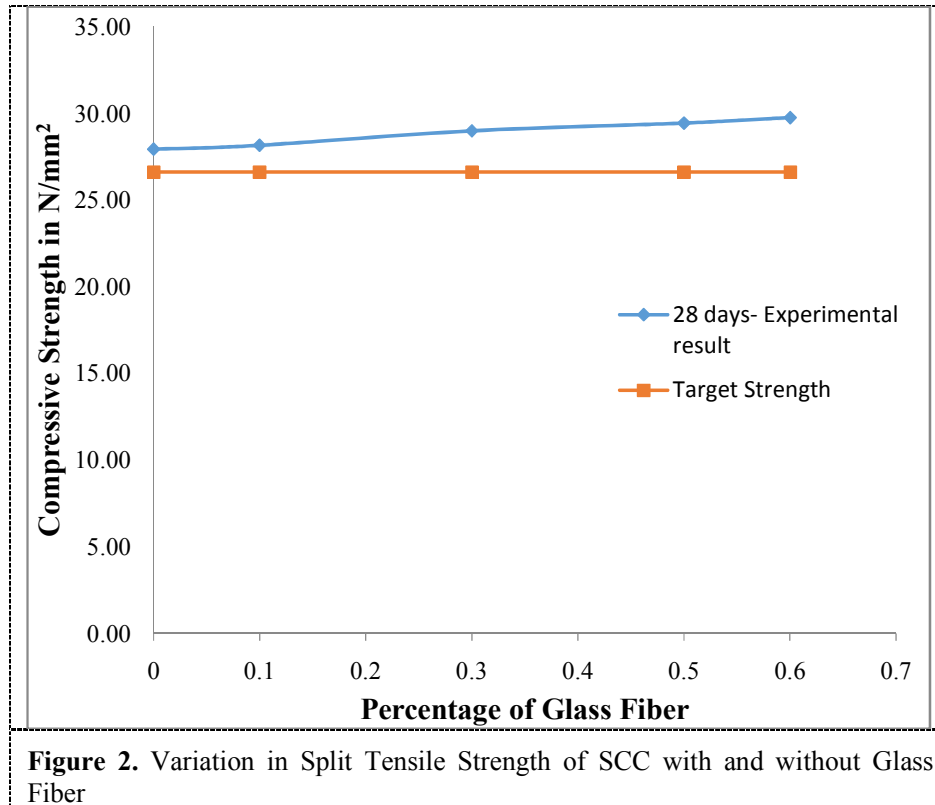
4.2.1 Compressive Strength. Fig 1 shows the compressive strength test results of SCC with and without fiber. It is interesting to note that the mix containing fiber content resulted in the increasing rate of the strength. The percentage increase in strength was 0.80 %, 3.82%, 5.41% and 6.53% for SCC-01, SCC-03, SCC-05 and SCC-06 respectively.



The increase in the strength may be due to bridging of pre-existing crack in ITZ and also presence of fiber improved interface between aggregate and hardened paste [26]. Similar observations were reported by other researchers [26, 27 & 28]

4.2.2 Split Tensile Strength. The average split tensile found to increase with increase in the content of glass fiber. Figure 2 shows the split tensile strength of concrete for various percentage of glass fiber and also compared with the model proposed by Felekoglu et.al [29]. The increase in split tensile strength when compared with SCC were 8.33%, 9.37%, 11.46% and 11.11% for SCC-01, SCC-03, SCC-05 and SCC-06 respectively., The increase in split tensile strength was also reported by other researchers [11, 27, 28].

4.2.3 Flexural Strength. The modulus of rupture value increases with increase glass fiber percentage. The flexural strength were 5.33 N/mm², 5.51 N/mm², 5.69 N/mm², 5.87 N/mm² and 6.04 N/mm² for SCC, SCC-01, SCC-03, SCC-05 and SCC-06 respectively., the addition increase in strength is may be due to proper orientation of fiber, presence of fiber at the cracking zone which arrest theformation of micro cracks and interestingly failure of the specimens shows ductile failure when compared with SCC. The Fig 3 shows the comparison of experimentally value with the various empirical formulas developed by various codes for concrete.



The SCC itself found to have modulus of rupture value greater than empirical relation and simultaneously the addition of glass fiber increases the modulus of rupture. The empirical relation provided in various codes under estimates by large margin. Based on the experimental results a new empirical relation was proposed to calculate the modulus of rupture value and the expression proposed gives a conservative prediction.

$$f_r = 0.42 * (f_{ck})^{(3/4)} \quad (1)$$

4.2.4 Modulus of elasticity

Figure 4 shows the variation in the instantaneous elastic modulus for various percentage of glass fiber [32]. Some of the previous researchers concluded that the SFR SCC has elastic modulus greater than the plain concrete [33-35]. Similarly other researchers reported that the variation in elastic modulus between SFR SCC and Plain SCC is insignificant [27, 28, 34 – 36].

Generally, the elastic modulus of concrete depends upon the elastic modulus of aggregate and hardened cement paste [33], and also the ratio between binder content to coarse aggregate. The Fig 4 shows the comparison of experimentally value with the various empirical formulas developed by various codes for concrete. The empirical relation provided by Indian code and ACI code found to underestimates the actual modulus of elasticity, where the margin is large in the case of ACI code than India code. In considering Eurocode it over estimates the value marginally.

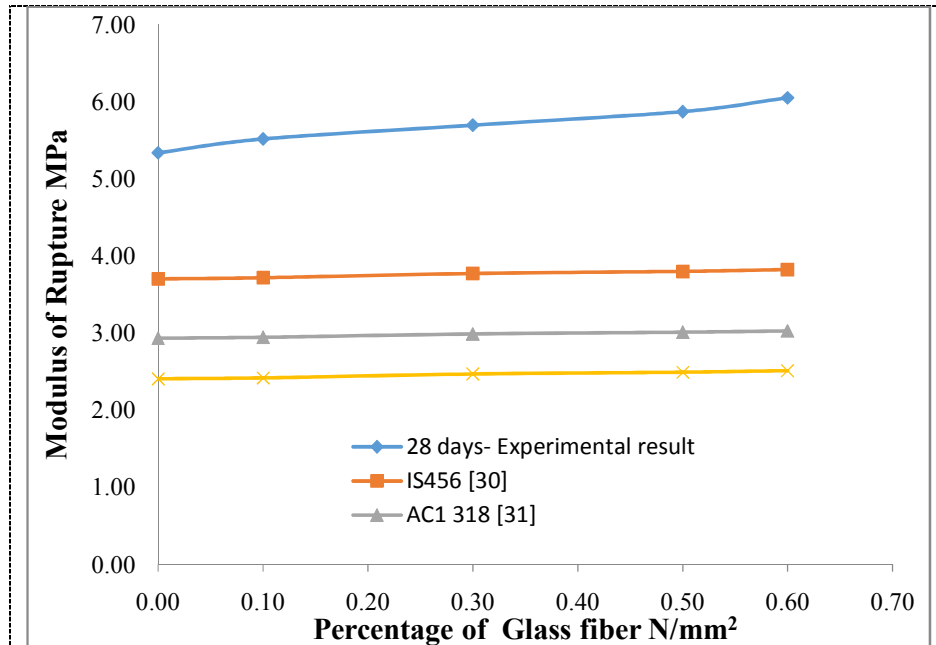


Figure 3. Variation in Modulus of rupture Value for Different percentage of Glass Fiber and Comparison with Empirical Relationship of IS456, ACI318 and EC2

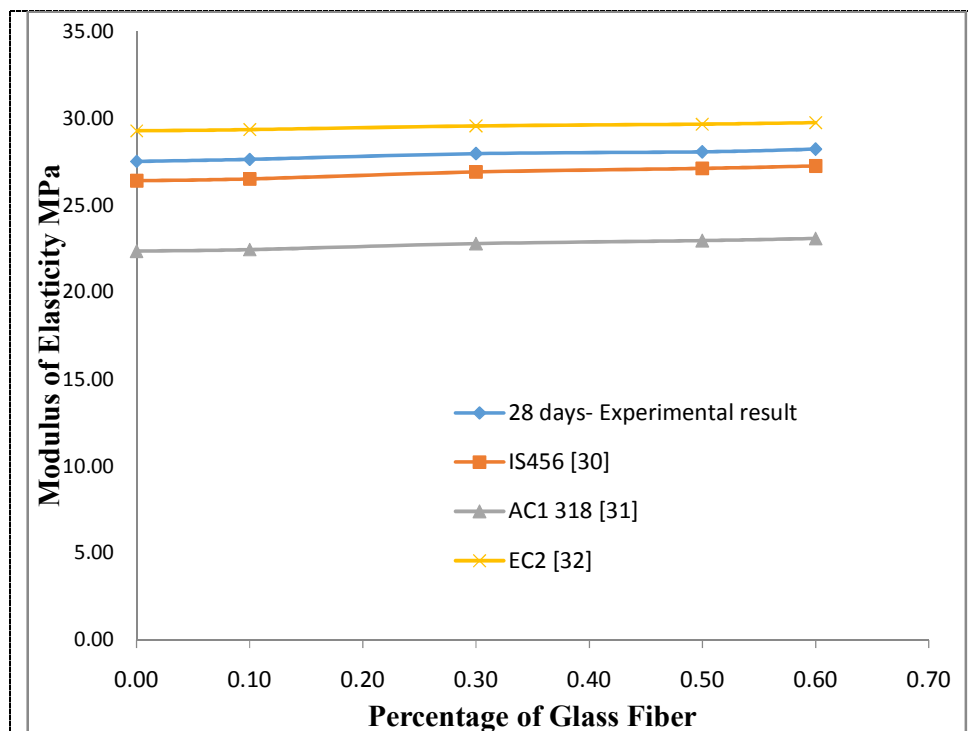


Figure 4. Variation in Modulus of Elasticity Value for Different percentage of Glass Fiber and Comparison with Empirical Relationship of IS456, ACI318 and EC2

5. Conclusion

The following conclusion may be deduced from the experimental investigation

- Addition of glass fiber to SCC reduces the workability but it is within the permissible limit of EFNARC.
- The strength properties were increased with increase addition of glass fiber upto 0.6 %.
- The fiber addition enhances the strength by suppressing the development of micro crack to macro level crack; increase the mortar strength, proper orientation of the fiber in case of flexural loading and the effect of bridging between the cement mortar and coarse aggregate.
- A new empirical relation was proposed to calculate the modulus of rupture value while the existing empirical values in various code found to under estimating
- It was observed that upto 0.6% of glass fiber can be added to the SCC.

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