Investigation of Flexural Strength of Steel Fibre Reinforced Concrete Beams

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Abstract : As a universal truth, concrete is weak in tension, it has less ductile property and little resistance to cracking. Hence Fiber Reinforced Concrete is being used popularly against PCC (Plain cement concrete) which gives more ductility, resistance to cracking and strengthening of concrete. Due to the richer flexural strength property of fiber reinforced concrete, it can act as crack arrester.An attempt is made in this dissertation work to investigate experimentally the performance of fiber reinforced concrete with regard to compressive strength and flexural strength by varying the percentage of steel fibers. The percentage variation of steel fiber from 0%, 1%, 2%, 3% and 4% by weight of concrete is added in the designed mix concrete of M-25 grade.

The type of Steel fiber used is of hooked end of aspect ratio 66.67. The cubes and prism were cured for 7, 14 and 28 days and tested to understand the compressive strength and flexural strength.

Model RCC (Reinforced cement concrete) beams of 700X150X150mm with nominal longitudinal reinforcement and shear reinforcement with a layer of steel fiber provided at 5cm from bottom of beam unidirectional with varying percentages of steel fibers (0% to 4%) were cast and cured for 28 days. The beams were tested under two point loading system and load deflection characteristics are recorded.

It is observed that the beams having a layer at 5cm level have shown excellent ductility characteristics giving sufficient warning before complete failure.

IndexTerms - **Steel fibers, flexural strength, compressive strength, aspect ratio.**

I. INTRODUCTION

Steel Fiber Reinforced Concrete is a new innovation and technique used in concrete; it has developed through wide researches and developed work from last two decades. And it is proved that, it is the best suited construction material having ultimate performance properties when compared to conventional concrete. Incorporation of fibers use in concrete helps to perform the concrete better against cracking, ductility, fatigue, impact and wear.

A Fiber Reinforced composite material is made with varying amount of particular fiber reinforcement mass in a protective material, which is called matrix. Fiber Reinforced Concrete is extensively used in various construction work such as airport pavements, bridge decks, machine foundations, blast resistant structures, hip- hulls and storage tanks etc

The Steel Fiber Reinforced Concrete has found number of new applications in the past two decades due to its superiority over conventional concrete and RCC among following properties; rich flexure strength, higher tensile strength, modulus of rupture, better shear strength, better ductility, fatigue and more.

Since concrete is used as most common structural material, it possesses very negligible tensile strength, less ductility and little resistance against cracking.

From several years together the compressive strength of concrete increased relatively, but not many researches have been done to improve the tensile strength on other hand. Compressive strength up to 80 N/mm2 has been achieved very easily in present days. The flexural strength of same concrete would be very less. Due to these reasons it is difficult for concrete to meet the serviceability properties of deflection as well as cracking.

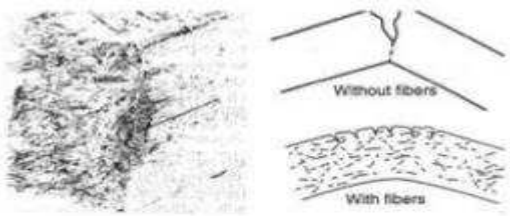


Fig 1: Effects of Fibers

Figure 1 indicates that specimen behavior with fiber and without fiber. Steel fibers are used in concrete to overcome these problems. Incorporating short discrete crack propagates into slow controlled growth`, this gives cement based material more ductility over coming its low tensile strength.

Fig 2. Different types of fibres

i) STEEL FIBERS

Steel fibers(SF) are manufactures fibers; use of steel fibers in concrete is an alternative way to the normal steel bars or welded fabrics. This concept was developed many years ago, but its existence taking place nowadays is in extensive range, the very first patent on this has applied in 1874. This innovation was being used during World War II in patching of bomb craters in runways. However this development was mainly happened from developed countries like Europe, Japan and USA, in their advanced structures.

Today the major application of steel fiber is in industrial floors and pavements. In United Kingdom several million m2 of slabs made with steel fiber reinforced concrete were used over the many years together, for ground supported floor as well as pile supported floor.

Other important applications of steel fiber reinforced concrete are paved areas, sprayed concrete and precast elements.

Steel fibers are extensively used in ground floor slabs on piles, to replace more. By using these we can avoid misplacement of normal steel in the depth of the slab.

ii) TYPES OF STEEL FIBRES

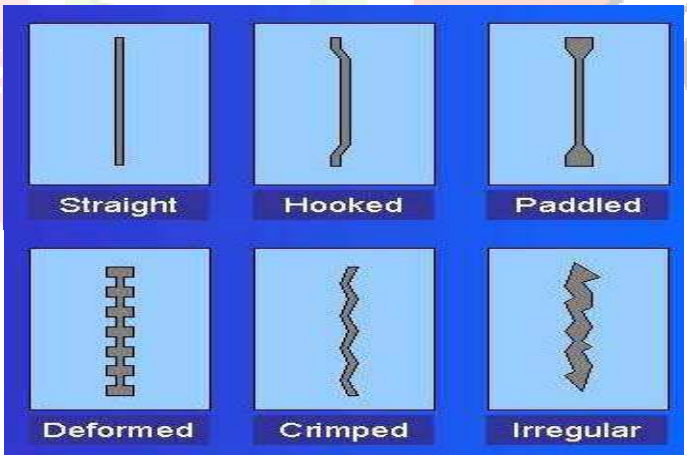


Fig 3:Different forms of Steel fibers

ii) HOW STEEL FIBERS AFFECT THE CONCRETE

In general fibers are introduced in concrete to reduce cracking due to both drying shrinkage and plastic shrinkage. These also have tendency to minimize permeability in concrete, and it resulting in less bleeding. Total amount of fibers added to the concrete is demonstrated in terms of % of total volume of the compound, compound is nothing but concrete and fibers. This volume is indicated as Vf and ranges from 0.1%to 3%. Aspect ratio can be determined by dividing diameter of steel fiber by its length (l/d). If the young's modulus of the fiber is greater than binder, that will helps to carry the maximum load by gaining the tensile strength. Studies on this discipline shown that use of micro fibers are better impact resistance Medias than long fibers.

II. RESEARCH METHODOLOGY

The methodology carried out overall consists of the various percentages of steel fibers are used to find the optimum mix and to get the maximum flexural strength, such SF's percentage ranges from 0% (conventional concrete) to 4% with random mix, and 5cm layer and both 5cm and 10 cm layers are taken. In this hooked end steel fibres are used. The steel fibers quantity are calculated by the weight of the concrete. The grade of concrete is considered is M25 and aspect ratio of steel fiber was 66.67, length was 30mm and diameter was 0.45mm. Workability test was carried out for each trial mix, and compressive strength, and flexural strength is observed by using CTM and UTM respectively

i)MATERIALS USED

a) Cement

Birla super 53 grade OPC confirming to IS 12269 is utilized in this project, having specific gravity of 3.15 and a physical property of cement was tested under specified codal provision.

b) Fine aggregate

Fine aggregate of M-sand, which is got from locally available source having the specific gravity of 2.58 and water absorption of 7.47%, this sand of zone II, confirming to IS 383-1970 was used.

c) Coarse aggregate

Coarse aggregate of 20mm down size confirming to IS 383-1970 is taken from nearest source, having the specific gravity of 2.69 and water absorption was 0.705%.

d) Steel Fiber

Steel fiber having proper composition of chemical and having density of 7980 kg/m3 is obtained from Stewols India private limited, Nagpur. Test results are as per ASTM.

e) Super plasticizer

Poly carboxylic based eather, in the form of viscous fluid of dark brown color and having the pH of 6.6 is taken in this practice.

ii)TESTS CONDUCTED DURING DISSERTATION WORK

a)WORKABILITY

b) COMPRESSIVE STRENGTH

The calculation of compressive strength for cubes is given by,

$$\text{Compressive strength} = \frac{\text{Ultimate load (N)}}{\text{Area of cross section } (\text{mm}^2)}$$

c)FLEXURAL STRENGTH

Calculation of flexural strength for prisms and beams is given by formula,

$$f_{bt} = \frac{Pl}{bd^2}$$

III.EXPERIMENTAL PROGRAM

In this division, detail explanation of initial tests have conducted is tabulated, and results of flexural strength and compressive strength is noted down to compare for different replacement of steel fiber. Initial tests are carried out to find physical properties of the ingredients, such as specific gravity, water absorption, and bulk density of coarse aggregate. Normal consistency, initial setting time, specific gravity, of cement. Specific gravity and moisture content of fine aggregate. Chemical composition of steel fiber, physical characteristics of super plasticizer is conducted during the experimental work.

Chemical and Mechanical Properties of Steel Fiber

Chemical property	**Composition**
Carbon	0.030
Manganese	0.3300
Silicon	0.035
Phosphorus	0.014
Sulphur	0.009
Mechanical properties	**Composition**
Size	0.45mm dia
Length	30mm
Aspect Ratio	66.67
Tensile strength	1179MPa
Density	7.98gm/cc
Tolerance for diameter and length	(+-) 10%(As per ASTM)

Fig 4 :Steel Fibres

i).REINFORCEMENT DESIGNING

The beam of size 150mmx150mmx700mm is considered and reinforcement is provided to it.
The percentage of Steel Fibres is taken as 0% to 4% as a layer of 5cm to the beam during casting.

Steel (Main bars)	3 no's of 10mm dia
Steel (Nominal bar)	2 no's of 8mm dia
Steel (Stirrups)	8mm dia @ 200mm c/c

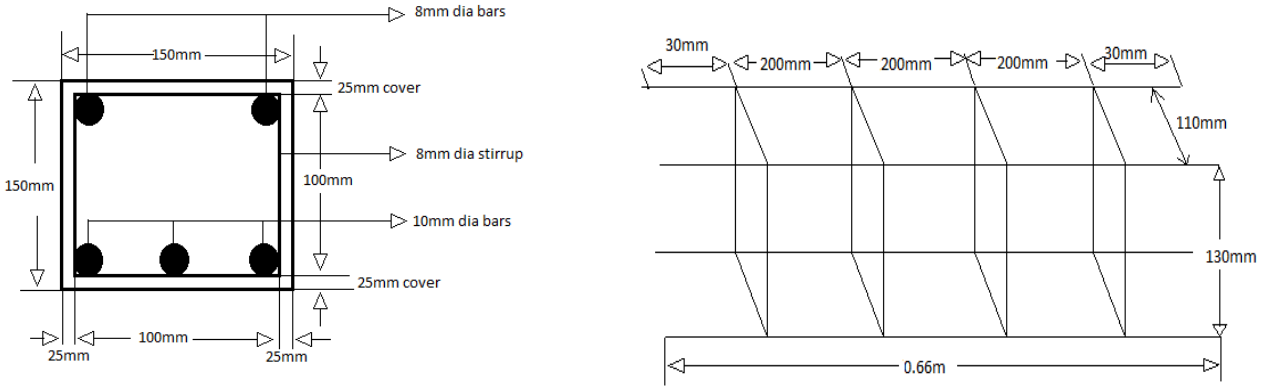


Fig 5:Reinforcement details

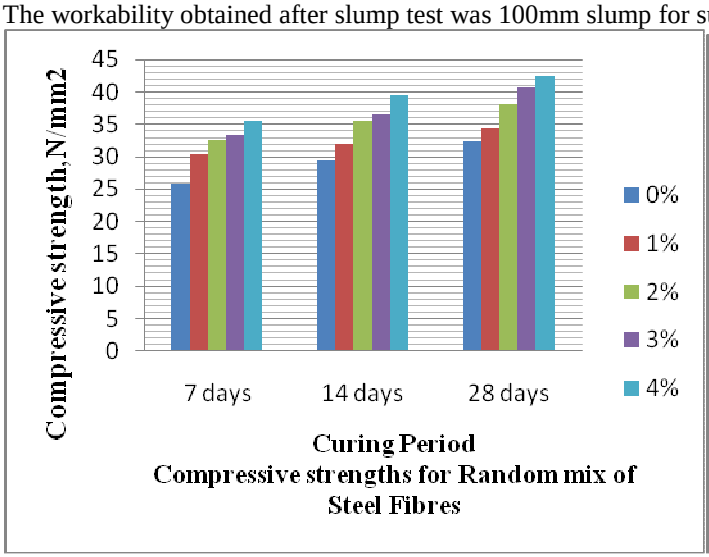
IV. RESULTS AND DISCUSSION

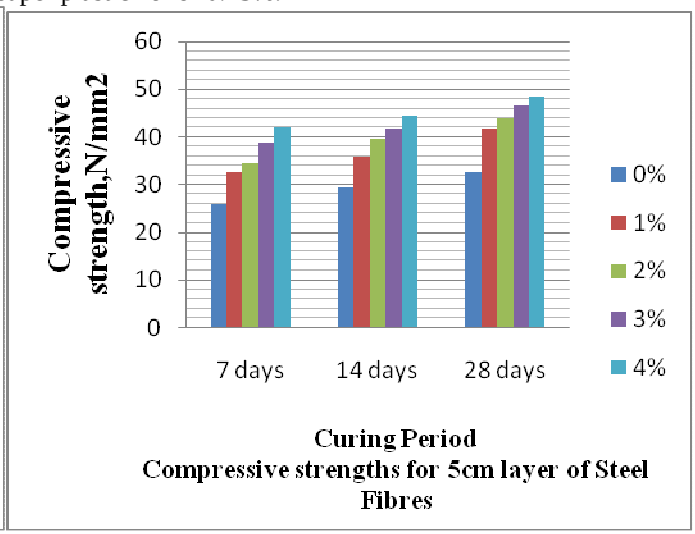
The Steel Fibres of 0%, 1%, 2%, 3% and 4% by the weight of concrete are used with various parameters of mixing with concrete during casting as random mix, 5cm layer, 5cm and 10cm layer for cubes and for prisms, the parameters are with random mix and 5cm layer.

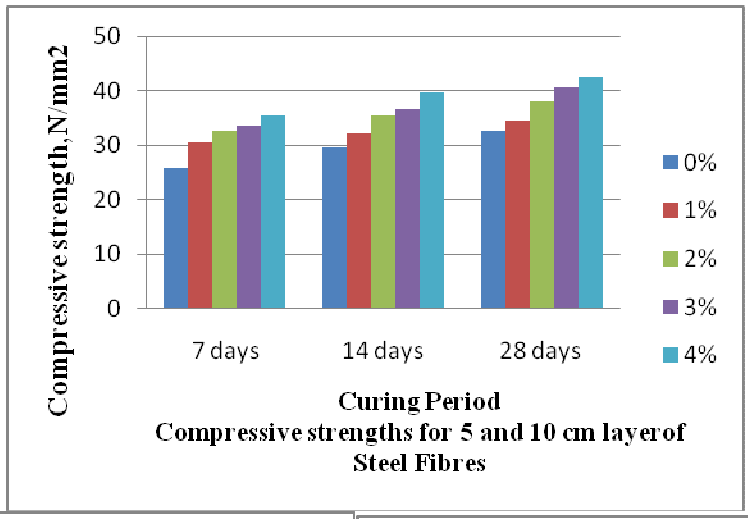
After testing for all specimens for compressive strength for cubes and flexural strength for prisms, the results are more for parameter of 5cm layer of Steel Fibres for both cubes and prisms when compared to random mix, 5cm and 10cm layer.

So by taking 5cm layer will give best results, the beams were casted with 5cm layer of Steel Fibres of 0%, 1%, 2%, 3%, 4% of beam size 150mmx150mmx700m and there cracking load, ultimate load and deflection are calculated.

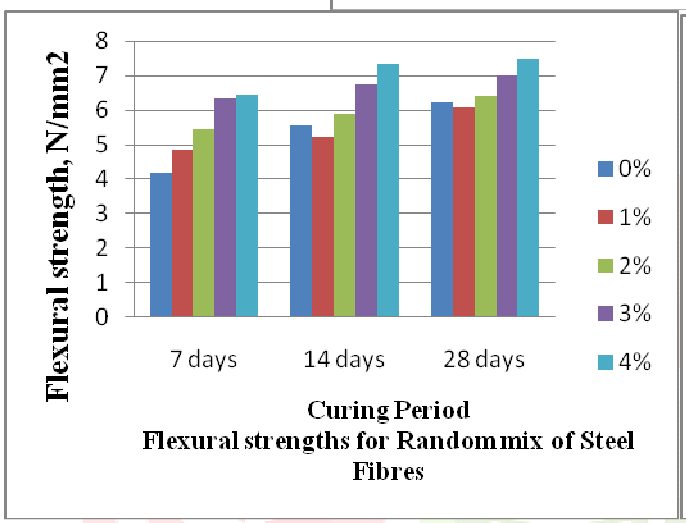
The workability obtained after slump test was 100mm slump for super plasticizer of 0.45%.



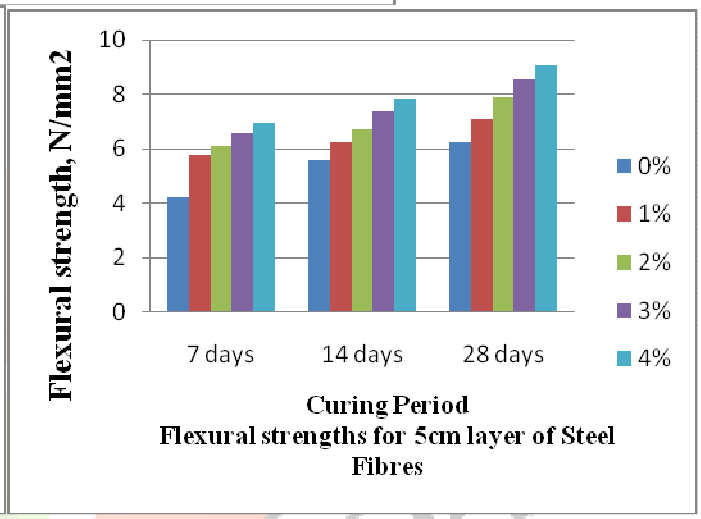




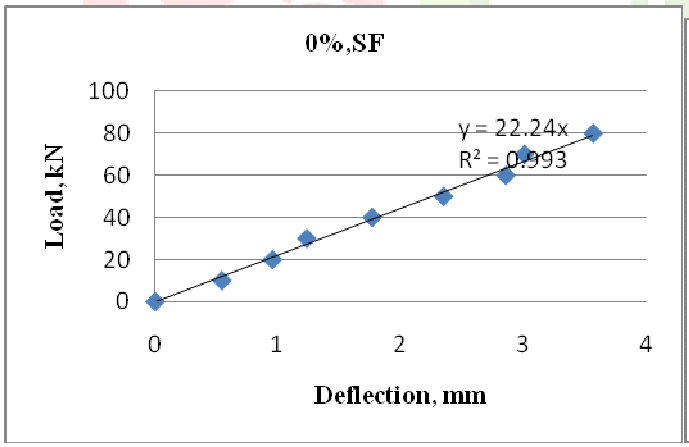
Compressive strengths for 5 and 10 cm layer of Steel Fibres

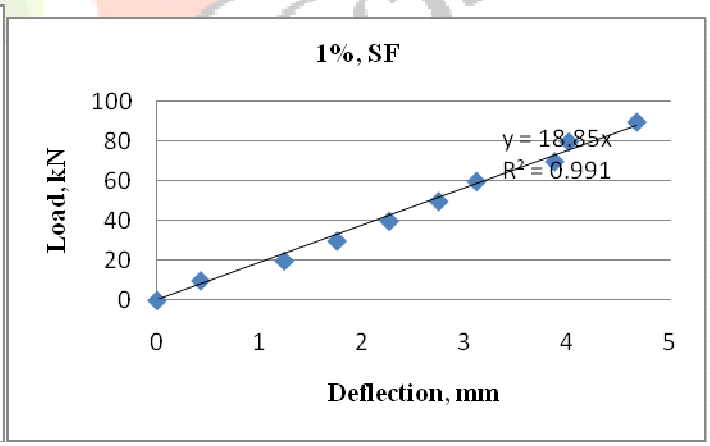


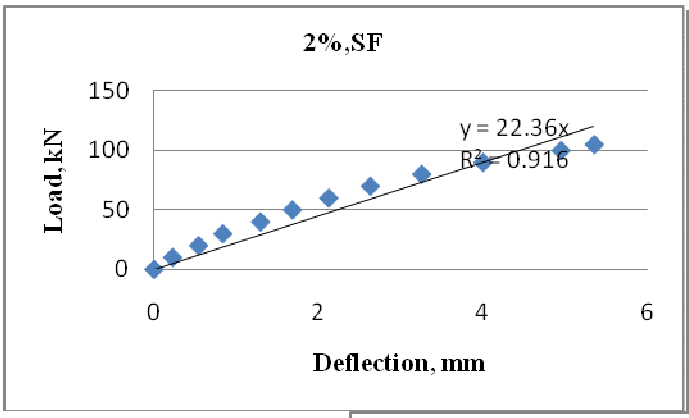
Flexural strengths for Randommix of Steel Fibres

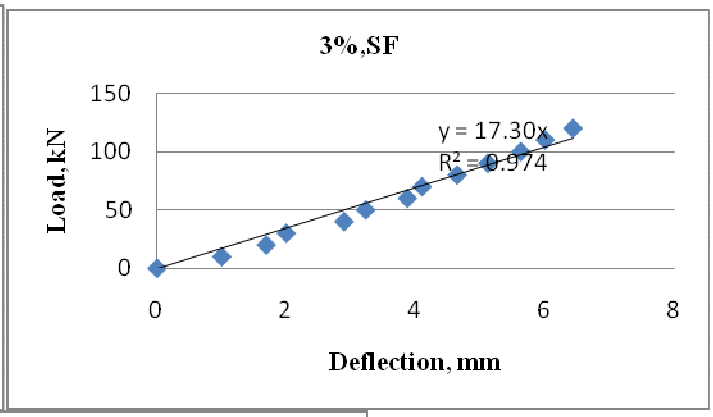


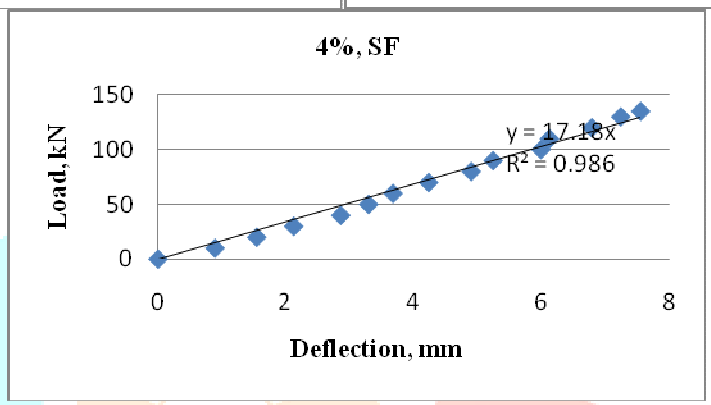
Flexural strengths for 5cm layer of Steel Fibres











Figures gives load vs deflection graphs which results are got after testing in Universal Testing Machine.
Also with load vs deflection, ultimate load, cracking load and cracking pattern were found out. In the figures, the curves are drawn by using the regression curves by taking linear case.
After studying the graphs, the graph give regression value should be 1or to near to 1 and for y axis a equation is got which can be used for checking the at a particular deflection. With the increase in load, deflection will be increasing ad after achieving the ultimate load it will reduce the load.

4.1 Results of Descriptive Statics of Study Variables

1)The increase in percentage of Steel Fibers increases the compressive strength and also increase the flexural strength. So percent of Steel Fibres are considered by the weight of concrete to give more strength and ductility.

2) Steel fibres gives more toughness to arrest cracks and also increases extensibility and tensile strength, both at first crack and at ultimate load during flexural loading and has ability to hold the matrix together even after extensive cracking.

3) The workability of Steel Fiber Reinforced Concrete gets reduced as percentage of Steel Fibres increases.

4) The compressive strength is more, for 5cm layer placement of steel fiber mix proportion when compared to random mix, 5cm and 10cm layer of SF proportion mix and 5cm layer gave more binding properties and also resistance to binding.

5) For 5cm layer of steel fiber prism, improves the compressive strength by adding more quantity of steel fiber. 4% steel fiber replacement has shown maximum result for all mix proportion.

6) While testing specimens, the plain cement concrete specimens i.e.0% of Steel Fibres have shown a typical crack propagation pattern which leaded into splitting of beam into two piece geometry. But due to addition of Steel Fibres in concrete, cracks gets ceased which results into ductile behavior of SFRC.

7) Ultimately we can conclude that, increase in percentage of steel fiber will give the better result.

FiguresandTables

Compressive strength (N/mm2) (Cubes)

Parameters	0%			1%			2%			3%			4%		
No of Days	7	14	28	7	14	28	7	14	28	7	14	28	7	14	28
Random mix	25.78	29.47	32.44	30.4	32	34.35	32.65	35.44	38.07	33.4	36.6	40.56	35.48	39.57	42.44
5cm layer	25.8	29.5	32.4	32.6	35.8	41.7	34.4	39.6	43.8	38.6	41.77	46.52	42	44.5	48.57
5 and 10cm layer	25.78	29.47	32.44	31.4	33	34.35	33.75	35.44	37.07	34.4	37.6	40.86	36.48	40.57	42

Flexural Strength (N/mm2) (Prisms)

Parameters	0%			1%			2%			3%			4%		
No of Days	7	14	28	7	14	28	7	14	28	7	14	28	7	14	28
Random mix	4.2	5.56	6.07	4.87	5.24	6.24	5.45	5.88	6.43	6.33	6.74	7.01	6.46	7.34	7.48
5cm layer	4.2	5.56	6.07	5.74	6.24	7.06	6.07	6.72	7.86	6.55	7.36	8.52	6.95	7.81	9.06

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