Experimental Study on the use of Bamboo as Structural Reinforcements in RCC Structures

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Abstract—Bamboo is a natural material obtain from plants family. It is fast growing, light weighted, renewable and environment friendly. Bamboo material is very interesting topic in construction for research. Bamboo has good tensile strength; from a study it is found that tensile strength specific weight ratio of bamboo is twenty times more than that of steel.

An experimental investigation of bamboo characteristics and bamboo as reinforcement in concrete study is carried out in this paper. Here we have foc used on to identify water absorption in bamboo during curing period and flexure strength of bamboo reinforce beam, cracking pattern and other experimental value to step more towards bamboo as alternative to steel.

Keywords—Bamboo, Reinforcement, flexure, compression, tension, naturally available construction material.

I. INTRODUCTION

In recent year, many researchers around the world have already begun to explore the use of low cost and low energy substitute construction materials. [1]

Among the many possibilities for such substitutions Bamboo, which is one of the fastest growing plants, has great potential. [2] [4]

Bamboo has been used in construction of bridges and houses for thousands of years in Asia. Bamboo takes less energy to harvest and transport. [3]

Bamboo is hygroscopic material thats why it also absorbs moisture from surrounding hence determination of properties, improve over moisture absorption and bamboo reinforcement in concrete beam has been investigated by the authors in the lab and results are presented. [5] [6]

II. EXPERIMENTAL PROCEDURE

A mix design of M25 concrete was used to conduct experiment. Bamboo used were collected from Local Market, Lalgunj, Azamgarh Uttar Pradesh (India). The age of bamboo used was four and half year. Several tests were conducted to calculate different strength properties which are necessary to find such as compressive strength test, tensile strength test and water absorption test of bamboo specimen in laboratory.

TEST N0. 01

Compressive Strength Test for Bamboo Specimen
TEST NO. 02

Tensile Strength Test for Bamboo Specimen

The tensile test was carried out on bamboo splints to determine the ultimate tensile strength of bamboo. The ultimate tensile strength of bamboo is important to calculate the maximum allowable tensile stress in bamboo, when bamboo is being used as reinforcement in concrete elements to take the tensile loads. We have taken 5 test specimens namely, A1, A2, A3, A4, A5.

| Specimen | Crosssectional Area (Mm²) | Tensile Load (Kn) | Tensile Strength (N/Mm²) |
|----------|--------------------------|-------------------|--------------------------|
| A1       | 202                      | 33.50             | 164.851                  |
| A2       | 190                      | 29.5              | 154.2105                 |
| A3       | 186                      | 26.80             | 139.7849                 |
| A4       | 262                      | 47.04             | 179.542                  |
| A5       | 224                      | 39.24             | 176.428                  |

Fig 2.3: Bamboo Specimen for tensile test, Source: Material Testing Lab, IIT BHU

Table 2.3: Bamboo splints tensile test

| SPECIMEN | Elongation (mm) | Strain | Cracking Load (KN) |
|----------|-----------------|--------|--------------------|
| A1       | 8.50            | 0.0168 | 28.5               |
| A2       | 8.00            | 0.0158 | 26.5               |
| A3       | 8.00            | 0.0158 | 22.5               |
| A4       | 9.32            | 0.0170 | 37.9               |
| A5       | 8.75            | 0.0164 | 36.7               |

Fig 2.4: Tensile Strength of Bamboo Specimens (MPa)

TEST NO. 03

Water Absorption Test for Bamboo Specimen

Since Bamboo is a hygroscopic material having a tendency to absorb moisture from air and surroundings. In green concrete bamboo splints absorb moisture and swell, when the concrete becomes dry the bamboo splints contract and creates spaces between the contacts, the bamboo-concrete bond strength decreases and member fails in bond. Hence water absorption is one of the main drawbacks of bamboo, when it is used as reinforcement in concrete so our main aim is to perform this test to find out percentage of water absorb by bamboo and percentage of volume increase.

We have taken six (WA1, WA2, WA3, W1, W2, W3) sample of bamboo specimen of 50*50mm² and let it dry for 24hrs in an oven. After that the specimen was allowed to cool for 30 minutes. 3 Specimen painted with water proof coating (W1, W2, W3) but remaining three were not. Calculation of dimension, weight was made initially. Then all the 6 samples were allowed to soak in water at normal temperature pressure. Reading for changes in dimension and weight was made at every 24-hour interval for next 28 days.

Fig 2.5: Bamboo Specimen into Water, Source: REC Azamgarh Lab

Table 2.5: Water absorption of bamboo sample without paint

| DAY | WA1(g)  | % GAIN | WA2(g)  | % GAIN | WA3(g)  | % GAIN | AVG % GAIN |
|-----|---------|--------|---------|--------|---------|--------|------------|
| 1   | 4.273   | 0.00%  | 4.638   | 0.00%  | 4.404   | 0.00%  | 0%         |
| 2   | 6.671   | 56.12% | 7.61    | 64.08% | 7.215   | 63.82% | 61.34%     |
| 3   | 7.429   | 73.85% | 8.329   | 79.58% | 7.956   | 80.65% | 78.03%     |
| 4   | 7.584   | 77.49% | 8.304   | 79.04% | 7.923   | 79.91% | 78.81%     |
| 5   | 7.700   | 80.20% | 8.269   | 78.71% | 7.945   | 80.42% | 79.78%     |
| 6   | 7.783   | 82.15% | 8.352   | 80.77% | 7.852   | 78.29% | 80.40%     |
| 7   | 8.3661  | 95.67% | 9.290   | 92.15% | 8.577   | 94.75% | 94.19%     |
| 8   | 8.493   | 98.75% | 9.572   | 93.14% | 8.617   | 95.66% | 95.85%     |
| 9   | 9.491   | 122.74%| 10.228  | 120.5% | 9.778   | 122.3% | 121.67%    |
| 28  | 10.209  | 138.92%| 11.647  | 151.00%| 11.007  | 164.46%| 151.46%    |

Table 2.6: Water absorption of bamboo sample with paint

| DAY | W1(g)   | % GAIN | W2(g)   | % GAIN | W3(g)   | % GAIN | AVG % GAIN |
|-----|---------|--------|---------|--------|---------|--------|------------|
| 1   | 5.878   | 0.00%  | 4.549   | 0.00%  | 4.557   | 0.00%  | 0%         |
| 2   | 8.405   | 42.69% | 7.127   | 56.67% | 6.856   | 50.44% | 49.93%     |
| 3   | 9.194   | 61.36% | 7.815   | 73.73% | 7.616   | 67.12% | 67.42%     |
| 4   | 9.572   | 62.84% | 8.079   | 77.59% | 7.825   | 71.71% | 70.71%     |
| 5   | 9.838   | 67.33% | 8.240   | 81.38% | 7.989   | 75.32% | 74.68%     |
| 6   | 10.154  | 72.74% | 8.428   | 85.27% | 8.046   | 76.56% | 78.19%     |
| 9   | 10.940  | 91.54% | 9.182   | 101.8% | 9.357   | 103.7% | 100.35%    |
| 11  | 11.306  | 92.34% | 9.558   | 110.8% | 8.823   | 95.83% | 99.66%     |
| 14  | 11.689  | 98.86% | 10.114  | 122.3% | 9.286   | 103.7% | 108.29%    |
| 28  | 12.533  | 113.22%| 10.684  | 134.86%| 11.209  | 145.97%| 131.35%    |
TABLE 2.7: Calculation of c/s area change due to moisture

| Sample | Area before test (Without painted in mm$^2$) | Area After test (Without painted in mm$^2$) | % change in area (mm$^2$) | Area before test (Painted in mm$^2$) | Area After test (Painted in mm$^2$) | % change in area (mm$^2$) |
|--------|---------------------------------------------|---------------------------------------------|--------------------------|--------------------------------------|---------------------------------------|--------------------------|
| A1     | 225                                         | 239                                         | 0.062                    | 225                                  | 230                                   | 0.022                    |
| A2     | 225                                         | 232                                         | 0.031                    | 225                                  | 229                                   | 0.017                    |
| A3     | 225                                         | 236                                         | 0.048                    | 225                                  | 232                                   | 0.031                    |

TEST N0. 04

Flexural Strength Test for Bamboo Specimen

Bamboo splints of 12*12mm$^2$ were used as reinforcement. Bamboo splints were tied in frame of 55cm length and within 10*10cm$^2$. Binding bar is use to tie. Since bamboo absorbs water so a moisture resistance paint was applied over bamboo splints. Bamboo reinforced concrete beam of 150*150*600mm$^3$ were casted with clear cover of 25mm. For casting beam, we have used mix designed concrete grade of M25. After 28 days of curing, beams were subjected to standard Flexure test and the flexural strength was calculated.

TABLE 2.8: Design mix Grade of M25 concrete ratio.

| Cement Kg/m$^3$ | F.A Kg/m$^3$ | C.A Kg/m$^3$ | Water Kg/m$^3$ |
|-----------------|--------------|--------------|----------------|
| 435.409         | 653.384      | 1173.782     | 216.49         |
| 1               | 1.5          | 2.696        | 0.497          |

Fig 2.6: Water absorption vs time graph of bamboo specimens.

Fig 2.7: % change in c/s area of bamboo sample

Fig 2.8: Cross sectional detailing of Beam for Flexure

Fig 2.9: Bamboo frame for reinforcement, Source: Material Testing Lab, REC Azamgarh

Fig 2.10: Beam during curing, Source: Material Testing Lab, REC Azamgarh

Fig 2.11: Bamboo reinforced Concrete Beam during test
III. RESULT AND DISCUSSION

We have obtained compressive strength of bamboo was good for short building but on application of heavy load, it can fail along the longitudinal direction in form of buckling.

1. Avg Compressive strength with node = 49.07 MPa.
2. Avg Compressive strength without node = 47.25 MPa.

By tensile test, it was found out that bamboo follow brittle failure.

1. Average tensile strength of bamboo specimen = 162.96 MPa.

By water absorption experiment results it was found out that water absorption and change in area volume due to absorbed water, both are decreased when coated with moisture resistant paint. That is positive result and helping in maintaining strength of bamboo.

1. Avg % Area Change (Paint) = 0.047%
2. Avg % Area Change (Non-Paint) = 0.035%
3. % by weight of max water absorbed in Painted = 131.55%

IV. CONCLUSION

The experimental analysis is done for compressive strength of bamboo specimen. And it was found that compressive strength of bamboo specimen with node has greater strength than that of specimens without node this could be because of additional cross-sectional area at nodes and due to the dense mass present at nodes. Some of the specimen showed an ideal failure by cracking longitudinally but most of them showed a mixed mode of failure where in the specimen cracked as well as got crushed and buckled along length.

As per result an average ultimate tensile strength of bamboo splints is 160 MPa which is comparatively lower than the yield strength of structural steel i.e. 250MPa. But bamboo splints can resist sufficient tensile loads in a concrete flexure element. All the bamboo specimens showed brittle failure.

The water absorption value is decreased by using moisture resistant paint and can help in maintain strength and shrinkage and swelling problem.

Bamboo Reinforced Concrete Beam follows same pattern those in steel reinforcement elements. The ultimate moment is 50.73MPa i.e. good result for short building. After testing, cracks are developed at the mid span in beam i.e. flexural type failure.

V. REFERENCES

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