International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

AN INVESTIGATIONAL APPROACH ON SIGNIFICANT CHANGES IN STRENGTH OF CONCRETE WITH PARTIAL SUBSTITUTION OF STEEL AND BAMBOO FIBRES

DILEEP TOLETI[1], CH. SOWMYA[2]

[1]*M. Tech Student, Department of Civil Engineering, Lingayas Institute of Management and Technology, Andhra Pradesh, India.*
[2]*Assistant Professor, Department of Civil Engineering, Lingayas Institute of Management and Technology, Andhra Pradesh, India.*

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Abstract - *There is a growing awareness of the advantages of fibre reinforcement techniques of construction all over the world. Even though concrete possesses several desirable properties, its relatively low tensile strength and deformation properties prompted many researchers to work on to improve these properties. One such development of improving or modifying the brittle characteristics of concrete is by supplementing the concrete matrix with fibre reinforcement. STEEL FIBRES Reinforced Concrete has become very popular due to its exceptional mechanical performance compared to the conventional concrete. This paper aims to have a comparative study between ordinary reinforced concrete and STEEL FIBRES reinforced concrete. Experimental investigations and analysis of results were conducted to study the compressive & flexure strength behaviour of composite concrete with varying percentage of such fibres added to it. The concrete mix adopted were M40 (1: 2.537: 3.531) with varying percentage of fibres ranging from 0, 0.5, 1.0, 1.50, 2.0, 2.5 & 3.0 by volume, slump, Compressive and Split tensile strength tests were performed on fresh and hardened concrete. On the analysis of test results the concrete with turn STEEL FIBRES and BAMBOO FIBRES had improved performance as compared to the concrete with conventional fibres which were readily available in market. Comparing the result of FRC with plain M40 grade concrete, this paper validated the positive effect of different fibres with percentage increase in compression and splitting improvement of specimen at 28 days, analyzed the sensitivity of addition of fibres to concrete with different strength. 28 days peak compressive & split strength values are 50.25N/mm^2 & 4.95N/mm^2 respectively was obtained when alternatively increase the percentage also increase the strength for best results obtained from 2%.*

Key Words: **Fibres Reinforcement, Steel Fibres, Bamboo Fibres, Partial Substitution, Strength Analysis, Comparison of Strength.**

1. INTRODUCTION

The plain concrete possesses a very low tensile strength, limited ductility, and little resistance cracking. Concrete is a brittle material, addition of fibres to concrete makes it homogeneous and isotropic and converts it brittle to more ductile material. Since ancient times FRC has been replaced with plane concrete which is brittle material while it continuous which improves one or more properties of concrete, are used at present time. Fibres are usually used in concrete to control plastic shrinkage & drying shrinkage and cracking. Generally, FRC can be regarded as a composite material with two or more phases in which concrete represents the matrix phase and the fibre consistent the inclusion phase. The various types of fibres are steel fibres, glass fibres, synthetic fibres and natural fibres. Concrete containing hydraulic cement, water, aggregate and fibres is called fibre reinforced concrete. These fibres can lead to useful improvements in the mechanical behavior of tension weak concrete. Moreover, reinforcement of two or more types of fibres can be referred as the concept of hybridization. Therefore, the presences of one fibre provide a suitable condition for other fibre to use its potential properties.

Concrete is weak in tension and has a brittle character. The concept of using fibres to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete increases strength and ductility, but requires careful placement and labour skill. Alternatively, introduction of fibres in discrete form in plain or reinforced concrete may provide a better solution. The modern development of fibres reinforced concrete (FRC) started in the early sixties. Addition of fibres to concrete makes it homogeneous and isotropic material. When concrete cracks, the randomly oriented fibres start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fibres or matrix or material failure. In this paper, the state-of-the-art of fibres reinforced concrete is discussed and results of intensive tests made by the author on the properties of fibre reinforced concrete using local materials are reported.

1.1 Fibre Reinforced Concrete

Fibre-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres – each of which lends varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities.

Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post cracking "ductility". If the fibres are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post cracking stage.

The concept of using fibres as reinforcement is not new. Fibres have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks In the 1900s, asbestos fibres were used in concrete. In the 1950s, the concept of composite materials came into being and fibre-reinforced concrete was one of the topics of interest. Once the health risks associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibres such as polypropylene fibres were used in concrete. Research into new fibre-reinforced concretes continues today.

1.2 Effect of Fibres in Concrete

Fibres are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact–, abrasion–, and shatter–resistance in concrete. Generally, fibres do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete.

The amount of fibres added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed "volume fraction". Typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fibre's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres that are too long tend to "ball" in the mix and create workability problems. Some recent research indicated that using fibres in concrete has limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that ductility increases when concrete is reinforced with fibres. The results also indicated that the use of micro fibres offers better impact resistance to that of longer fibres.

2. OBJECTIVES OF STUDY

The main objectives of the study with the incorporation of steel and bamboo fibres in the normal concrete were:

- The main objective of this investigation was to make concrete a brittle material to slightly improved ductile material by adding external source of material.
- With the help of this external source of material, the fibres the overall tensile strength in concrete can be improved.
- Incorporation of steel and bamboo fibres in concrete by percentile substitutions.
- To find the mechanical properties of steel fibre reinforced concrete and bamboo fibre concrete with (0%, 0.5%, 1%, 1.5%, 2%, 2.5% & 3%) substitution in reinforced concrete for M40 grade of concrete.
- Investigating the strength behaviour of concrete by the percentile inclusions of fibres in concrete and evaluating strength for 7days,14 days & 28days of curing.

3. MATERIALS AND PROPERTIES

3.1 Steel Fibres

Steel fibre reinforced concrete (SFRC) is made with hydraulic cements and containing fine and coarse aggregates along with discontinuous discrete steel fibres. Steel fibres are obtained by cutting draw wires. Fibres can be crimped shaped in irregular order to provide better mechanical bonding. Steel fibres are short, length is discrete and has an aspect ratio in the range 20-100 with diameter ranging between 0.15mm to 1mm. when steel fibres are added to concrete mix, they are uniformly distributed and randomly dispersed. This is called steel fibre reinforced concrete. When compared to plain concrete SFRC shows increase in impact, strength, toughness, ductility, tensile toughness and flexural strength properties. But creep and shrinkage are unaffected by adding steel fibre. SFRC is very effective in controlling the cracks, and also improves impact and abrasion resistance. The SFRC is used in refractory linings, blast resistance structure, tunnel linings, pavements and precast concrete unit. Balling or clumping is a problem when these fibres are used in concrete in higher percentages and for aspect ratios greater than 100.

Table 2.1: Physical Properties of steel fibre

Property	Value
Type of steel fibre	Crimped
length of fibre	30mm
Diameter	0.5
Aspect ratio	60
Tensile strength (Mpa)	280-2800
Young's modulus (Gpa)	203
Ultimate elongation	0.5-3.5%
Specific gravity	7.8

3.2 Bamboo Fibres

Bamboo has been widely used for many purposes. Mainly as a strength bearing material. It is also used for building shelters from an earlier time. Bamboo has used for scaffolding works, formwork supporting stands and many in building construction works. These are limited to medium-large projects.

Bamboo is a multipurpose reserve categorized by large ratio of strength to weight and its ease of work with simple tools. It is one of the rapidly growing natural reserves also it is easily and locally available. Bamboo had been using for construction even from early times. It can be used as Technical and Non-Technical ways. For building the houses our forefathers used Bamboo as basic material. Because of its high strength to weight ratio, traditionally it has been used in varied living facility and tools. This property is due to the longitudinal alignment of fibres.

Bamboo fibres have better modulus of elasticity than any other natural material. The longer is the fibre the higher it gives the tensile strength. Addition of Bamboo fibres to the concrete elevates the mechanical strength and tensile strength. It has low specific weight too. As the bamboo fibres are susceptible to the biological attacks; that is from fungus, termites etc. It was given treatment of Wood Guard's anti-termite solution. In practice, in addition to the extraction of bamboo fibres in controlled way from bamboo trees it is mandatory to fabricate the bamboo-based composites.

Table 2.2: Physical Properties of Bamboo fibre

Property	Value
Strength (g/tex)	34.3
Elongation	16.0
Short fibre index (12.7mm)	5.58
Uniformity index (%)	92.7
UHML (mm)	38.745
ML (mm)	35.62
Moisture (%)	6.5
Micron aire	4.0

3.3 Cement

Ordinary Portland cement available in the local market of standard brand of 53 grade confirming to IS 12269 - 1987 was used for the concrete mix. The cement should be fresh and of uniform consistency and there is no evidence of lumps or any foreign matter in the material. The cement should be stored under dry conditions and for as short duration as possible. The physical properties obtained from various tests are listed in Table 3.3. All tests are carried out in accordance to procedure laid in IS 1489 (Part 1): 1991

Table 3.3: Physical Properties of cement

S. No.	Property	Value Obtained Experimentally	Value as per IS: 1489-1991
1.	Normal Consistency	29%	-
2.	Soundness	3.7	Not >10
3.	Initial setting time	45min	Not<30
4.	Final setting time	217min	Not >600
5.	Specific gravity	1685.66kg/m3	-

3.4 Fine Aggregate

Local sand was used as fine aggregate in concrete mix. Properties such as void ratio, gradation, Specific gravity, Fineness modulus, free moisture content, Specific surface and bulk density have to be assessed to design a dense HSC mix with optimum cement content and reduced mixing water. The physical properties and sieve analysis results of sand are shown in Table 3.4.

Table 3.4: Physical Properties of Fine Aggregate

S. No.	Property	Value Obtained
1.	Specific gravity	2.51
2.	Bulk density	1.5
3.	Fineness modulus	2.16
4.	Water absorption	1.8%
5.	Grading Zone	Zone II

3.5 Coarse Aggregate

Crushed stone aggregate of 10mm size were used for concrete. Properties such as void ratio, gradation, Specific gravity, Fineness modulus, free moisture content, Specific surface and bulk density have to be assessed to design a dense HSC mix with optimum cement content and reduced mixing water. The physical properties and sieve analysis results of coarse aggregate are shown in Table 3.5.

Table 3.5: Physical properties of Coarse Aggregate

S. No.	Property	Value Obtained
1.	Type	Crushed
2.	Specific gravity	2.74
3.	Fineness modulus	2.64
4.	Water absorption	1.58%
5.	Bulk Density	1.42

3.6 Water

Water conforming to the requirements of BIS: 456-2000 is found to be suitable for making HSC. It is generally stated that water fit for drinking is fit for making concrete. The water used is potable water collected from laboratory taps and satisfies the code IS 3025:1984. Water cement ratio of 0.45for M40 grade of concrete was adapted in the experimental program.

4. MIX DESIGN

Design stipulations

Grade Designation = M40

Type of cement used = OPC 53 grade confirming to IS 8112

Aggregate size = 20mm

Minimum cement content = 320 kg/m^3

Maximum water - cement ratio = 0.45

Workability = 100 mm

Exposure condition = severe (for R.C)

Type of aggregate = crushed angular concrete

Specific gravity of cement = 3.15

Specific gravity of F.A. = 2.66

Specific gravity of C.A. = 2.70

Step 1: Target mean strength for mix proportioning

$f'_{ck} = f_{ck} + 1.65s$

= 40 + 1.65 x 5

= 48.25 N/mm^2

Step 2: Selection of water-cement ratio

From table 5 of IS 456, Maximum water - cement ratio is 0.50

Based on experience, adopt water - cement ratio as 0.45

Hence OK

Step 3: Selection of water content

From table 2 of IS 10262, maximum water content for 20 mm aggregate =

186 litres (for 25 to 50mm slump range)

Estimated water content for 100 mm slump = 186+186*(6/100)

= 197 litres.

water content arrived =197×0.75=148liters

Therefore, the selected water content = 148 litres.

Step 4: Calculation of cement content

Water - Cement ratio = 0.45

Cement Content = 148/0.45= 328.889 kg/m^3

From table 5 of IS 456, minimum cement content for 'Severe' exposure condition = 320 kg/m^3

328.889>320, Hence OK

Step 5: Proportion of volume of coarse aggregate and fine aggregate content

From table 3 of IS 10262, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (zone - II) for water cement ratio of 0.50 = 0.62

In the present case water-cement ratio = 0.45

Volume of coarse aggregate content = 0.58

Volume of fine aggregate content = 1 - 0.58 = 0.42

Step 6: Mix calculations

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1.000 m^3

b) Volume of cement $\frac{329}{3.15} * 1000 = 0.104$ m^3

c) Volume of water = $\frac{197}{1000}$ = 0.197m^3

d) Volume of all in aggregate = a - (b + c)

= 0.104+0.148 = 0.748 m^3
e) Mass of coarse aggregate= d * volume of coarse aggregate x
sp. gravity of coarse aggregate * 1000
= 0.748* 0.58 * 2.7 * 1000
= 1171.368 kg/m^3.
f) Mass of fine aggregate = d x vol. of fine aggregate x Specific gravity of fine aggregate x 1000
= 0.748 x 0.42 x 2.66 x 1000
= 835.66 kg/m^3.

Step 7: Final Mix Proportions

Weight of cement = 329kg/m^3
Weight of fine aggregate = 835.66kg/m^3
Weight of coarse aggregate = 1171.368 kg/m^3
Water Content = 148litres

Mix Proportion

Cement	F.A.	C.A.	W/C
1	2.537	3.531	0.45

5. TESTS AND RESULTS

5.1 Tests on Workability

Slump Cone Test

Slump cone test is a very common test for determination of workability of concrete. This test was carried out for M40 grade concrete mix, before casting the specimens.

Compaction Factor Test

This test is more accurate than slump cone test and this test is used to determine the workability of low water cement ratio concrete more accurately. This test is conducted as per IS 1199-1959.

The slump cone test and compaction factor tests are conducted to determine the fresh properties of concrete. The slump and compaction factor values for different mixes of steel fibre i.e. (0%,0.5%,1%,1.5%,2%,2.5%,3%), Bamboo fibre (0%,0.5%,1%,1.5%,2%,2.5%,3%) and fibre (2%S &2%B) are given in the table 5.1 & 5.2.

Table 5.1: Fresh properties of different mixes of steel fibres

Mix	Slump (mm)	Compaction factor
M1 (0% S)	40	0.91
M2(0.5% S)	40	0.91
M3(1.0% S)	50	0.92
M4(1.5% S)	55	0.93
M5 (2.0%S)	60	0.95
M6 (2.5%S)	62	0.96
M7(3.0% S)	64	0.97

Table 5.2: Fresh properties of different mixes of Bamboo fibres

Mix	Slump (mm)	Compaction factor
M1 (0% B)	40	0.91
M2(0.5% B)	40	0.91
M3(0.1%B)	48	0.91
M4(0.1.5% B)	53	0.92
M5 (0.2%B)	58	0.93
M6 (0.25%B)	61	0.93

5.2 Test for compressive strength

The specimens of 100 X 100 X 100 mm cubes were placed in the compression testing machine such that the load was applied on the opposite sides of the cube. The axis of the cube was meticulously aligned with the center of steel plate of the test machine. The load was gradually applied without any shock and increased continuously at a rate of 140 kg/cm^2/min(approximately) until the resistance of the specimen to the increasing load broke down and no greater load was sustained. The compressive strength of the specimen was computed by dividing the maximum load received by the specimen with the cross-sectional area. Average of three test results of the specimen was considered as the compressive strength by ensuring the individual variation is not more than 15% of the average value.

Table 5.3: Compressive Strength of different mixes of steel fibre

S. No	Steel Mix	Average Compressive Strength, MPa		
		7 days	14days	28 days
1	0%	30.23	35.34	41.57
2	0.5%	33.15	39.15	44.28
3	1.0%	33.97	41.68	45.89
4	1.5%	34.84	42.60	48.32
5	**2.0%**	**35.63**	**43.02**	**50.25**
6	2.5%	32.65	41.23	48.36
7	3.0%	30.56	39.46	47.82

Graph 5.1: Compression strength of concrete vs. % of steel fibres

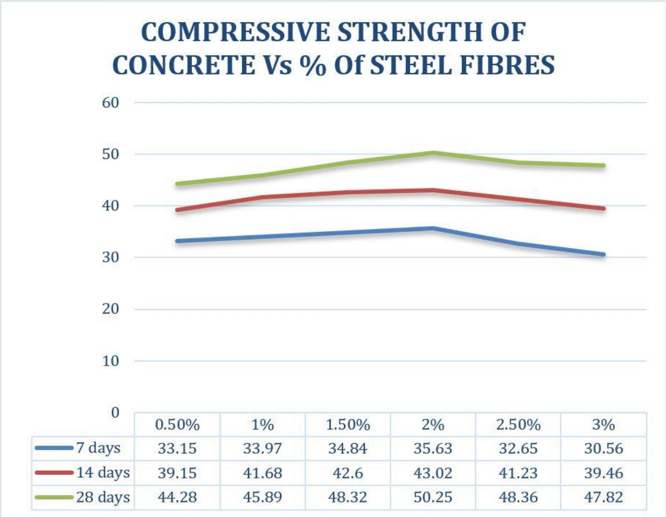
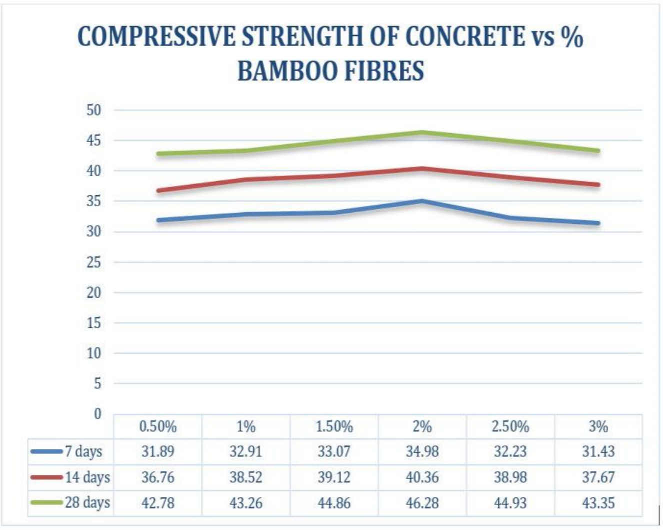


Table 5.4: Compressive Strength of different mixes of Bamboo fibre

S. No	Bamboo Mix	Average Compressive Strength, MPa		
		7 days	14days	28 days
1	0%	30.23	35.34	41.57
2	0.5%	31.89	36.76	42.78
3	0.1%	32.91	38.52	43.26
4	0.15%	33.07	39.12	44.86
5	**0.2%**	**34.98**	**40.36**	**46.28**
6	0.25%	32.23	38.98	44.93
7	0.3%	31.43	37.67	43.35

Graph 5.2: Compression strength of concrete vs. % of Bamboo fibres



5.3 Split Tensile Strength

This test is done to determine the Split tensile strength of concrete specimens as per IS: 516-1959.The splitting test is carried out on a standard cylinder specimen by applying a line load along the vertical diameter. Test should be done at recognized ages of the test specimens, usually being 3, 7, 14, 28, 60 days. The ages should be calculated from the time of the addition of water to the drying of ingredients.

Table 5.5: Split Tensile Strength of different mixes of steel fibre

S. No.	Steel Mix	Average tensile Strength, MPa		
		7 days	14days	28 days
1	0%	2.26	2.75	3.80
2	0.5%	2.52	2.90	4.53
3	1.0%	3.02	3.55	4.72
4	1.5%	3.21	3.95	4.80
5	**2.0%**	**3.52**	**4.02**	**4.95**
6	2.5%	2.31	3.89	4.60
7	3.0%	2.05	3.15	4.43

Graph 5.3: Split Tensile Strength of Concrete Vs. % of Steel Fibres

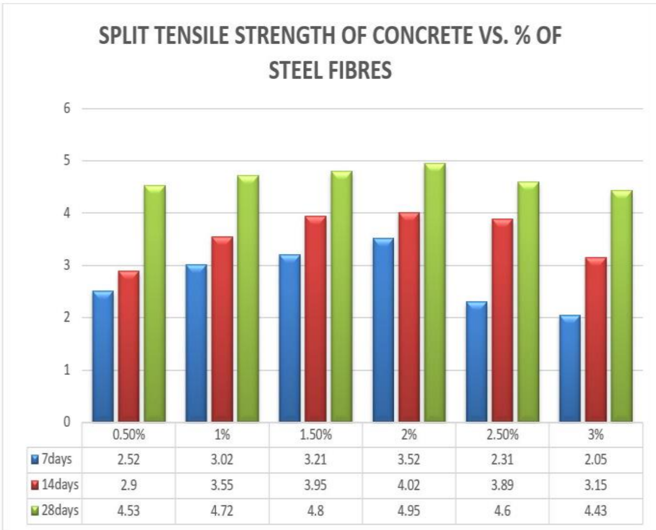
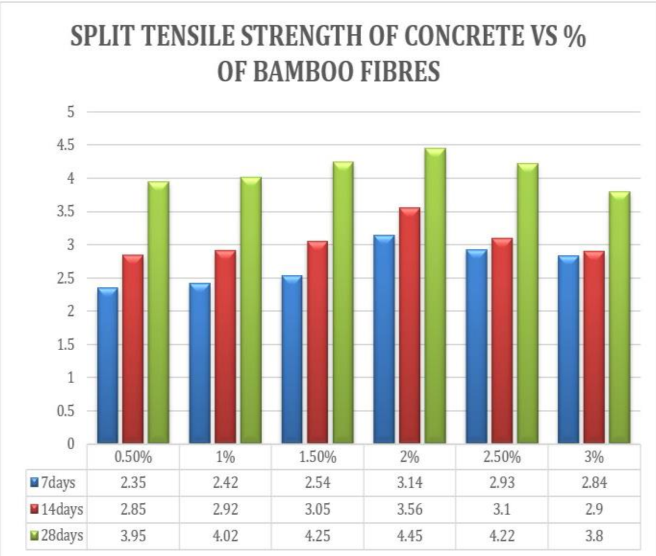


Table 5.6: Split Tensile Strength of different mixes of Bamboo fibre

S. No	Bamboo Mix	Average tensile Strength, MPa		
		7 days	14days	28 days
1	0%	2.26	2.75	3.80
2	0.5%	2.35	2.85	3.95
3	0.1%	2.42	2.92	4.02
4	0.15%	2.54	3.05	4.25
5	**0.20%**	**3.14**	**3.56**	**4.45**
6	0.25%	2.93	3.10	4.22
7	0.30%	2.84	2.90	3.80

Graph 5.4: Split Tensile Strength of Concrete Vs % of Bamboo Fibres



6. CONCLUSIONS

Based on the experimental investigation carried out, the following conclusions are made:

1. Maximum compressive strength of SFRC is 50.25Mpa achieved at 2% adding of concrete by steel fibres (M40grade). When compared to normal concrete it increases to 15%
2. Maximum compressive strength of BFRC is 46.28Mpa achieved at 0.20% adding of concrete by polypropylene fibres (M40grade). When compared to normal concrete it increases to 1.5%
3. Maximum split tensile strength of SFRC is 4.95Mpa achieved at 2% adding of concrete by steel fibres (M40 grade). When compared to normal concrete it increases to 13%
4. Maximum split tensile strength of BFRC is 4.45Mpa achieved at 0.20% adding of concrete by Bamboo fibres (M40 grade). When compared to normal concrete it increases to 11%.
5. When compared to normal concrete mono fibres give maximum resultant.

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BIOGRAPHIES

DILEEP TOLETI
P.G Student,
Department of Civil Engineering,
Lingayas Institute of Management and Technology, Andhra Pradesh.

CH. SOWMYA
Assistant Professor,
Department of Civil Engineering,
Lingayas Institute of Management and Technology, Andhra Pradesh.