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# Experimental study on behavior of fiber reinforced concrete for rigid pavements

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***Abstract:*** *This paper deals with experimental investigation on mechanical properties of $M_{20}$ grade concrete by incorporating polyester fibers in the mix. Polyester fibers of 0.1%,0.2%,0.3%,0.4% by weight of cement are added to the mix. A comparitive analysis has been carried out for conventional concrete to that of the fiber reinforced in relation to compressive, split tensile, flexural strengths. As the fiber content increases compressive, split tensile and flexural strengths are proportionally increasing. It is observed that 0.3% fibers by weight of cement is the optimum dosage. It is found that with 0.3% fiber content results in 20% reduction of pavement thickness.*

***Keywords:*** *Fiber reinforced concrete, Mix design, pavement thickness, Polyester fiber, Strength.*

## I. Introduction

A pavement is the layered structure on which vehicles travel. It serves two purposes, namely, to provide a comfortable and durable surface for vehicles, and to reduce stresses on underlying soils. In India, the traditional system of bituminous pavements is widely used. Because Concrete has some deficiencies as low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformations, low impact strength. Cement concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. Within two to three decades the bituminous pavement would be a history and required periodical maintenance. Now it is very essential to rethink of another material which satisfies required facilities.

More recently micro fibers, such as those used in traditional composite materials have been introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. FRC is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. The plain concrete structure cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation. The fiber reinforced concrete structure cracks at the same peak tensile load, but does not separate and can maintain a load to very large deformations. Fibers help to improve the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. FRC satisfies two of the much demanded requirements of pavement material in India, economy and reduced pollution. It also has several other advantages like longer life, low maintenance cost, fuel efficiency, good riding quality, increased load carrying capacity and impermeability to water over flexible pavements.

### 1.1 Literature review

Vasudev R[1] studied steel fiber reinforced concrete the fibers which were used are scarps from lathe shop. Experimental investigations and analysis of results were conducted to study the compressive & tensile behaviour of composite concrete with varying percentage of such fibers added to it. The concrete mix adopted were M20 and M30 with varying percentage of fibers ranging from 0, 0.25, 0.5, 0.75 & 1%.On the analysis of test results the concrete with turn steel fibers had improved performance as compared to the concrete with conventional steel fibers. Dipan patel [2] studied the use of steel fiber in rigid pavement. M20 Concrete mix was prepared with crimped end steel fibers with 25mm length and 0.5mm diameter (A/R 50). Cube specimens were casted and tested for 0.4 and 0.5% of volume of concrete. The results showed that the compressive strength of steel fiber concrete increased when compared to plain cement concrete. Addition of steel fiber in concrete, the pavement thickness is decreased by 23% and which is economical when compared to plain cement concrete slab. S.A Kanalli [3] conducted a preliminary study on compressive strength, tensile strength and flexural using different proportions of polypropylene fibers resulted in an varying ratio of fiber dosage of 0.25 percent by volume of $M_{20}$ grade concrete. Experimental studies show that maximum values of compressive split tensile and flexural strength of concrete are obtained at 0.75% fiber dosage. Rakesh kumar [4] investigated suitability of concrete reinforced with synthetic fiber for the construction of pavements. Author briefly discussed the effects of addition of polypropylene discrete and fibrillated fiber on the properties of a paving grade concrete mix of 48

Mpa compressive strength at 28-days. Six concrete mixes were casted with fiber dosages 0.05%, 0.10% and 0.15%. The properties such as settlement, compressive strength, drying shrinkage, and abrasion resistance of the concrete were evaluated. Rajarajeshwari B Vibhuti [5] studied the effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete for pavements. Steel fibers of 1% and polypropylene fibers 0.036% were added individually to the concrete mixture as mono fibers and then they were added together to form a hybrid fiber reinforced concrete. Mechanical properties such as compressive, split tensile and flexural strength were determined. The results show that hybrid fibers improve the compressive strength marginally as compared to mono fibers. Whereas, hybridization improves split tensile strength and flexural noticeably. She suggested that the improved mechanical properties of HFRC would result in reduction of warping stresses, short and long term cracking and reduction of slab thickness.

## II. Materials And Mix Specifications

### 2.1 Materials

Ordinary Portland Cement (OPC) of grade 53 conforming to IS:12269 was used for the studies. Locally available quartzite aggregate with a maximum size of aggregate of 20mm down size, and sand were used as coarse aggregate and fine aggregate respectively. The polyester fibers of 8 mm length and diameter of 0.045 mm which was produced from reliance industries Ltd., Mumbai are used in the present study. A water reducing admixture, Rheobuild 920kk is used in concrete. Its density and pH are 1.19 and >6 respectively.

### 2.2 Mix Proportion

All the mixes prepared are corresponds to M-20 grade. For the design of mix IS: 10262-2009 recommendations are adopted. Design mix proportions of M-20 grade are given in the following table.1.

**Table No.1** Concrete Mix-proportions

| Ingredient | Cement | Water | Fine aggregate | Coarse aggregate | Chemical admixture | Water cement Ratio |
|---|---|---|---|---|---|---|
| Weight | 300kg/m$^3$ | 150 lit. | 737.23 kg/m$^3$ | 1248 kg/m$^3$ | 2.17 kg/m$^3$ | 0.55 |

## III. Experimental Procedures And Tests Conducted

### 3.1 Test specimen and testing procedures

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were casted. The moulds were prepared with 0%, 0.1%, 0.2%, 0.3% and 0.4% polyester fibers. The samples were tested for their compressive strength at 3, 7 and 28 days. Cubes were tested on compression testing machine as per I.S. 516-1959. In each category three cubes were tested and their average value is reported. To determine the Split tensile strength, cylinder specimens of dimension 150 mm diameter and 300 mm length were casted. These specimens were tested under compression testing machine as per I.S. 5816:1999. For flexural strength test beam specimens of dimension 100x100x500 mm were casted. These flexural strength specimens were tested under four point loading as per I.S. 516-1959, using universal testing machine.

**Fig. No. 1. Compressive strength test**

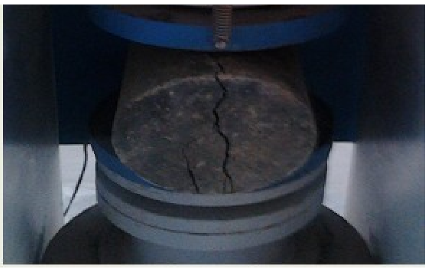

**Fig. No. 2. Split tensile strength**

**Fig.No. 3. Flexural strength test**

## IV. Experimental Results

**4.1 Workability:** Slump cone test was performed to determine the slump of the mixes. The slump values for various mixes are shown in figure.4. It is evident from the figure.4 that as the percentage of fiber content increases slump values are decreasing. The reduction in the slump with the increase in the fiber will be attributed to presence of fibers which causes obstruction to the free flow of concrete.

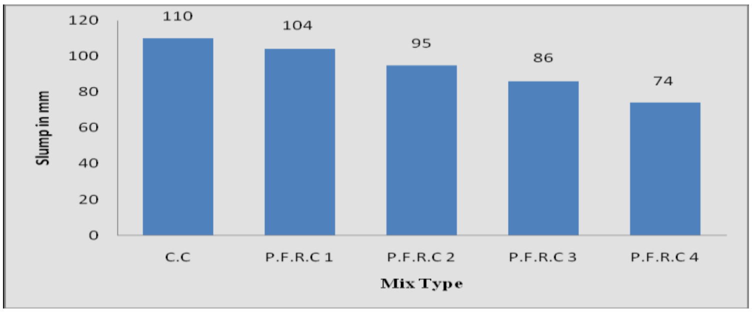


**Fig. No.4 :- Workability of mixes**

### 4.2 Compressive strength

The compressive strength values of the cube specimens at the age of 3, 7 and 28 days are as shown in figure.5.

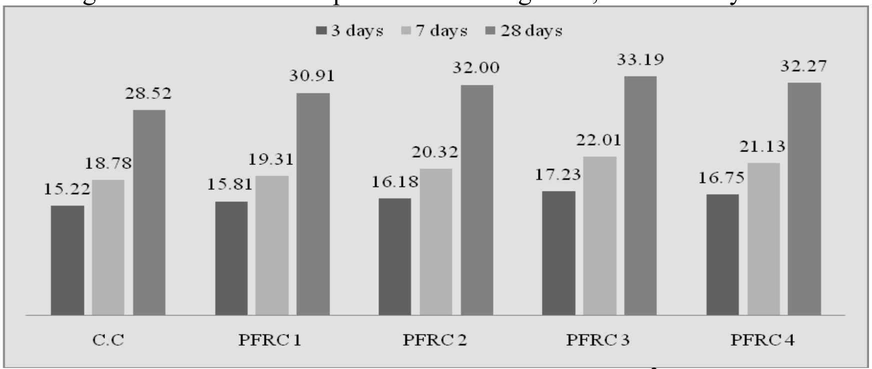


**Fig. No.5**:- Type of mix vs. Compressive strength (N/mm$^2$) at 3, 7& 28 Days

From the above fig. it is observed that the compressive strength of concrte is increasing with the increase in fiber content compared to conventional concrete at 3, 7 and 28 days.It is observed that at 0.3% of fiber in the weight of cement, maximum strength was attained and later with increase in fiber content strengths are falling down. The increment in the compressive strength at 0.3% fiber content is 13.2%,12.51% and 16.37% at the age of 3, 7 and 28 days respectively.

### 4.3 Split tensile strength

The test cylinders were tested for their tensile strength values at the age of 3, 7 and 28 days are as shown in figure.6.

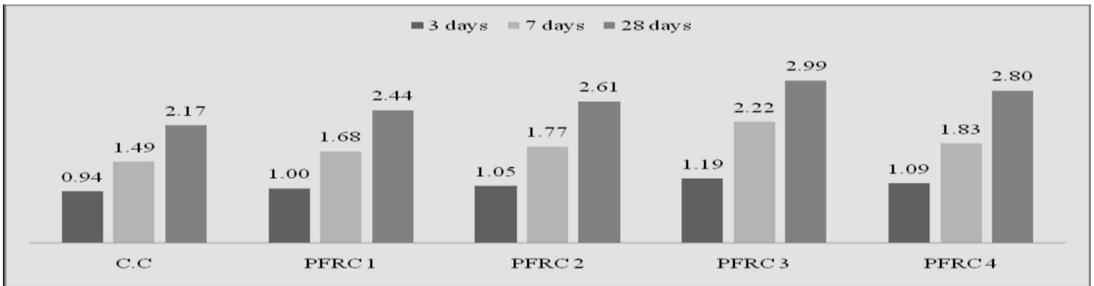


**Fig.no.6**:- Type of mix vs. Split tensile strength (N/mm$^2$) at 3, 7& 28 Days

From the above graph it is observed that tensile strength of P.F.R.C mixes is increasing significantly when it is compared with conventional concrete at 3, 7 and 28 days.It is found that 0.3% addition of polyester fibers in the weight of cement is the optimum doasge. For this optimum doasge the increment in the tensile strength of the fiber concrete is 26.59%,48.99% and 37.78% at the age of 3,7 and 28days respectively.

**4.4 Flexural strength**

The prism specimens were tested for their flexural strength using UTM, the results were shown in fig.7

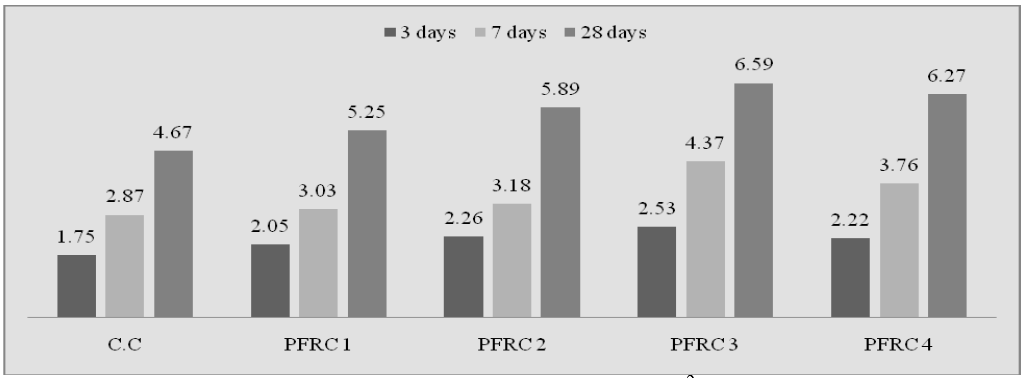


**Fig.no.7**:- Type of mix vs. Flexural strength ($N/mm^2$) at 3, 7& 28 Days

From the above fig. it is observed that the flexural strength of concrete is increasing drastically with the increase in fiber content compared to conventional concrete at 3, 7 and 28 days.It is observed that at 0.3% of fiber dosage in the weight of cement, maximum strength is obtained and later strengths are reduced, although the fiber content is increased. This is evident from the figure.7 at 0.4% fiber content.The increment in the flexural strength at 0.3% fiber content is 44.57%,52.27% and 41.13% at the age of 3, 7 and 28 days respectively.

**4.3 Design of slab thickness**

Pavement slab is designed as per IRC 58:2002. The flexural strength is directly taken from the beam flexural test. The axial load spectrum is taken from IRC: 58-2002 and other data used in this design is given below:

A cement concrete pavement is to be designed for a two lane two-way National Highway. The total two-way traffic is 3000 commercial vehicles per day at the end of the construction period. The design parameters are:

| | | |
|---|---|---|
| Effective modulus of subgrade reaction of the DLC sub-base | = | 8 $kg/cm^3$ |
| Elastic modulus of concrete | = | $3\times10^5$ $kg/cm^2$ |
| Poisson's ratio | = | 0.15 |
| Coefficient of thermal expansion of concrete | = | $10\times10^{-6}/^0C$ |
| Tyre pressure | = | 8 $kg/cm^2$ |
| Rate of traffic increase | = | 0.075 |
| Spacing of contrction joints | = | 4.5 m |
| Width of slab | = | 3.5 m |
| Design life | = | 20 years |
| Present traffic | = | 3000 cvpd |

By the considering the above parameters the thickness of the pavement is calculated by taking flexural strength of conventional concrete and as well as polyester fiber reinforced concrete at 0.3% fiber content . From the results slab thickness, fatigue life consumed and corner stresses are given in following table.2.

**Table No.2** Variation in the thickness in concrte mixes.

| Grade of concrete (M20) | Flexural strength ($kg/cm^2$) | Slab thickness | Fatigue life consumed | Corner stress ($kg/cm^3$) |
|---|---|---|---|---|
| C.C | 46.7 | 31 | 0.98 | 17.17 |
| PFRC | 65.9 | 25 | 0.83 | 23.85 |

## V. Conclusions

1. Compressive Strength enhancement ranges from 8.38% to 16.37% when % of fiber increases from 0.1% to 0.3% for PFRC when compared to the conventional concrete at 28 days.
2. As the fiber content is increased from 0.1% to 0.3% in weight of cement there is an increase in the split tensile strength from 12.44 to 37.78% compared to the conventional concrete at 28 days.

3. At the age of 28 days, there is a significant improvement in the flexural strength with the addition of fibers. The increment in the flexural strength is from 12.42% to 41.13% when % of fibers varied from 0.1% to 0.3% respectively. 0.3% is observed as the optimum value**.**
4. Addition of polyester fiber in concrete, the pavement thickness is decreased by 20% and which is economical when compared to plain cement concrete.

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