Use of Poly Vinyl Chloride (PVC) Tape to Increase the Strength of Bamboo

Rishabh Rastogi, Yogesh, Nikhil Kumar Pankaj, B. R. G. Robert

Abstract: Poly vinyl chloride is suggested to use as confining material around bamboo to increase its strength. Investigation is done on PVC confined bamboo by performing tensile and compressive strength test. Then we compared the mechanical performance of unconfined bamboo and PVC confined bamboo. In this research bamboo is also tested for water absorption with and without PVC tape reinforcement. Later, on these grounds we also derived adhesive value of PVC tape, which can be used to find out length of tape required for any percent of increment in strength of bamboo. Preliminary results of tensile tests, compressive tests and water absorption test on bamboo (scientific name Bambusa vulgaris native name chadao bans or jad vala bans) are presented in this research. As bamboo confined in PVC is 27.25% more strong in tension and 77.19% more strong in compression than unconfined bamboo which depicts that bamboo confined with PVC tape can be a future alternative for steel in reinforced concrete.

Keywords*: Poly Vinyl Chloride (PVC) tape, Bamboo splint, Bamboo culm, Splitting buckling, End bearing buckling, Tape adhesion.

I. INTRODUCTION

There are mainly three basis on which building materials are selected and these are financial, functional and technical specification since long time. But these days one important aspect is sustainability which emerged as even more critical basis to select a building material to reduce environmental pollution and efficient utilization of resources. The building industry, creating a substantial part of total environmental deterioration. One must invent new environment friendly ways in construction and thus contributing in sustainable use of resources. This can be done by many ways like using renewable material in construction, using green and ecofriendly resources in construction, reusing same resource as many time as possible and least utilization of resources. In this paper we focused on using renewable material for construction purpose. Bamboo a fast growing, natural and renewable resource which can be used as a reinforcement may be partially or fully in concrete structure.

Revised Manuscript Received on July 22, 2020.

Rishabh Rastogi, Department of Civil Engineering, Delhi Technology University, New Delhi, India.

Yogesh, Department of Civil Engineering, Delhi Technology University, New Delhi, India.

Nikhil Kumar Pankaj, Department of Civil Engineering, Delhi Technology University, New Delhi, India.

B.R.G. Robert, Assistant Professor, Department of Civil Engineering, Delhi Technological University, New Delhi, India.

But bamboo strength is not as much high as that of steel so in this paper we tried to increase the strength of bamboo by confining it with PVC tape. India stands at the second spot in the production of bamboo resources in the world, next to China. Bamboo can be sustainable alternative for reinforcement by adequate research. Being hollow in nature bamboo can resist bending forces upto larger extent. Keeping in mind it is not easy to do connections of bamboo but this problem can be overcome by research once its strength is increased considerably. So, our prime objective is to increase strength of bamboo anyhow. Around 23% of air pollution, 40% of water pollution, 50% of landfill wastes and 50% of climatic changes is contributed by construction industry. More than 1 ton of carbon dioxide gas is emitted in the atmosphere for production of 1 ton of cement. Similarly, more than 2 ton of carbon dioxide gas is emitted in atmosphere just to produce 1 ton of steel. As per researches, bamboo fails in tension at strength of around 100 to 130 MPa and in compression at strength of around 40 to 50 MPa. Due to compressive buckling failure of wall of bamboo it has a low compressive strength. In dry environment wall of bamboo get cracked easily and these cracks also contribute in low compressive strength. Hence considering these drawbacks of bamboo we used PVC tape as confining material to increase its load carrying capacity.

II. MATERIAL USED

Bamboo (scientific name *Bambusa vulgaris* native name chadao bans or jad vala bans) was brought from R K plywood Bawana road Delhi, Poly vinyl chloride (PVC) tape was acquired from electrical shop.

III. USE OF PVC TAPE FOR CONFINING BAMBOO

In steel or concrete engineering carbon fiber reinforced polymer (CFRP) is already in extensive use. But it is costly so, we have used a cheaper durable alternative that is PVC as confining material and tested the strength of bamboo.

In this report we have suggested the use of PVC tape as confining material by circularly confining bamboo to increase its mechanical strength.

IV. TENSILE STRENGTH TEST OF BAMBOO SPLINT

A. Testing bamboo specimen without PVC confinement

Tensile strength of bamboo splint without PVC confinement was studied firstly.

Bamboo (scientific name *Bambusa vulgaris* native name chadao bans or jad vala bans) was used as specimen for conducting all the test. From the wall of bamboo culm four equal size bamboo splint specimen was cut along the length of bamboo. We sanded all bamboo splint sample of equal dimensions into dog-bone shape and then tested two of them without confining in PVC tape. We have shown one sample in figure 1.

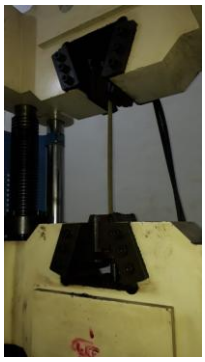
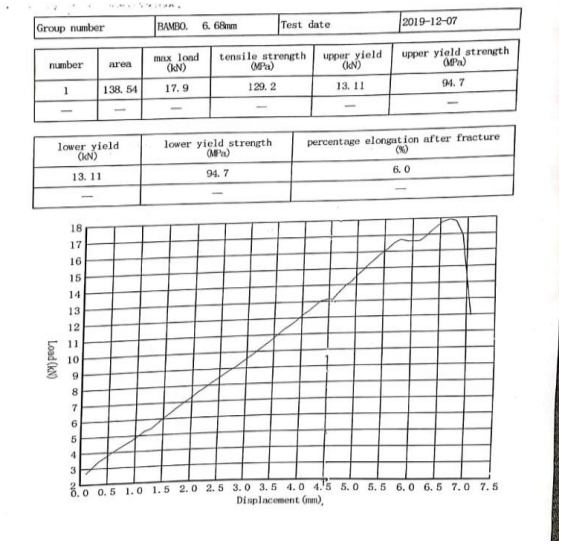


Fig. 1 Bamboo splint without PVC tape in UTM

Each bamboo splint specimen was 430mm long. Although the specimen cross-section is in the shape of quadrant of arch but we have considered it as rectangular in shape for ease of calculations. To calculate cross-section area, each specimen area is calculated at three points that is at top node, bottom node and middle position then their average is taken. Cross-sectional area coming out to be using this method is 138.5mm^2 for one of the two sample. The sample fractured in the middle portion of its length. The average strength of two test sample was found to be 124.4 MPa.

Fig. 2 Fractured sample after loading

Maximum stress obtained in bamboo at failure is measured by dividing the maximum tensile load taken by specimen at failure with the average area of cross-section. Strength of two samples was found to be 129.2MPa and 119.6MPa, with a mean of 124.4MPa. The Percentage elongation of specimen after fracture was 5.5%. In figure 3 load vs displacement curves are shown for tensile specimens. In table I results of tensile test without PVC tape confinement are summarized.

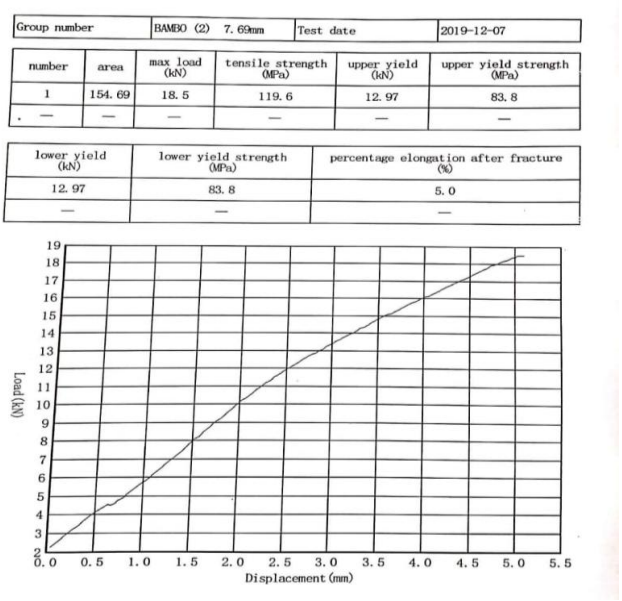


Group number	BAMBO. 6.68mm	Test date	2019-12-07

number	area	max load (kN)	tensile strength (MPa)	upper yield (kN)	upper yield strength (MPa)
1	138.54	17.9	129.2	13.11	94.7
—	—	—	—	—	—

lower yield (kN)	lower yield strength (MPa)	percentage elongation after fracture (%)
13.11	94.7	6.0
—	—	—

Fig. 3 Load vs Displacement curve of first sample



Group number	BAMBO (2) 7.69mm	Test date	2019-12-07

number	area	max load (kN)	tensile strength (MPa)	upper yield (kN)	upper yield strength (MPa)
1	154.69	18.5	119.6	12.97	83.8
—	—	—	—	—	—

lower yield (kN)	lower yield strength (MPa)	percentage elongation after fracture (%)
12.97	83.8	5.0
—	—	—

Fig. 4 Load vs Displacement curve of second sample

Table – I : Results of the tensile tests without PVC confinement

	Sample 1	Sample 2	Average
Maximum load (kN)	17.9	18.5	18.2
Tensile strength (MPa)	129.2	119.6	124.4
Upper yield (kN)	13.11	12.97	13.04
Upper yield strength (MPa)	94.7	83.8	89.25
Lower yield (kN)	13.11	12.97	13.04

Lower yield strength (MPa)	94.7	83.8	89.25
Percentage elongation after fracture (%)	6.0	5.0	5.5

B. Testing bamboo specimen with PVC tape confinement

In this case, the fiber strength test was performed on the tensile sample wrapped with the PVC tape. The variety of bamboo was same as earlier and it was *Bambusa vulgaris* native name chadao bans or jad vala bans. A sample of that kind has been shown in Figure 5 and 6.

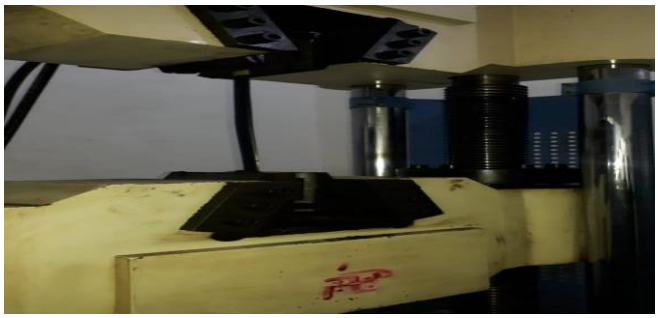


Fig. 5 Testing of bamboo with tape confinement in UTM

Fig. 6 Dog bone shape sample of bamboo splint

Each of the sample used for the test was found to be 430 mm long. The sample is finished into 'Dog bone' shape having a average cross sectional area of 154.72mm^2. The width of PVC tape is 15mm. The number of PVC tape wrapping is 24 without overlapping of PVC tape over a length of 360mm out of 430mm leaving a space of 35mm on both sides. The sample fractured in the middle portion of its length. The strength of tensile test sample was found to be 158.3Mpa.

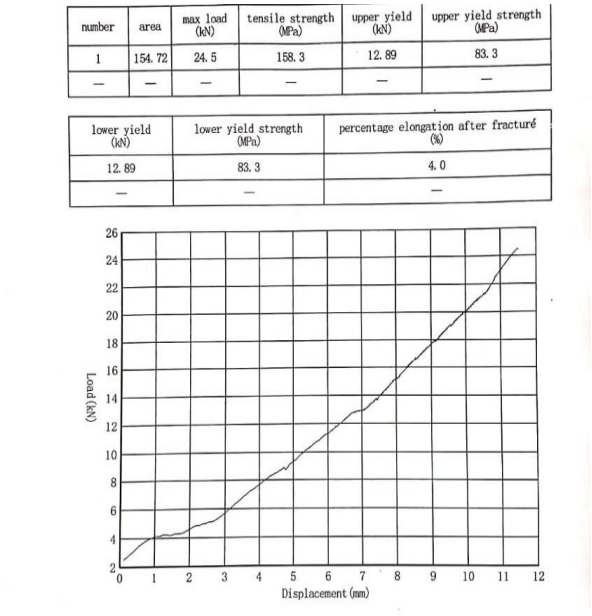


Fig. 7 Load vs Displacement curve for confined bamboo sample

The strength of the tensile samples without PVC tape confinement gave an average value of 124.4Mpa. On the other hand, the strength of the samples with PVC tape gave an average value of 158.3Mpa. Thus, the mean strength of tensile bamboo sample confined with PVC tape can be enhanced to 27.25% more than the mean strength of bamboo sample without PVC tape.

V. DERIVATION OF TAPE ADHESION ON BAMBOO

Maximum tensile load without tape confinement = 18.2kN
Maximum tensile load with tape confinement = 24.5kN
Increase in load bearing because of tape confinement = 24.5 - 18.2 = 6.3kN

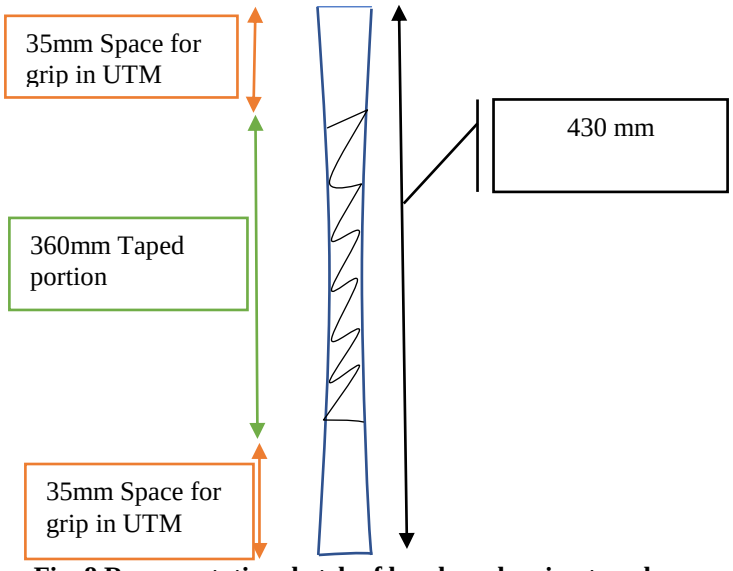


Fig. 8 Representative sketch of bamboo showing taped portion

Tape width = 15mm

No. of tape wrappings around bamboo splint = $\frac{360}{15}$ = 24

Perimeter of bamboo splint = $2(20.12 + 7.69)$ = 55.62mm

Length of total tape used = No. of wrappings × Perimeter of bamboo splint

= 24 × 55.62 mm

= 1335mm

Using increment in load and total tape length used we can derive the value of Adhesion force per unit length of tape wrapped around the bamboo.

So, **Adhesion of tape on bamboo** = $\frac{6.3 \times 1000}{1335}$ N/mm = **4.72 N/mm**

Now using this Adhesion value, we can find out the length of tape required corresponding to the load increment.

VI. COMPRESSIVE STRENGTH TEST OF BAMBOO CULM

A. Testing bamboo specimen without PVC confinement

Each of the samples used in the test has a minimum length which was approximately three times the external diameter of culms of bamboo, but it was not exceeding 200mm.The internal diameter of the sample was 12.58mm and the external diameter was 30.7mm so the net area was 619.8mm^2.

Fig. 9 Splitting failure of bamboo culm

After putting sample in CTM we applied compressive load and then noted the compressive strength by dividing it with net cross section area of bamboo.

Fig.10 Compressive load is applied on sample

Due to applied load the bamboo fractured at the middle. The failure mode of specimens without the PVC tape is splitting fracture. The splitting fracture occurred due to the compressive buckling failure of the walls of bamboo. The maximum compressive load taken by sample was 26kN.

B. Testing bamboo specimen with PVC tape confinement

This test was performed as per the Guiqiu Huang, Zhen Huang where they used carbon fiber as confining material and we have used PVC tape instead of carbon fiber. The number of wrapping of PVC tape around the sample was 10. The length of sample was 150mm. The external diameter was 27.56mm and internal diameter was 14.54mm. The net area was 430.51mm^2.

Fig. 11 PVC confined bamboo culm

Fig.13 is showing the compressive failure modes along with PVC tape. The mode of failure of the samples with the PVC tape was the end bearing failure. The maximum compressive load taken by the specimen with PVC confinement was 32kN.

Fig.12 Applying load on PVC confined sample using UTM

Fig. 13 End bearing failure of sample

Table – II : Results of the Compressive tests without and with PVC confinement

Properties	Sample without PVC tape	Sample with PVC tape
Load (N)	26000	32000
Area (sq.mm)	619.8	430.51
Compressive strength (MPa)	41.95	74.33
Failure mode	Splitting buckling	End bearing buckling

VII. WATER ABSORPTION TEST

A. Bamboo without PVC tape confinement

Splint of bamboo with dimensions 20.74mm×6.68mm and height 430 mm was left dipped in water for 24 hours. The weight of the splint before and after dipping was recorded.

Weight before dipping, $W_1 = 20g$

Weight after dipping, $W_2 = 50g$

Weight of water = $W_2 - W_1 = 30g$

Water content, $M_1 = \{(W_2 - W_1)/ W_1\}\times100$

$= 150\%$

B. Bamboo with PVC tape confinement

Splint of bamboo with same dimensions 20.74mm x6.68mm and height 430 mm was also left dipped in water for 24 hours. The weight of the splint before and after dipping was recorded.

Weight before dipping, $W_1 = 20g$

Weight after dipping, $W_2 = 30g$

Weight of water = $W_2 - W_1 = 10g$

Water content, $M_2 = \{(W_2 - W_1)/ W_1\}\times100$

$= 50\%$

Fig. 14 Water bath of samples for 24 hours

VIII. RESULTS AND DISCUSSION

A. Results of tension test

The strength of the tensile samples without PVC tape confinement gave an average value of 124.4Mpa. On the other hand, the strength of the samples with PVC tape gave an average value of 158.3Mpa. Thus, the mean strength of tensile bamboo sample confined with PVC tape can be enhanced to 27.25% increased than the mean strength of bamboo sample without PVC tape.

B. Result of compression test

A Bamboo culm of height 150 mm without PVC tape was tested for compression strength test and the maximum compressive load was coming as 26kN.

The compressive strength was recorded as 41.95 MPa. When a Bamboo culm of same height 150 mm with PVC tape was tested for compression strength test and the maximum compressive load was coming as 32kN. The compressive strength was recorded as 74.33 MPa. Thus, the mean compressive strength of bamboo confined with PVC tape can be enhanced to 77.19 % greater than the value obtained for bamboo not confined with PVC tape.

C. Results of water absorption test

As w2 < w1, so splint with PVC tape wrapped over it has less water absorbed in comparison to splint without PVC tape.
So, we can use PVC tape as it does not absorb much water from the concrete thus enhancing its durability.

IX. CONCLUSION

Due to wrapping of PVC tape there was substantial increase in tensile strength and compressive strength of splint of bamboo and bamboo culm respectively. Hence it can be a future alternative for reinforcement in concrete structures.
The test for water absorption was also performed on two bamboo splints of same kind that were used in tensile test. The results were positive and specified the norms as per the standard research papers.

REFERENCES

1. Bhalla, S., Gupta, S., Puttaguna, S. and Suresh, R. (2009), "Bamboo as Green Alternative To Concrete and Steel for Modern Structures", Journal of Environmental Research and Development.
2. Fei Ye1 and Wenxi Fu, Ph.D., "Physical and Mechanical Characterization of Fresh Bamboo for Infrastructure Projects" American Society of Civil Engineers.
3. A. W. Mekonnen and J. N. Mandal, "Model Studies on Bamboo-Geogrid Reinforced Fly Ash Walls under Uniformly Distributed Load" 2017 American Society of Civil Engineers.
4. Wenqing Wu, M.ASCE, "Experimental Analysis of Bending Resistance of Bamboo Composite I-Shaped Beam" 2013 American Society of Civil Engineers.
5. Vishal Puri and Pradipta Chakrabortty, "Policy Issues in Affordable Housing Made with Bamboo Reinforced Structural Component" 2013 American Society of Civil Engineers.
6. Nathan Schneider, Weichiang Pang, Mengzhe Gu, "Application of Bamboo for Flexural and Shear Reinforcement in Concrete Beams" Structures Congress 2014 © ASCE 2014.
7. Guiqiu Huang, Zhen Huang, Xueyuan Deng, Jing Jiang, "Experimental Study on Carbon Fiber Polymer Reinforced Bamboos" Civil Engineering and Urban Planning 2012 (CEUP 2012) ©ASCE 2012.

AUTHORS PROFILE

Rishabh Rastogi, Bachelor of technology in Civil engineering from Delhi Technology University, New Delhi.
Membership - Present member of Indian Geotechnical Society Delhi Chapter.
Achievement - Secured 2nd position in INSPIRE AWARD, DST, Govt. of India at Delhi state level at thyagraj stadium, august-2014. Project – A chimney which works on the principle of electrostatic charge to reduce air pollution. Participated in INSPIRE AWARD, DST, Govt. of India at national level at Pragati maidan (ITPO),Oct-2014. Awarded with a novel of Sudha Murthy and completion certificate of USIP internship by Prof. Yogesh Singh (vice chancellor, DTU) at USIP valediction ceremony (30 May,2019), Ex-intern at L&T Panipat Elevated Corridor Limited (L&T PECL), Panipat Haryana (June, 2018- July, 2018).

Yogesh, Bachelor of technology in Civil engineering from Delhi Technology University, New Delhi.
Membership - Member of University Student Internship Program (USIP) during the year 2018. It is an Internship Program to engage DTU students in various activities of the university
Achievement-Awarded with a novel of Chanakya and completion certificate of USIP internship by Prof. Yogesh Singh (Vice Chancellor DTU) at USIP valediction ceremony held on 30 May 2019. Did summer training at BAANI City Center Sector – 63, Gurugram, Haryana from June 2019-July 2019.It was a commercial project offering High street retail food court and Service apartments. There I gained knowledge about the construction activities held at the site and structural members like footing, columns, etc. Achieved Consolation prize in Bharat Ko Jaano Quiz Competition in 2013.

Nikhil Kumar Pankaj, Bachelor of technology in civil engineering from Delhi Technological University, New Delhi.
Ex intern at Larsen and turbo barapullah flyover (June -July) 2019.
Achievement- Member of Innova (tech and management team of DTU).
Membership - Present member of Indian Geotechnical Society Delhi Chapter.

B.R.G. Robert, Assistant professor in Delhi Technological University, New Delhi.
Areas of Interest - Geology, Surveying, Building materials & Construction. Testing of Materials, Design Mix of Concrete & Job mix for road works, Third party Quality Assurance. Conducting Survey camp & Industrial visits for students. Teaching Building material and Construction and Surveying to IV Sem Students of Civil Engineering.