Strength Properties of Bamboo Fiber Reinforced Concrete

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Abstract. A comparative study of the experimental results of the properties concrete with variable percentage of ratios natural fiber with Concrete. The Bamboo was used in structural element like supports, columns, roofs etc. and in the construction of the building. For the construction work concrete is used as the basic materials. The concrete is strong in compression but fragile in the tensile strength. It has become involved in making concrete using natural materials. Bamboo fibre with high tensile strength is expected to contribute significantly to quick growth, large growth distribution and low-cost earthquake-resistant construction and seismic retrofit skill. This thesis explores the mechanical properties of reinforced concrete made of bamboo fibre. In order to study the basic concrete properties such as compressive strength, split tensile strength and Flexural strength by adding in volume of concrete at 0%, 0.5%, 1.0%, 1.5%, 2.0% and 2.5% with concrete and finally the results were compared with conventional concrete and bamboo fiber concrete.

1. Introduction

The building industry indirectly plays a major role in environmental damage, so it is our responsibility to find more environmental techniques of construction for development [1]. One of the solutions is to search for a new material that can be recycled and reused. Therefore, it is necessary to go for a new material that is naturally available such as bamboo[2], glass [3], agricultural product[4], coconut shell[5] rice husk[6], ceramic[7], silica[8], crump rubber[9] etc., Bamboo is one of the renewable natural resource known to us. But sufficient care has not been given to investigation and change in bamboo[10]. Due to the beneficial physical characteristics of bamboo, research has been made of bamboo as fiber material in concrete[11]. With the development of science and technology, new techniques are implemented for treating of bamboo to make it durable and more working in terms of construction materials. In this project bamboo will be used in concrete to study of strength characteristics[12].

Concrete is commonly used as the base of infrastructure in most countries. Concrete has the requisite construction properties, such as its ability to withstand large compressive stresses [13]. Concrete is mostly used because it is cheap and readily available. Since it has low tensile strength [14], the use of concrete is limited. For this reason, it is strengthened and the tensile strength properties of the concrete are improved.

Many buildings are only made of concrete or mud-bricks in certain parts of the world. In the event of seismic activity[15], this is risky. In the case of an earthquake, these structures have no chance of
standing. An ideal solution would be steel reinforcement, but cost is a major issue. For structural structures, scientists and engineers are constantly searching for new materials; the concept of using bamboo as a potential reinforcement has gained popularity[16].

Natural fibres consist of those prepared from the sources of plants, animals and minerals. It is possible to identify natural fibres according to their origin. Proteins are normally made of animal fibres. For eg, wool, silk, alpaca, angora, mohair. The fibres that are taken from animals or hairy mammals are animal fur (wool or fur). Sheep fur, goat hair (cashmere, mohair), alpaca hair, horse hair, etc., for example. Silk fibre is the fibres of bugs or insects which are extracted from dried saliva. Examples involve silk from worms made of silk. Avian fibre is bird fibres, e.g., feathers and feather fiber. Mineral fibres are naturally occurring fiber or slightly modified fiber procured from minerals. The following groups are known as mineral fibres: asbestos is the only naturally occurring mineral fiber[17]. The variations are serpentine and anthophyllite amphiboles. Glass fibres (glass wood and quartz), aluminium oxide, silicon carbide, and boron carbide are made of ceramic fibres. Aluminium fibres contain metal fibres. Generally, plant fibres are mostly made of cellulose[18,19].

Solid concrete is weak in tensile strength so to raise the tensile strength of the concrete steel is used to attain Tensile Strength. Corrosion the main problem when concerned about the steel. Therefore, researches are going on to utilize Bamboo fibre as a reinforcement in concrete and as structural material because of its positive physical features[20]. By the nature of conventional Concrete, it creates cracks, creep, tensile failure and fatigue failures, to avoid these failures in the concrete bamboo fibres were added. This has been showed. the mixing of fibre is raising the ductility of concrete. Such a multifaceted Fiber Reinforced Concrete (FRC) is a material. Aluminum, coir, jute, carbon, steel and so on are some of the fibres which that can be used in FRC processing. Bamboo fibres are also used as a natural fibre in concrete to manufacture Bamboo Fibers Reinforced Concrete (BFRC) to give concrete some desirable properties[21].

2. Experimental Programme

2.1. Cement
OPC of 43 grade conforming to is ASTM was used. Tests were conducted on OPC cement various physical properties of cement and the results are shown in table-1 test information of materials. Fineness test was conducted as per ASTM C 184-83, in that Finesses of hydraulic cement determined by means of the 75µm (No.200) sieves and it’s satisfied condition as per standard. Followed by Initial setting time and Final setting Time of Cement (ASTM C191-82) completed using vicat apparatus, Specific gravity of cement (ASTM C188-87) have done using Le Chatelire flask.

| Description                        | Results | As per ASTM Standards |
|------------------------------------|---------|-----------------------|
| Fineness test                      | 7.5%    | >10%                  |
| Normal consistency                 | 31%     | -                     |
| Initial Time of Setting of Cement  | 44min   | < 45 min              |
| Final Time of Setting of Cement    | 360 min | >375 min              |
| Specific gravity of cement         | 3.14    | -                     |

2.2. Fine aggregate Characteristics
As fine aggregate, river sand was used. By conducting tests as per ASTM, the physical properties of sand were determined. Table 2 offers the findings obtained from the sieve analysis. Apparent special gravity of bulk specific gravity (SSD), absorption test, sieve analyses, silt content, test on fine aggregate has done as per ASTM standards. In that test we determined absorption of fine aggregate and Bulk Specific Gravity of fine aggregate as per ASTM C 127 – 88, Silt test and Sieve analysis (result given below).

Table 1. Cement Characteristics.
Table 2. Fine Aggregate Characteristics.

| Description               | Results | As per ASTM Standards |
|---------------------------|---------|-----------------------|
| Bulk Specific Gravity     | 2.55    | -                     |
| Bulk Specific Gravity (SSD)| 2.63    | -                     |
| Apparent Specific Gravity | 2.75    | -                     |
| Absorption%               | 2.5%    | >10%                  |
| Sieve analysis            | Well graded | -             |
| Silt content              | 5%      | >6%                   |

2.3. Coarseaggregate
Broken stones acquired from local quarries were used as coarse aggregate. The coarse aggregate size used as 20 mm. The coarse aggregate of physical properties was found and determined by conducting tests as per ASTM the results are shown in table-3 test information of materials. Coarse aggregate tests Bulk specific gravity, Bulk specific gravity (SSD), Apparent specific gravity, Absorption, Impact test, Moisture content, Sieve analysis. Above all test on coarse aggregate has followed as per ASTM standards. In that test we determined Bulk, Apparent Specific Gravity and Absorption of coarse aggregate as per ASTM C 127 – 88, “Moisture Content of Concrete Aggregate” (ASTM C-566-84), impact test and Sieve analysis. (Result given below).

Table 3. Coarse Aggregate Characteristics.

| Description          | Results | As per ASTM Standards |
|----------------------|---------|-----------------------|
| Bulk Specific Gravity| 2.77    | -                     |
| Bulk Specific Gravity (SSD) | 2.62    | -                     |
| Apparent Specific Gravity | 2.88    | -                     |
| Absorption%          | 1.31%   | >5%                   |
| Impact test          | 3.46%   | Strong               |
| Moisture Content     | 0.2%    | >5%                   |
| Sieve analysis       | Well graded |                |

2.4. Fibre
Bamboo is a versatile replacement characterized by large ratio of strength to weight and it is easy to work due to its nature. It is one of the fast-growing natural reserves and it is also locally accessible. For building purposes, bamboo has been used since ancient times. The non-technical and technical methods of bamboo can be used. Our ancestors used Bamboo as basic material for building the structure. Because of its high strength to weight ratio, conventionally it has been used in different existing ability and tools. The bamboo has longitudinal alignment of fibre due its inherited property. Compared to any other natural fibre material bamboo fibre having higher modulus of elasticity. The lengthier the fibre advanced it gives the tensile strength. Adding of Bamboo fibres to the concrete increases the tensile and mechanical strength. The specific weight of the bamboo fibre is very low. The bamboo fibre is susceptible to the natural attacks that is from toadstool, insects etc… To prevent from termites and insects a treatment was given using Timber Protector’s anti-termite solution. It is necessary to fabricate the bamboo fibre after extracting the bamboo fibres from the bamboo in a controlled way.

There has been very little investment in the bamboo sector until recently, with Ethiopia having no formal bamboo economy until 2012. As African bamboo is at the forefront of this bamboo revolution,
this has sparked growing interest in adding value to this abundant resource in Africa. Two bamboo
categories, low-land bamboo and high-land bamboo, occur naturally in Ethiopia. Low land bamboo,
known locally as Shimel, makes up about 80 percent of the bamboo resources in the region. Highland,
locally known as Kerekeha In Ethiopia, bamboo makes up 6.5 percent of the total forest cover. In
Ethiopia, bamboo is primarily used for building and as a source of fuel. For this reason, many farmers
harvest and sell young green bamboo culms, although they are immature
and lack the strength and
durability of mature culms. Natural bamboo fibre materials that were locally available were collected
from different areas and properly shaped in the form of fibres. Using the cutting machine, standardised
lengths of fibres were obtained.

Table 4. Bamboo fibre Characteristics.

| Properties of bamboo fibre | Results |
|---------------------------|---------|
| Aspect ratio              | 104.2   |
| Specific Gravity          | 0.87    |
| Water Absorption, in %    | 104.2   |
| Thickness                 | 0.50mm  |

3. Methods employed

3.1 Preparation of design mix concrete
To select the water and sand content the required water content is 219.17 lt/m3 and the cement content
is to be 393.61kg/m3 this content is for mild exposure condition. The aggregate used is 10 to 20mm
sieve size. The sand used is 1.19mmm and the water used is 05 w/c ratio. The mixture proportions of
cement, fine aggregate, coarse aggregate, are 1:1.86:2.51. To adopt C30 concrete the mixture
proportion taken and the cement used is OPC43 grade and aggregate used is for 10 to 20mm sieve size
and the sand used is 1.19mm and water used is 0.47W/C ratio. Bamboo fiber of volume
0.5%,1%,1.5%,2% and2.5% percent of concrete was mixed in concrete homogeneously the fiber of
longer size was chosen to reduce the number of fibers per kg to avoid workability problem.

3.2 Mixing and casting
Machine mixing was used for convenient handling of bamboo fiber[22][10]. Cement and Sand were
mixed dry and kept separately. The three layer of Then coarse aggregates, bamboo fibers and dry mix
of cement and sand and approximate quantity of water was spread on each layer and mixed carefully.
Procedure of Mixing was felt to be extremely monotonous due to formation of small bulges. In order
to evade the formation of bulges the fibers were randomly oriented in the mix. The cubes (15cm x
15cm), cylinders (15cm dia& 30cm deep) and flexure beams (10cm x 10cm x 50cm) of both
conventional and fiber reinforced concrete specimens were casted. Samples were cured for 28 days in
water after 24 hours of their casting and still 48 hours before testing. Along with the conventional
cement concrete bamboo fibre is added from 0.5 % to 2.5%.

4. Result and discussion
The cube specimen (15X15X15 cm) was put over the compression testing machine and the load was
applied progressively until the specimen abortive.[23] The final load was noted as the collapse load
and the crushing strength was measured as (load/area)[24]. The cylinder specimen (15cm diameter &
30cm height) be located in compression testing machine with horizontal position to determine the split
tensile strength of concrete. Concrete prisms (10*10*50cm) were tested with the span of 40cm in the
universal testing machine to determine the flexural strength of concrete. The failure load was noted
down and the modulus of rupture on 28 days’ flexural strength was determined as f = pl/bd2.

4.1 Compressive strength test
Table 5 and figure 1 shows compressive strength of concrete for different fibre mix proportions such as 0%, 0.5%, 1%, 1.5%, 2% and 2.5% for 7 days, 14 days and 28 days. When compared to conventional concrete with the bamboo fiber reinforced concrete the compressive strength of fiber reinforced concrete has improved with respect to the additions of bamboo fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fiber ratios. When compared to conventional concrete with the bamboo fiber reinforced concrete the compressive strength of fiber reinforced concrete has increased with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fiber ratios. When compared to conventional concrete with the bamboo fiber reinforced concrete the compressive strength of fiber reinforced concrete has increased with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fiber ratios.

| Sl. No. | % of fiber | 7 Days  | 14 Days | 28 Days |
|---------|------------|---------|---------|---------|
| 1       | 0          | 24.47   | 30.25   | 36.23   |
| 2       | 0.5        | 24.66   | 30.34   | 36.54   |
| 3       | 1          | 24.91   | 30.51   | 36.73   |
| 4       | 1.5        | 25.00   | 30.67   | 36.87   |
| 5       | 2          | 25.06   | 30.79   | 36.95   |
| 6       | 2.5        | 24.70   | 30.41   | 36.36   |

Figure 1. Compressive strength

### 4.2 Split tensile strength

Table 6 and figure 2 show 7 days, 14 day and 28 day split tensile strength of concrete for different fiber mix proportions such as 0%, 0.5%, 1%, 1.5%, 2% and 2.5%. When compared to fiber reinforced concrete with conventional concrete the split tensile strength of fiber reinforced concrete has increased with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fiber ratios. When associated to conventional concrete with fibre reinforced concrete the split tensile strength of fibre reinforced concrete has increased with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fibre ratios. It is experiential that with adding of fiber in the concrete the split tensile strength has increased (up to 2% fiber addition). The addition of fiber with the concrete at 5%, 1%, 1.5% and 2% respectively causes the increment of split tensile strength of the concrete at .2%, 1.3%, 1.85%, and 3.3%. at 2.5% addition of fiber with the concrete the split tensile strength started declining and reduced by 0.43%. 
Table 6. Split Tensile Strength of Concrete

| Sl. No. | % of Fiber | 7 Days | 14 Days | 28 Days |
|---------|------------|--------|---------|---------|
| 1       | 0          | 3.24   | 4.43    | 4.84    |
| 2       | 0.5        | 3.34   | 4.49    | 4.85    |
| 3       | 1          | 3.37   | 4.64    | 4.90    |
| 4       | 1.5        | 3.47   | 4.78    | 4.93    |
| 5       | 2          | 3.54   | 4.96    | 5.00    |
| 6       | 2.5        | 3.26   | 4.45    | 4.82    |

Figure 2. Split tensile strength

4.3 Flexural strength

Table 7 and figure 3 show 7-day, 14 day and 28 day flexural strength of concrete for different fibre mix proportions such as 0%, 0.5%, 1%, 1.5%, 2% and 2.5%. When compared to fibre reinforced concrete with conventional concrete the flexural strength of fibre reinforced concrete has augmented with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fiber ratios. When related to conventional concrete with the bamboo fibre reinforced concrete the split tensile strength of bamboo fibre reinforced concrete has increased with respect to the additions of fiber with concrete at 0.5%, 1%, 1.5%, and 2% but it was decreased for 2.5% compared to other fibre ratios. It is observed that with adding of fiber in the concrete flexural strength has increased (up to 2% fiber addition). The addition of fiber with the concrete at 5%, 1%, 1.5% and 2% respectively causes the increment of flexural strength of the concrete at .2%, 1.3%, 1.85%, and 3.3%. at 2.5% addition of fiber with the concrete the flexural strength started declining and reduced by 0.43%
Table 7. Flexural Strength of Concrete

| Sl. No. | % of Fiber | 7 Days | 14 Days | 28 Days |
|---------|------------|--------|---------|---------|
| 1       | 0          | 3.84   | 4.36    | 5.16    |
| 2       | 0.5        | 4.31   | 4.87    | 5.69    |
| 3       | 1          | 4.48   | 5.39    | 5.81    |
| 4       | 1.5        | 4.73   | 5.82    | 5.98    |
| 5       | 2          | 4.86   | 5.77    | 6.13    |
| 6       | 2.5        | 4.12   | 4.75    | 5.29    |

Figure 3. Split tensile strength

6. Conclusion
The compressive strength, split tensile strength and flexural strength of bamboo fiber reinforced concrete have been tested for the various proportion of bamboo fiber concrete. The outcomes obtained specifies the strength of bamboo fiber reinforced concrete that increases with an addition of fiber up to 2% and slightly decreases after that. The test result obtained from the flexural strength shows that the bending strength increases with addition of bamboo fiber in the concrete up to 2% and slightly decreases after that. From the results its concluded that bamboo fiber reinforced concrete provides added strength than conventional concrete.

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