# Effect of Using Short Fiber Composite Materials on RC Slabs under Static Loading

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**Abstract:** ***The advanced composite materials are increasingly being used in engineering applications, especially for concrete structures. One of the new advanced composite materials is short fiber composite materials (SFCM), which have been one of the most exciting and promising technologies in materials/structural engineering. The behavior of SFCM of RC slabs under static loading, despite its importance, has received relatively little attention. One of the objectives of this study is to determine the behavior of RC slabs using short fiber composite materials under static loading. In this paper, special attention is given to (1) development of short fiber composite materials while maintaining good mechanical properties such as flexural strength, ductility, and toughness, and (2) development of static loading of RC slabs using SFCM. This paper presents a complete description of the experimental investigation carried out under static loading of RC slabs containing either 0.5 % or 1.0 % by volume of either polypropylene fibers (PF) or steel fibers (SF). All slabs are reinforced with constant amount of steel bars and its dimensions are 150 cm length by 40 cm width and 12 cm thick in plan. Experimental results of large-scale model of RC slabs subjected to four point loads are presented for the mid-span deflections, crack width, cracks propagation, first crack load, and ultimate load capacity, under static loading.***

**Keywords:** Short fiber composite materials, Static loading, slabs, cracking

## 1. Introduction

Plain concrete is not only weak in tension, but is also a material that absorbs only a minimal amount of energy during fracture. The capability of concrete to absorb energy, often called toughness, is of critical importance in service when concrete structures may be subjected to static, dynamic, and fatigue loads, and when the crack widths in concrete must be restricted to prevent the ingress of deleterious agents in harsh environments [1-3]. Reinforcement of concrete with randomly distributed short fibers is known to improve the toughness of concrete and to also restrict the crack widths in service. In addition, improve the flexural strength, impact strength, shear and torsion strength, direct tensile strength, fatigue strength, shock resistance, ductility, and failure toughness [4-6].

Proper design and construction of RC slabs is an important part of the building process, in particular for warehouse and distribution type centers where deterioration and failure of slabs can lead to a costly disruption of services. The behavior of short fiber composite materials in static loading of RC slabs, despite its importance, has received relatively little attention. One of the objectives of this investigation is to determine the behavior of RC slabs using short fiber composite materials under static loading.

This paper presents a complete description of the experimental investigation carried out under static four-point loading of RC slabs containing either 0.5 % or 1.0 % by volume of either polypropylene or steel fibers. The experimental program deals with the mechanical properties most important for such materials, namely, a mid-span deflection, crack width, cracks propagation, first crack load, and ultimate load capacity, under static loading.

## 2. Experimental Program

### 2.1. Materials and mix proportions

All concrete mixtures were prepared with ordinary Portland cement with 3.15 specific gravity. The fine aggregate used in concrete was Natural River sand with 2.55 specific gravity and 2.3 fineness modulus. The coarse aggregate was crushed sand stone with 20 mm maximum size and 2.73 specific gravity. Two types of fiber, either polypropylene fibers (PF) or steel fibers (SF)(30 mm long) have generally been used in RC slabs with either 0.5 % or 1.0 % by volume. Fibers can be added to the concrete mixer at the site, and special attention to the mix design is needed to help ensure a workable mix. Although plasticizers are usually required to account for the loss of slump when the fibers are added to the mix, there is a practical limit on the amount of fibers that can be used. Superplasticizer admixture was used as 0.5 % of the total cement and was considered as part of the mixing water. All mixes have constant water/cement ratio of 0.46. All the batches were mixed in a double drum mixer of 0.085 $m^3$ capacity. The raw materials were batched in a pan mixer. First aggregate and cement were mixed, then superplasticizer and water gradually added to the dry mix. Finally, the fibers were added. The constant and variables parameters are given in Table 1.

**Table 1:** Mix proportion of concrete

| Specimen | Fiber's ratio (%) | W/C (%) | SP/C (%) | s/a (%) | Weight per unit volume ($Kg/m^3$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | C | W | S | G | SP | Fiber |
| F0.0 | 0.00 | 46.00 | 0.50 | 45.00 | 350 | 159.3 | 800 | 1040 | 1.75 | 0.00 |
| PF0.5 | 0.50 | | | | | | | | | 4.55 |
| SF0.5 | | | | | | | | | | 39.2 |
| PF1.0 | 1.00 | | | | | | | | | 9.10 |
| SF1.0 | | | | | | | | | | 78.5 |

F0.0: control (without fiber); PF: polypropylene fibers; SF: steel fibers; SP: superplasticizer

### 2.2. Test Specimens

The following specimens were made from each mix: nine 100 x 200 mm compression cylinders, and ten 400 x 120 x 1500 mm slabs for flexural static test. All slabs were reinforced with constant amount of steel bars. The slab dimensions and steel bars used are given in Figure 1. The amount of steel bars was chosen so that they would yield. To ensure flexural failure in slabs, the shear span should be over 5 times the effective depth. The slabs and cylinders were cast in metal molds and compacted by shutter vibrator.

### 2.3. Test for plastic concrete:

The freshly mixed concrete was tested for temperature, slump, air content, and inverted cone time. The test for inverted cone time is a new workability test for fibrous concrete [4]. The inverted cone is loosely filled with concrete and struck off level at the top. Primarily the test measures the mobility or fluidity of the mix, and the result is dependent on the parameters such as aggregate, size, shape and gradation, air content and admixtures, and surface friction of the fibers.

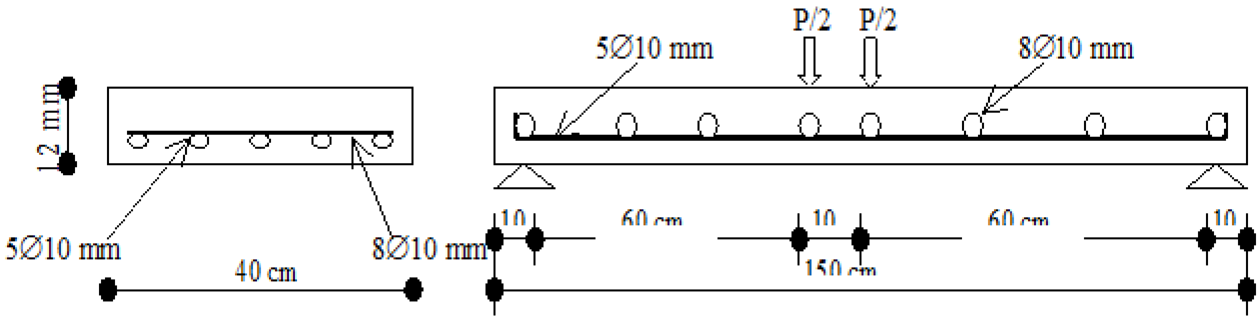


**Figure 1:** Setup of experimental test of RC

### 2.4. Test for hardened concrete:

The hardened concrete was tested for compressive strength at 7, 28, and 91 days. A flexural static test was conducted at 56 days. Deflection measurements were obtained using a dial gage accurate to 0.01 mm. Measurements were recorded at mid-span. In order to measure the flexural strain during loading; electrical resistance strain gauges were fixed on the surface of the slab. They were fixed at top fiber as well as at the level of tension steel. The strain gauges were fixed at equal intervals between the load points. The dial gage and strain gauge readings were recorded using the data logger. Load was applied in increments, and at each load increment all the required measurements were taken. Cracks width was measured at the level of tension steel using a crack microscope reading to 0.02 mm. A typical test setup is shown in Figure1.

## 3. Experimental Results and Discussion

The test results are very promising. Several versions of the short fiber composite materials such as, polypropylene fibers and steel fibers show very strong and ductile behavior.

### 3.1 Workability

Slump, air content and the newly developed inverted slump cone test were conducted to compare the performance of the plastic concrete reinforced with the two different types and content of fibers. The results are shown in figures 2 and 3.

### 3.2 Compressive strength

The Compressive strength and Young's modulus results at age of 7, 28, and 91 days as shown in Figures 4 and 5. A slight increase in compressive strength by (10-12 %) and Young's modulus by (5-7 %) can be noted and it depended on the fiber type" and content [1].

### 3.3 Flexural static test

A significant difference in performance of the two types of fibers was found in the static flexural test. From the flexural test on RC slabs it has been observed that cracks were numerous and uniformly spaced. Large deflection at mid-span was noticed at the time of failure of the RC slabs. The steel fiber proved its capacity as a crack arrested.

The cracks are prevented from propagation until the composite ultimate stress is reached. Consequently, the RC slabs using steel fiber are stiffer. On the other hand, it seems obvious that the polypropylene fibers contribute significantly to increase the ductility of slabs.

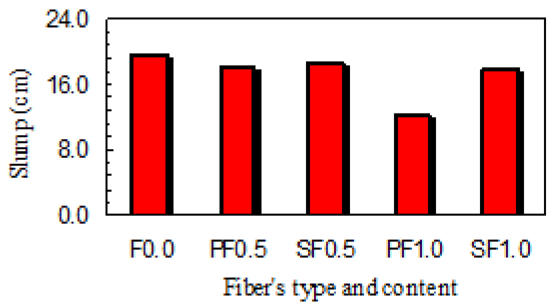


**Figure 2:** Effect of various type and content of fibers on concrete slump

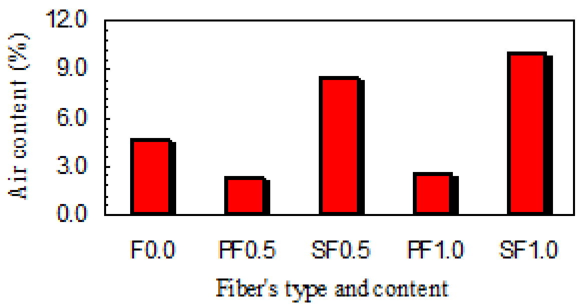


**Figure 3:** Effect of various type and content of fibers on air content

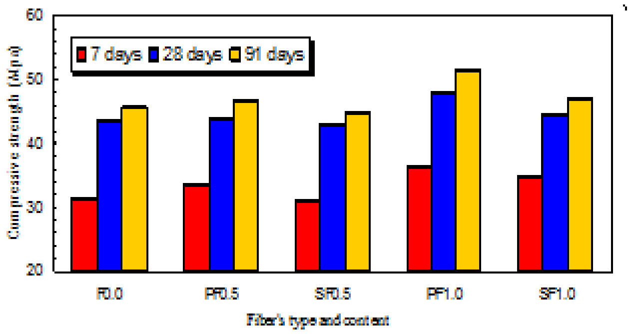


**Figure 4:** Effect of various type and content of fibers on compressive strength

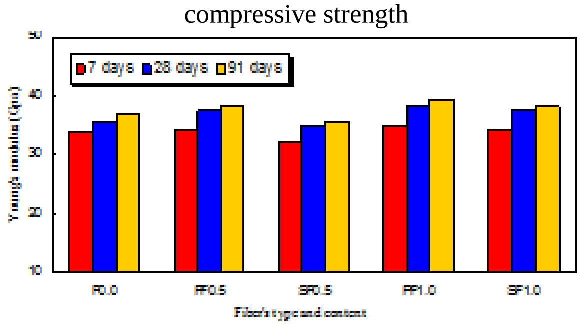


**Figure 5:** Effect of various type and content of fibers on Young's modulus

The load deflection curves are shown in Figure 6, which are typical curves. These curves indicate a ductile behavior and large energy absorption. The first crack and the maximum load capacity of different types of RC slabs are shown in Figure 7.

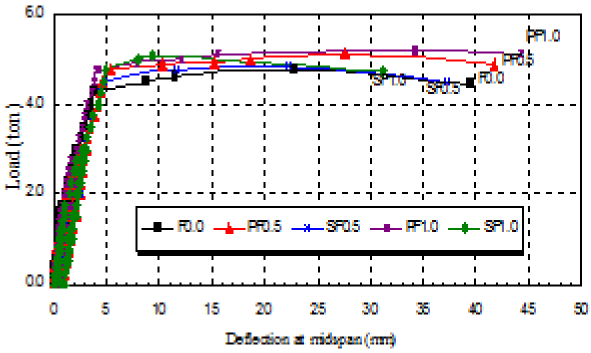


**Figure 6:** Load-Deflection curves for RC slab with various ratio and type fibers

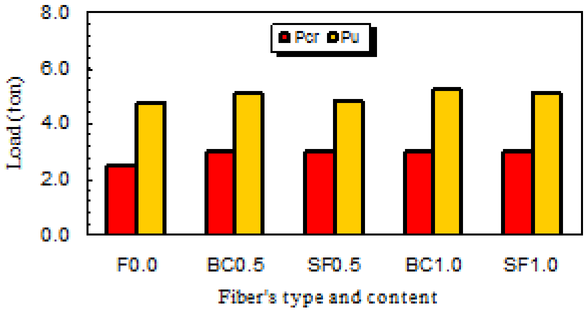


**Figure 7:** Effect of various type and content of fibers on first crack and ultimate load

## 4. Conclusions

The following conclusions can be drawn from the study reported herein:

1) The inclusion of fiber decreases the workability of fresh concrete; this effect is more pronounced for fibers with higher ratios.
2) The compressive strength and Young's modulus of the fibrous concrete are slightly higher than the plain concrete mix by (10-12 %) and (5-7 %), respectively.
3) The polypropylene and steel fibers have better ability to delay static crack initiation, width, and to prolong the crack propagation interval in the concrete structures.
4) The polypropylene fiber reinforced composites develop a ductile behavior that is maintained with static loading.
5) Steel fibers have excellent performance in resisting crack initiation and propagation; thus; the ability of resistance to static loading is increased greatly, and hence steel fibers remain one of the most commonly used fibers for reinforcing concrete structures.

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