

# Cyclic behaviour of RC beams using SIFCON Sections

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**ABSTRACT:** SIFCON is a relatively new material and can be considered as special type of fiber reinforced concrete. This SIFCON is a new method to increase the strength of concrete. SIFCON is incorporated by using some amount of steel fibre in mould to form very dense network of fibre. The network is then infiltrated with cement based slurry or mortar. In this study, the mechanical properties and flexural properties of SIFCON members are evaluated and they are compared with conventional concrete of grade M40. The cement based slurry is a composition of cement, fly ash, silica fume, Ground Granulated Blast Furnace Slag. From the results obtained it is found that SIFCON members are much better than conventional concrete. The compression strength of SIFCON was found to be 33% more than conventional concrete and 102.4% more than SIFCON specimens without fibre. The flexural strength of SIFCON was 179% more than conventional concrete and 232% more than SIFCON specimens without fibre. The parameters like ductility, stiffness and energy absorption were higher for SIFCON section than conventional concrete. Thus this study shows that SIFCON can be used as an effective alternative in special concreting purposes or where the concrete or conventional SFRC cannot perform as expected/required or in situations where such high strength is required.

**KEYWORDS:** SIFCON, Mechanical Properties, fly ash, silica fume, Ground Granulated Blast Furnace Slag, steel fibre.

## I. INTRODUCTION

There are many new type of concrete that are being introduced to increase the strength of the concrete. In such case SIFCON Slurry Infiltrated Fibre Reinforced Concrete is also new type of concrete.. In two aspects, however, it is different from normal fiber reinforced concrete. In FRC, the fiber content usually varies from 1% to 3% by volume, whereas in SIFCON the fiber content varies between 4% to 20%. In FRC, the fiber is added to the wet or dry mix of the concrete but SIFCON is prepared by infiltrating cement slurry into a bed of preplaced fiber. SIFCON is incorporated by using some amount of steel fibre in mould to form very dense network of fibre. The network is then infiltrated with cement based slurry or mortar. As the fibre concentration is increased along with fibre aspect ratio(length/diameter), it becomes difficult to mix and place these materials. In practice it has been found that the amount of fibre must be kept fewer than 2% volume and aspect ratio must be kept under 100. This situation places bounds on the improvements in the engineering properties of concrete (flexural strength, flexural toughness index, impact and fatigue resistance) that can be gained through the use of steel fibres. The elastic modulus, tensile strength and compression strength of the slurry affect the behavior of the composite SIFCON matrix. Fiber pullout strength is just one variable that depends upon the slurry compressive strength. As stated before, the fiber volume depends only upon the fiber type and the vibration effort. Smaller or shorter fibers will pack denser than longer fibers. The ultimate strength, residual strength, ductility and energy absorption are affected by the fiber alignment. The main aim of this project is to study the mechanical properties of SIFCON by using cementitious materials like fly ash, silica fume, GGBS . Moreover, the usage of very high amounts of cement not only affects the economy of construction, but also has negative effects on the heat of hydration and may cause shrinkage problems. The use of supplementary cementitious materials seems to feasible solution to overcome these problems.

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## II. RELATED WORK

Yazici et al., studied the effect of incorporating high volume of class C fly ash on mechanical properties of the SIFCON and concluded that by increase in the fibre volume remarkably increases flexural strength and toughness of SIFCON. Sharma H.K et al. studied the structural optimization and performance of SIFCON plates with an optimum fibre volume fraction of 8%. Sundarsana Rao et al. tested the SIFCON slab elements under flexure and compared the results with FRC and PCC slabs and concluded that SIFCON slabs exhibit superior performance in flexure when compared to FRC and PCC slabs. However, literature review reveals that a very little work has been carried out on SIFCON without sand.

## III. EXPERIMENTAL WORKS

### 3.1 Materials Used

The materials used for Conventional Concrete was, cement, fine aggregate, coarse aggregate and water. The materials used for preparing SIFCON was cement, Mineral admixtures that includes Fly Ash, GGBS and Silica fume, steel fibre, plasticizer and water.

Ordinary Portland cement of 53 grade conforming to IS: 12269 was used. The specific gravity of cement was found to be 3.15. Locally available river sand passing through 4.75 mm sieve was used. The specific gravity was found as 2.71. Silica fume conforming to ASTM C 1240 and ground granulated blast furnace slag conforming to ASTM C 989 and flyash conforming to ASTM C 618 was used. The specific gravity of silica fume, GGBS and flyash was found to be 2.2, 2.9 and 2.45 respectively. Coarse aggregate of 20 mm maximum size and typical particle shapes “average and cubic” was used as the coarse aggregate sample. Fresh water available from local sources was used for mixing and curing of specimens. To improve the workability of SIFCON, Cera Hyper Plast XR-W40, a high –range water reducing agent has been used. Fibre which used in this work is steel fiber

### 3.2 Mix proportions

Fibre content of 8% by volume was adopted for SIFCON. Water cement ratio of 0.4 and super plasticizer about 2% was adopted. The slurry consisted of cement, silica fume, fly ash and GGBS. The cement, silica fume, fly ash ratio is 1:0.15:0.5 by weight and GGBS varied from 0.2 to 0.6. The mix ratio adopted for conventional concrete of grade M40 is 1:1.62:2.98 with w/c ratio of 0.4. The following table 3.1 shows the mix proportion of SIFCON.

Table 3.1 Trial mix proportion for SIFCON

| Specimens | Materials used |             |         |      | Fibre | W/C | SP |
|-----------|----------------|-------------|---------|------|-------|-----|----|
|           | Cement         | Silica fume | Fly ash | GGBS |       |     |    |
| F1        | 1              | 0.15        | 0.5     | 0.2  | 8%    | 0.4 | 2% |
| F2        | 1              | 0.15        | 0.5     | 0.3  | 8%    | 0.4 | 2% |
| F3        | 1              | 0.15        | 0.5     | 0.4  | 8%    | 0.4 | 2% |
| F4        | 1              | 0.15        | 0.5     | 0.5  | 8%    | 0.4 | 2% |
| F5        | 1              | 0.15        | 0.5     | 0.6  | 8%    | 0.4 | 2% |
| S1        | 1              | 0.15        | 0.5     | 0.2  | -     | 0.4 | -  |
| S2        | 1              | 0.15        | 0.5     | 0.3  | -     | 0.4 | -  |
| S3        | 1              | 0.15        | 0.5     | 0.4  | -     | 0.4 | -  |
| S4        | 1              | 0.15        | 0.5     | 0.5  | -     | 0.4 | -  |
| S5        | 1              | 0.15        | 0.5     | 0.6  | -     | 0.4 | -  |

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### 3.3 Casting and testing details

SIFCON specimens were cast with varying mix proportions of SIFCON. They are kept in the mould for 24 hrs. After a period of 24 hours, the specimens were de moulded. The specimens were stored in water for curing after careful de moulding process for 28 days. Figure 3.2 and 3.3 shows the casting and testing of SIFCON beams

#### Beams

- 1200 mm X 150 mm X 100 mm
- Main Reinforcement: 4 nos of 8mm  $\phi$  bars
- Stirrups: 6mm  $\phi$  @ 100mm c/c

#### Laminates

- (i) 1200 mm X 150 mm X 20 mm
- (ii) 1200 mm X 100 mm X 20 mm

#### Beams with Precast SIFCON Laminates

- RC beam with precast SIFCON laminates at bottom
- RC beam with precast SIFCON laminates at sides
- RC beam with precast SIFCON laminates at bottom and sides

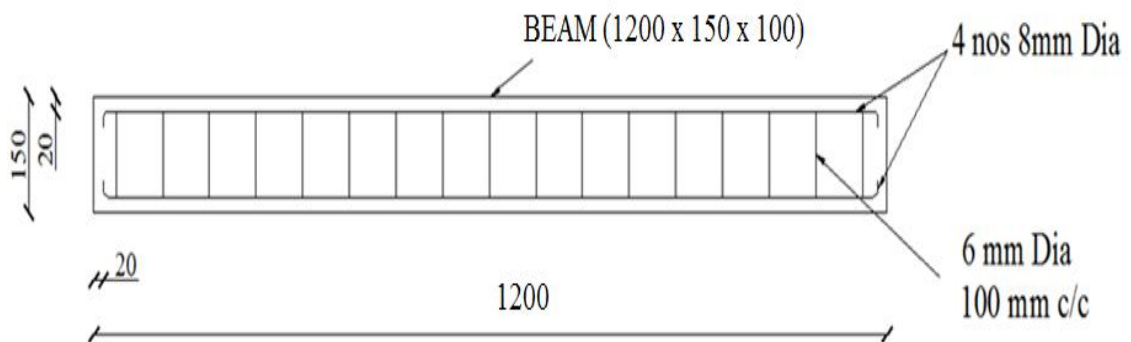


Fig 3.1 Reinforcement details



Fig 3.2 Casting of beam



Fig 3.3 Testing of beam

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## IV. EXPERIMENTAL RESULTS

### 4.1 Mechanical properties

Mechanical properties of SIFCON specimens with varying mix proportions are given in table 4.1 below.

Table 4.1 Test Results on Companion Specimens

| Property                                 | Without fibre |       |       |       |       | With fibre |       |       |       |       |
|--|---------------|-------|-------|-------|-------|------------|-------|-------|-------|-------|
|  | S1            | S2    | S3    | S4    | S5    | F1         | F2    | F3    | F4    | F5    |
| Compressive strength(N/mm <sup>2</sup> ) | 25.84         | 28.55 | 31.23 | 29.24 | 28.48 | 54.12      | 58.6  | 63.21 | 60.74 | 50.12 |
| Flexural strength(N/mm <sup>2</sup> )    | 2.5           | 2.75  | 3.75  | 3.15  | 2.05  | 9.35       | 11.05 | 12.45 | 10.35 | 8.5   |

### 4.2 Stress Strain Relationship for SIFCON

Since SIFCON contains large amount of fibre the split tensile strength test cannot be carried out. The various SIFCON cylinders are tested in UTM to obtain the stress strain curve of concrete. Figure 4.1 shows the stress strain relationship for various mixes.

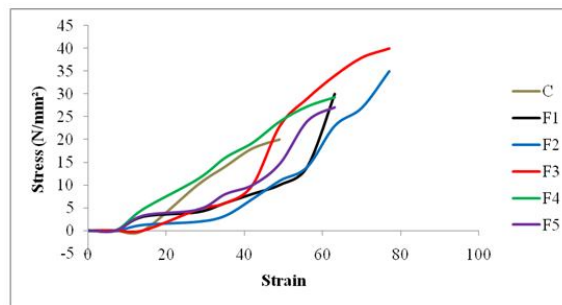
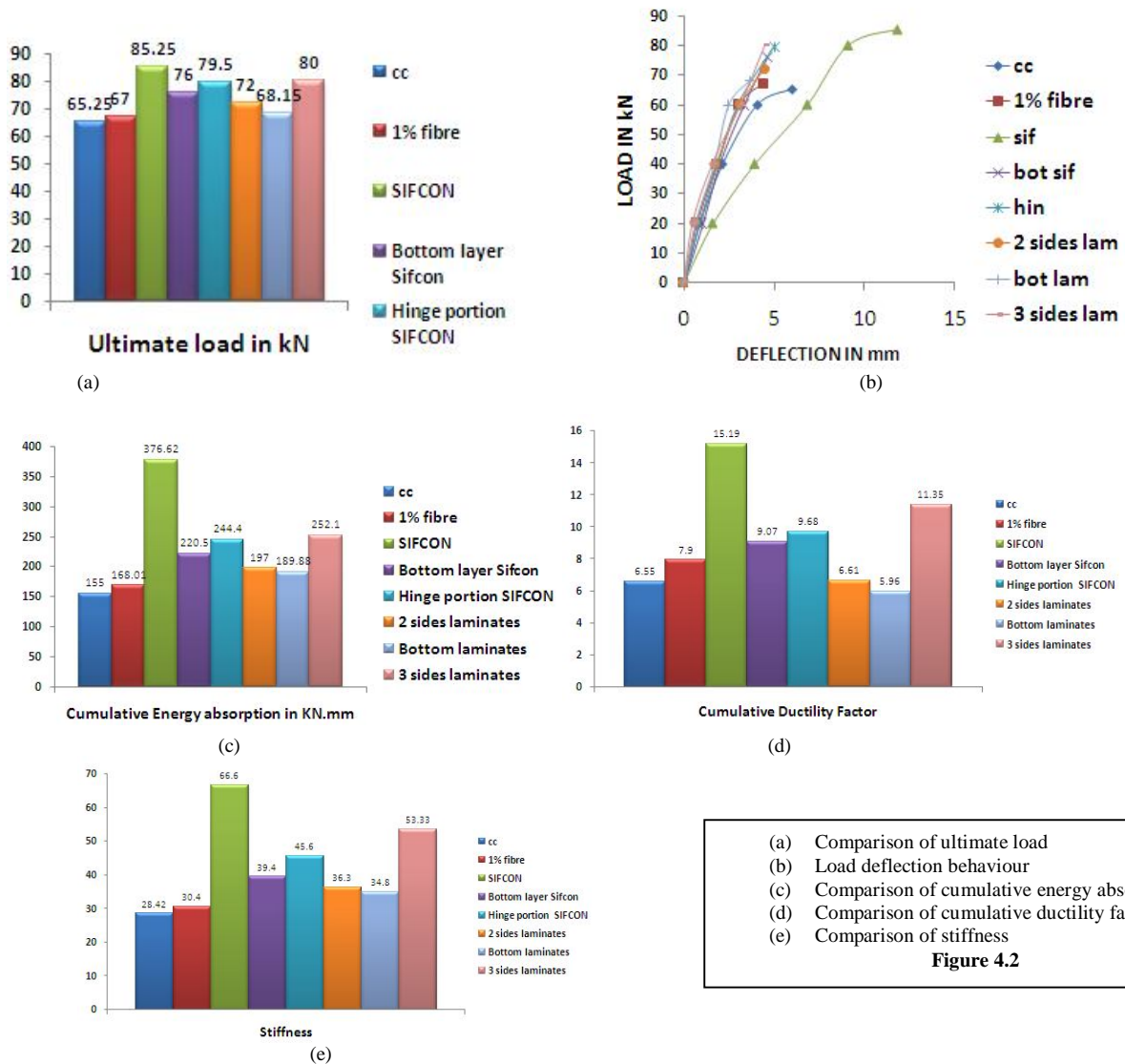


Fig 4.1 stress strain relationship

### 4.3 Comparison of various parameters

An experimental investigation on the behaviour of RC beam specimen & SIFCON beams under cyclic loading was carried out. The parameters like load carrying capacity, stiffness, Ductility and Energy Absorption were assessed. The result of the experimental investigation on the conventional reinforced concrete and various reinforced SIFCON specimens are compared.

Ductility may be broadly defined as the ability of a structure to undergo inelastic deformations beyond the initial yield deformation with no decrease in the load resistance. The ratio of maximum deformation of a particular cycle to that of the yield deflection can give a measure of displacement ductility. Figure 4.2 (a to e) represents the various parameters like load deflection behaviour, ductility, energy absorption capacity and stiffness of SIFCON beams under loading.



(a) Comparison of ultimate load  
(b) Load deflection behaviour  
(c) Comparison of cumulative energy absorption  
(d) Comparison of cumulative ductility factor  
(e) Comparison of stiffness  
**Figure 4.2**

**4.4 Behavior and mode of failure of beams**



**Fig 4.3 failure of beams**

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## V CONCLUSION

- The ultimate load of SIFCON beam is 85.25 kN which is 30% more than conventional beam, 27% more than FRC beam, 12% more than RC beam with bottom layer SIFCON, 7% more than RC beam with hinge portion SIFCON, 18% more than RC beam with SIFCON laminates at both sides, 25% more than RC beam with SIFCON laminates at bottom, 6% more than SIFCON laminates at three sides.
- The cumulative ductility factor of SIFCON beam is 15.19 which is 131% more than conventional beam, 92% more than FRC beam, 67% more than RC beam with bottom layer SIFCON, 56% more than RC beam with hinge portion SIFCON, 129% more than RC beam with SIFCON laminates at both sides, 153% more than RC beam with SIFCON laminates at bottom, 33% more than SIFCON laminates at three sides.
- The cumulative energy absorption capacity of SIFCON beam is 416.62 kN.mm which is 142% more than conventional beam, 124% more than FRC beam, 70% more than RC beam with bottom layer SIFCON, 54% more than RC beam with hinge portion SIFCON, 91% more than RC beam with SIFCON laminates at both sides, 98% more than RC beam with SIFCON laminates at bottom, 49% more than SIFCON laminates at three sides.
- The stiffness of SIFCON beam is 66.6 kN/mm which is 134% more than conventional beam, 119% more than FRC beam, 69% more than RC beam with bottom layer SIFCON, 46% more than RC beam with hinge portion SIFCON, 83% more than RC beam with SIFCON laminates at both sides, 91% more than RC beam with SIFCON laminates at bottom, 24% more than SIFCON laminates at three sides.

In general it is concluded that SIFCON can be used as an effective alternative in special concreting purposes or where the concrete or conventional SFRC cannot perform as expected/required or in situations where such high strength is required.

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