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# Effectiveness of Bamboo Fiber as a Strength Enhancer in Concrete

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**Abstract:** Fibers are generally used as resistance of cracking and strengthening of concrete. Normally various fibers are used in the concrete mix to attain the desired strength and resistance. Recently, in the attention in response to global warming issues and sustainable society, the manufacturing, using natural materials has become actively in the developing countries. Bamboo, low cost, fast growing, and broad distribution of growth, is expected to contribute significantly to earthquake-resistant construction and seismic retrofit technology in the developing countries. The authors have been studied for understanding the mechanical behavior of bamboo fiber reinforced concrete member. From these experimental work, the possibility of effective using of 'Bamboo' is discussed. Similarly results were also obtained for different fiber aspect ratios, where again results showed there was an aspect ratio(40). An increase in fiber weight fraction provided a consistent increase in ductility up to the optimum content (1.0%) with corresponding fiber aspect ratio of 40. Overall the study has demonstrated that addition of Bamboo fiber to concrete leads to improvement of concrete strength the toughness torsion and the tensile stress, further work is however, required to assess the long term durability of concrete enhanced with Bamboo fibers.

***Keywords:*** *Bamboo fibers, Aspect ratio, compression strength, tensile strengths, torsion*

## 1. Introduction

The plain concrete possesses a very low tensile strength, limited ductility, and little resistance to cracking. In plain concrete and similar brittle materials, structural cracks (micro cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. Hence to overcome to all of these type problems the alternate ways like fiber reinforced concreting method has been used. Fiber reinforced concrete is a composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously depend upon the efficient transfer of stress between matrix and the fibers, which is largely dependent on the type of fiber, fiber geometry, fiber content, orientation, and distribution of the fibers, mixing and compaction techniques of concrete, size and shape of the aggregate.

The concept of fibers in a brittle mix was first recorded with Egyptians who used a hair of animals and straw as reinforcement for bricks and walls in housing[1]. These fibers will provides the various mechanical properties and design applications. Natural plant fibers such as a jute and kneaf are now widely used for automobiles as substitution for glass fibers [1]. However less potential exists to increase that fiber production on the earth since there is less land to cultivate for those natural plants. Therefore we have to find an alternative form which similar fibers are extracted. For that the solution is Bamboo, it is not grass neither wood, while it has two of their characteristics. Bamboo itself is a very strong in its longitudinal direction due to strong fiber bundles [1].

## 2. Experimental Investigations

The experimental investigations were carried out on test specimens using one basic mix proportion with three variations of aspect ratio of bamboo fibers and different weight fraction of Bamboo fiber.

### 2.1 Materials

#### *2.1.1. Cement*

Ordinary Portland cement-53 grade have used in investigation. The cement was tested according to IS 4031:1988. It confirmed to IS 12269:2004 and cement properties are shown in table.1

***Table 1:*** *Physical characteristics of cement (OPC 530grade)*

| No | Properties | Test Method | Test Results | Limitations As per IS 12269-2004 |
|---|---|---|---|---|
| 1 | Normal Consistency (in % | Vicat Apparatus (IS: 4031Part- 4) | 33% | 30 -35 % |
| 2 | Specific Gravity | Sp. Gr bottle (IS: 4031Part-4) | 3.12 | ≤ 3.15 |
| 3 | Initial Setting | Vicat | 40 Min | >30 |

| | | | | |
|---|---|---|---|---|
| | Time | Apparatus | | |
| 4 | Final Setting time | (IS: 4031 Part – 5 | 220 Min | <600 |
| 5 | Fineness of cement | Sieve test on 90μSieve (IS: 4031 Part-1) | 5.00% | < 10% |

### *2.1.2. Coarse Aggregates*

The aggregate of size greater than 4.75mm is considered as coarse aggregate. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, while rounded aggregates improve the flow because of lower internal friction.

Locally available crushed granite aggregate passing through 20 mm and retaining on 12.5mm was used for all of the mixes of concrete. The properties are shown in table 2.

***Table 2:*** *Physical characteristics of coarse aggregates*

| No | Physical properties | Results | Code of reference |
|---|---|---|---|
| 1 | Specific gravity | 2.65 | IS 2386 part 3-1986 |
| 2 | Water absorption | 0.15% | IS 2386 part 3-1986 |
| 3 | Bulk density(kg/m3) | 1366(loose)1439(rodded) | IS 2386 part 3-1986 |
| 4 | Finness modulus | 6.02 | IS 2386 part 2-1986 |
| 5 | Impact value | 9.76% | IS 2386 part 3-1986 |
| 6 | Loss angles abrasion | 35.4% | IS 2386 part 3-1986 |
| 7 | Flakiness index | 14.06% | IS 2386 part 3-1986 |
| 8 | Elongation index | 62.4% | IS 2386 part 3-1986 |

### *2.1.3. Fine Aggregates*

Aggregate of size less than 4.75mm is considered as fine aggregate. Both crushed and rounded sands / Siliceous and calcareous sands can be used. The fine aggregate content should be in the range of 1/4th to 1/3rd of the total volume of the mixture. Fine aggregate plays a very important role in the reduction of segregation. Locally available sand passing through 4.75mm sieve was used for all of the mixes of concrete. The properties are shown in table 3.

***Table 3:*** *Physical characteristics of fine aggregates*

| No | Physical properties | Results | Code of reference |
|---|---|---|---|
| 1 | Specific gravity | 2.5 | IS 2386 part 3-1963 |
| 2 | Finness modulus | 2.81 | IS383-1970 |
| 3 | bulking | 10% | IS 2386 part 3-1963 |
| 4 | Bulk density | 1432(loose) 1600(rodded) | IS 2386 part 3-1963 |

### *2.1.4. Bamboo fibers*

Bamboo fibers are natural fibers that are extracted from the bamboo tree and are focused as one of substitution for natural plant fiber having many advantages such as low cost, low density, ecologically friendly, sustainability and biodegradability[1]. In this study bamboo fibers extracted by using mechanical method was used [2]. Scanning electron microscopy test has been conducted to find the micro structure of bamboo fibers and failure analysis as well as the diameter of bamboo fiber.

***Figure 1*** *Different ages of raw bamboo*

***Figure 2*** *Longitudinal striped bamboo*

***Figure 3*** *Longitudinal striped bamboo under roller*

***Figure .4*** *Bamboo fiber of diameter 1.156mm Of aspect ratio (l/d) 40*

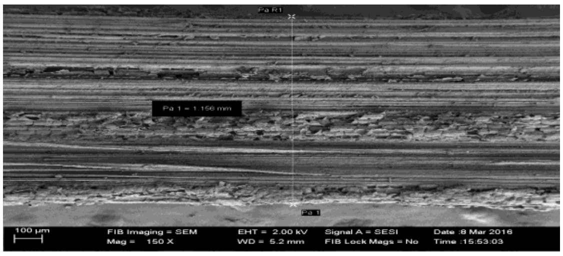

***Figure 5** Scanning electron micro scoping image of bamboo fiber diameter 1.156mm*

### 2.2 Investigations

The mix design is carried out as per IS 10262:2009.the proportioning is carried out to achieve strength at specified age, workability of fresh concrete and durability requirements. Mix design is carried out to arrive at the quantities required for 1 $m^3$ of concrete as shown below table 4

***Table.4** Quantities required for 1 m3 of concrete and (L/d) ratio of 40*

| W/C | Bamboo fiber (%) | Water (litre) | Cement (kg) | $F_A$ ( KG) | $C_A$ (KG) | Designation |
|---|---|---|---|---|---|---|
| 0.45 | 0 | 35 | 112 | 216 | 360 | N C |
| | 0.5 | | | | | BM1 |
| | 0.75 | | | | | BM2 |
| | 1 | | | | | BM3 |
| | 1.25 | | | | | BM4 |

To study the effect of bamboo fibers used for M30 grade concrete, cubes of sizes 150mmx150mmx150mm, cylinders of diameter 150 mm and height 300 mm and beams of sizes 500mmx100mmx100mm were casted and tested according to IS 516-1959.

### 3. Results

In the present experiment at attempt has been made to determine the effect of bamboo fiber by examining the slump, compressive strength, split tensile strength and flexural strength .the compression and split tensile strength test were conducted by the same compression testing machine which has a capacity of 200 tons.

### 3.1 Fresh Properties

#### *3.1.1. Workability*

The slump value decreased from 110 mm for normal concrete to the 55 mm for 1.25% fiber content. the slump values with corresponding fiber content is as shown in the table 5 and figure 6 shows the variation of slump with the change in the fiber content.

***Table.5** Slump value with for various mix proportions for aspect ratio 40*

| Fiber content (%) | Water/cement ratio | Slump(mm) |
|---|---|---|
| 0 | 0.45 | 110 |
| 0.5 | | 95 |
| 0.75 | | 80 |
| 1 | | 75 |
| 1.25 | | 60 |

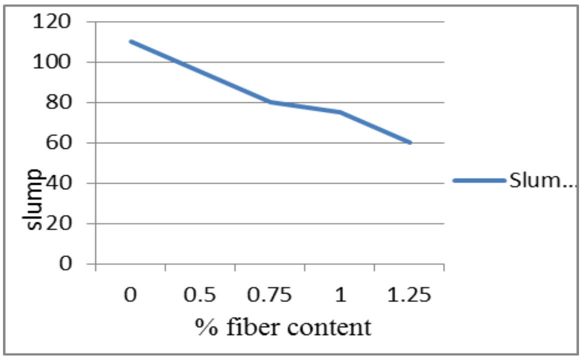


***Figure 6** Variation of slump with the change in the fiber content*

### 3.2 Hardened Properties

#### *3.2.1. Compressive strength*

The compressive strength increases from 32.8 $N/mm^2$ with 0% fiber content to a maximum of 41$N/mm^2$ with 1% of fiber content and then starts decreasing with an increase in fiber content..the compressive strength values obtained after 7,14 and 28 days of curing are shown in the table 6 and figure 7 shows the variation of compressive strength with the fiber content.

***Table.6** Compressive strength for varying volume fraction with aspect ratio 40*

| Fiber content (%) | Compressive strength ($N/mm^2$) | | |
|---|---|---|---|
| | 7 Day | 14 Day | 28Day |
| 0 | 16.8 | 21 | 32.8 |
| 0.5 | 20 | 28.2 | 33.7 |
| 0.75 | 21.2 | 32.6 | 36.8 |
| 1 | 27.2 | 36.2 | 41 |
| 1.25 | 25 | 30.6 | 38.9 |

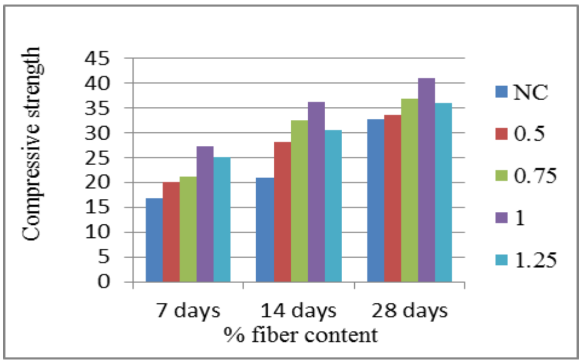


***Figure 7** Variation of compressive strength with the fiber content*

#### *3.2.2. Split tensile strength*

The split tensile strength increases from 2.68 N/mm2 with the 0% fiber content to a maximum of 4.8 N/mm2 with 1% fiber content and then again decrease with an increase in fiber content. the split tensile strength values obtained after 7,14 and 28 days of curing are shown in the table 7 and variation of split tensile strength with the fiber content in figure 8.

***Table.7*** *Split tensile strength for varying volume fraction with aspect ratio 40*

| Fiber content (%) | Split tensile strength (N/mm2) | | |
|---|---|---|---|
| | **7 Day** | **14 Day** | **28Day** |
| 0 | 1.27 | 2.14 | 2.68 |
| 0.5 | 2.12 | 2.6 | 3.1 |
| 0.75 | 2.5 | 3.1 | 4.01 |
| 1 | 3.8 | 4.2 | 4.8 |
| 1.25 | 3.6 | 4.0 | 4.3 |

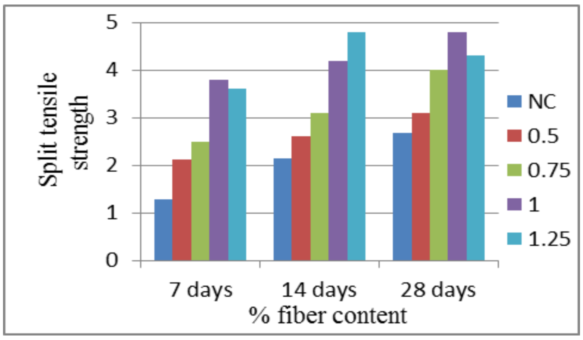


***Figure 8*** *Variation of Split tensile strength with the fiber content*

### *3.3.3. Flexural strength*

The flexural strength increased from 4.6 N/mm2 for 0% fiber content to a maximum of 7.5 N/mm2 for 1.25% and then starts decreasing the flexural strength. The flexural strength for various fiber content after 7, 14, 28 days are shown in table 8 and graphically represented by figure 9.

***Table.8*** *Flexural strength for varying volume fraction with aspect ratio 40*

| Fiber content (%) | Flexural strength (N/mm2) | | |
|---|---|---|---|
| | **7 Day** | **14 Day** | **28Day** |
| 0 | 3.03 | 4.1 | 4.6 |
| 0.5 | 4.3 | 5.7 | 6.8 |
| 0.75 | 5.2 | 6.07 | 7.02 |
| 1 | 5.8 | 6.37 | 7.25 |
| 1.25 | 6 | 6.8 | 7.5 |

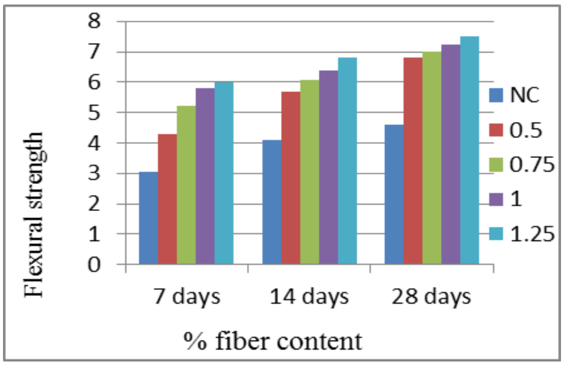


***Figure 9*** *Variation of flexural strength with the fiber content*

## 4. Conclusions

From the research following conclusions were obtained:

The bamboo fibers can be used as innovative fibers in concrete to increase the strength of the concrete and improve the ductility of concrete and its post – cracking load carrying capacity and strength difference between bamboo fiber concrete specimens and control concrete specimens became high distinct in the beginning age of curing itself.

The workability of fresh concrete was found to decrease with an increase in the fiber content and also a decrease in the workability with the increase in the aspect ratio and the addition of bamboo fibers at 1.0% by volume causes a significant enhancement in early as well as long term compressive strength and split tensile strength of concrete. The maximum improvement in 28 days strength was observed to be 41 N/mm$^2$and 4.8 N/mm$^2$; hence 1% fiber content is optimum fiber content for aspect ratio of 30 from compressive and split tensile strength view.

The addition of bamboo fibers makes the concrete very resistive in flexure and maximum improvement in 28 days strength was observed to be 7.5 N/mm$^2$, hence addition of fiber content increases the flexural strength.

## 5. Acknowledgement

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## References

[1] Nguyen tien phog, toru fujii, bui chuong, kazuya okubo,"study on how effectively extract bamboo fibers from raw bamboo and waste water treatment" *journal of materials science research*" vol 1,pp145-150,jan 2012.

[2] P. Xakikhani, R. zahari, M.T.H. Sultan, D.L. Majid "bamboo fiber extraction and its reinforced polymer composer material" *international journal of chemical, molecular, nuclear, materials and metallurgical engineering*, vol 8, no.4, 2014.

[3] Masakazu terai & koichi minami, Research and development on bamboo reinforced concrete structure, 15WCEE2012.

[4] Colin D. Johnston, "Fiber reinforced cements and concretes" *Advances in concrete technology* volume 3 – Gordon and Breach Science publishes – 2001.

[5] Perumalsamy N. Balaguru, Sarendra P. Shah, *''Fiber reinforced cement composites''*, Mc Graw Hill International Editions 1992.

[6] Arnon Bentur & Sidney Mindess, '' Fiber reinforced cementitious composites'' Elsevier applied science London and Newyork 1990.

[7] ASTM C1018 – 89, Standard Test Method for Flexural Toughness and First Crack Strength of Fiber Reinforced Concrete (Using Beam with Third – Point Loading), 1991 Book of ASTM Standards, Part 04.02, American Society for Testing and Materials, Philadelphia, pp.507 – 513.

[8] JCI Standards for Test Methods of Fiber Reinforced Concrete, Method of Test for Flexural Strength and Flexural Toughness of Fiber Reinforced Concrete (Standard SF4), Japan Concrete Institute, 1983, pp. 45 – 51.

[9] ACI committee, "State - of - the art report in fiber reinforced concrete'' ACI 554 IR – 82 Detroit Mechigan 1982.

[10] C.H. Henager, "Steel fibrous shotcrete". A summary of the State – of – the art concrete Int.: Design and construction 1981.

[11] J. Endgington, D.J. Hannant & R.I.T. Williams, "Steel fiber reinforced concrete" Current paper CP 69/74 Building research establishment Garston Watford 1974.

[12] C.D. Johnston, *"Steel fiber reinforced mortar and concrete",* A review of mechanical properties. In fiber reinforced concrete ACI – SP 44 – Detroit 1974.