Effect of Sand Coating with Solution on Bond Strength of Bamboo

Amol Ashok Kamble, Suppiah Subramaniam

Abstract — In a developing country like India, there is an increasing demand for RCC. The major component of RCC is steel. Steel is an alloy of carbon. In manufacturing processes of steel lots of energy is required. For such energy, lots of natural energy sources are used which can adversely affect the environment. For sustainable development, Bamboo may be a proper replacement for steel. Bamboo is fast growing grass which easily cultivated in any types of land. For replacement of bamboo, the bond between bamboo and concrete must be strong. The bond strength of bamboo and concrete is a major concern in the use of bamboo. The surface of the bamboo is naturally coated and has a smooth surface. Due to smooth surface bond strength is decreasing. For increasing bond strength there must be the proper coating for bamboo. In this paper, a solution is used for coating. For roughness, the surface is coated with sand with a solution. For comparing bond strength of different coated surface pull out the test is carried out. For pull out, test samples with the various coated surfaces are cast and tested after 7, 14 and 28 days. The result shows an increase in bond strength of the coated surface.

***Index Terms*: Bond strength of bamboo, Pull out test, Surface coating, development length**.

I. INTRODUCTION

In construction industry major material used along with concrete is steel. Steel is alloy of carbon and iron. In manufacture process of steel the energy consumption is very high. This largely contribute in the CO_2 emission. The CO_2 emission is the largest problem in environment. To overcome this problem we have to find natural material for replacement of steel.

For this Bamboo is good alternative. Bamboo is fast growing plant which has better tensile strength. It can cultivate in all terrain and climatic condition. It gives good income for farmer as well. This leads to consider bamboo as good replacement for steel.

This study mainly concentrate on use of Bamboo as reinforcement material. In reinforced material bamboo have to achieve good bond between bamboo and concrete. Bond strength of Bamboo with concrete is lesser as there is expansion and contraction effect observe in bamboo when contact with water.

To overcome this effect we have to apply proper coating on Bamboo. For that we choose PVC solvent which water reliant material. This PVC solvent is economical material.

A. Bond strength of bamboo

When bamboo placed in concrete, concrete adheres to the surface of bamboo and exert forces which are opposing the slippage of bamboo respect to the surrounding concrete. This phenomenon is known as a bond. The force requires to pull out bamboo from concrete is known as bond strength.

B. Bond Stress

Bond is achieved by the development of shear stress develop in between the surface of bamboo is known as bond stress.

C. Development length

It is the embedded length of bamboo required to place in concrete as it achieves its design shear strength.

D. Bamboo concrete bond

The bond between bamboo and concrete is not straightforward to understand as it contains lots of parameters continuously acting on each other. For better understanding, we can divide such parameter into two things i.e. friction between them and adhesive force of attraction between them.

The major factor affecting on the bond is…

1. Adhesion between concrete on bamboo surface.
2. Due to the shrinkage of concrete grips form around bamboo.
3. Friction resistance and interlocking between them.
4. Effect of the strength of concrete.
5. Mechanical anchorage effect through bond length trades on the surface of the bamboo, cross bamboo.
6. Dimension, the spacing of bamboo as its effects on the cracking of concrete.

The above factors are not only effects on bond strength but others also there. Factor 2, 3, and 4 are the most important factors which affect them considerably. Forgetting broader idea about bond strength we can do pull out test

Pull out the test is simple to perform. The bamboo is cast into a concrete sample to known length. The bamboo is pulled with the help of a tensile testing machine. This process is continuing until bamboo yields its strength or is pullout from concrete. This test has advantages as it eases to perform and finding bond strength. In this test, bamboo is in tension and concrete in compression. But concrete behaves differently in compression as in tension. Concrete has less strength in tension as it suddenly cracks under little tensile load.

E. Factor affecting bond strength

Bond strength mainly depends on

1. Chemical adhesive force between concrete and bamboo
2. Friction between

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Amol Ashok Kamble, Civil, Smt. Kashibai Navale College of Engineering Pune, Maharastra.

Dr. Suppiah Subramaniam, Civil, Vel Tech, Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai.

bamboo and concrete

3. Bearing against trades on bamboo

Some other factors also affect the bond strength as discus bellow

1. **Concrete strength and composition**

Bond strength is affected not only by strength but also by composition and consistency of concrete. Compressive strength is a major parameter in bond strength because the force is transferred by bearing and bond and failure can occur by tensile splitting and sharing of concrete (Orangun et al. 1977). The bond strength depends on both compressive as well as the tensile strength of concrete.

2. **Concrete cover**

The infection of bamboo by different insects depends on direct contact of bamboo in the atmosphere. As this infection is inversely proportioned to the concrete cover which is provided on bamboo. Bond strength increases with an increasing cover thickness. Tepfers (1973) & Orangun et al. (1977), observed that the concrete cover and the shear or tensile reinforcement spacing significantly influence the type of bond failure. Splitting tensile failure occurs with small concrete covers and the bond capacity in pullout will be higher for the larger cover thickness.

3**. Bamboo profile**

If bamboo has only plane smooth surface it eases to slip out through concrete. Due to this, there can be lesser bond strength. But if the particular type of bamboo has traded on its surface trades exert bearing forces. These bearing forces are considerably contributed to bond strength. Such bamboo has a higher band strength.

4. **Availability of oxygen**

Presence of oxygen is essential for the living of microorganism which can infect the bamboo. This microorganism can reduce the strength of bamboo. Therefore the availability of oxygen nearer to bamboo can reduce bond strength.

5. **Relative humidity and Temperature**

Lots of insects which are attacking bamboo have a favorable condition to live in a higher humid area and lesser temperature. Therefore bond strength increases as humidity increases and bond strength decrease with temperature increases. K. Ghawami (Cement & Concrete Composites 27 (2005) 637–649) [1] says during the casting and curing of concrete, reinforcing bamboo absorbs water and expands. The swelling of bamboo pushes the concrete away and then at the end of the curing period the bamboo loses the moisture and shrinks back almost to its original dimensions leaving voids around itself. The differential thermal expansion of bamboo with respect to concrete may also lead to cracking of the concrete during service life. The swelling and shrinkage of bamboo give a considerable reduction in bond strength.

6. **Water-cement ratio**

The w/c ratio does not itself control the rate of corrosion of reinforcement. Higher w/c ratio increase humidity nearer to bamboo but it also increases the oxygen diffusion coefficient. This can leads us to eliminate the consideration of w/c ratio in bond strength. Although high water-cement ratios can lead to bleeding under the Bamboo, especially the top bamboos and result in lower bond strength.

7. Effects of infection on bond strength

As bamboo is infected by various insects. It attacks bamboo which affects in reducing the strength of bamboo. This weaken bamboo have dust and insects saliva on its surface. This material forms a smooth surface on bamboo which considerably reduces the strength of bamboo.

II. IS: 456:2000 [9]

Table. I 26.2.1.1 IS 456:2000 Design bond stress in limit state method for plain bars in tension shall be as below

Sr.No.	Grade of concrete	Design bond strength N/mm2
1	20	1.2

For deformed bars conforming to IS 1786 these values shall be increased by 60 percent.

III. EXPERIMENTAL PROGRAM

This study involves the construction of various bamboo concrete specimens of 3 type's surface profile of bamboo. These specimens are tested under pull out test for studying the influence of different surfaces on bond strength of the bamboo. For this testing, we construct a concrete specimen of size 100mmX100mmX460mm with the embedded length of 300mm.

IV. MATERIAL PROPERTY

Bamboo

Greenish Yellow colored bamboo which are 3 to 4 year old bamboo is used for study.

Fig. I Types Bamboo

Concrete Mix Design

Type of cement- 53 Grade OPC cement

Concrete - M20

Maximum nominal size of aggregate – 10 mm

Workability – slump

values 75mm

Type of crushed aggregate – crushed angular
Fine aggregate – zone I
Test Data for material
Specific gravity of cement-3.15
Specific gravity of course aggregate- 2.95
Specific gravity of fine aggregates- 2.6
Mix proportion of
(Cement: Sand: Aggregate: Water) = (1: 2.1: 1.88: 0.5)

V. SPECIMEN DETAILS

Fig. II Formwork Sample

Specimen of dimension 460 X 100 X 100 and development length is 300 mm. 9 samples cast without any coating which are tested in a group of three samples on 7, 14 and 28 days. 9 Samples cast with solution coating with PVC solvent coating which is tested in a group of three samples on 7, 14 and 28 days. 9 Sample cast with solution coating with PVC solvent and sand coating which are tested in a group of three samples on 7, 14 and 28 days.

VI. MIXING, CASTING AND CURING

Before mixing the concrete, Bamboos were carefully cleaned. The Diameter of the bamboos in each specimen was recorded and bamboos are coated with different coating as discus in specimen details and bamboo were aligned and fastened to the molds. Mold releasing compound was applied to the specimen molds. Hand compaction was

Performed after pouring the concrete; the specimen surface was smoothened with the help of a trowel. The concrete specimens were cured for 24 hours. Demoulding and transportation of the specimens were done with great care to avoid any disturbance to the specimen. After demoulding specimens were cured in curing tank for 7, 14, and 28 days.

VII. PULL OUT TEST

Pull out test is performing to determine the bond strength of the specimen. This test was performed on the universal testing machine of capacity 250KN. The load was controlled by load value. The test set up is as shown in the figure. The specimen was inversely placed on the machine. A steel plate of 12mm thick is used with central whole placed on the plate to pass bamboo through the plate and distribute constant force on concrete. The arrangement was made such a way that the only bamboo can be in tension and concrete in compression. The maximum pullout force is recorded to calculate bond strength.

The bond strength is given by

$$\tau_{bd} = \frac{P_{max}}{\pi DL} \quad (1)$$

Where

$\tau_{bd} -$ *Bond strenght*
$P_{max} -$ *Maximum pull out force*
$D -$ *Diameter of bamboo*
$L -$ *Embedded lenght*

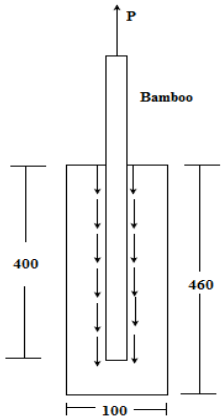

Fig. III Pullout Test

Fig. IV Sample Test Setup

VIII. TEST RESULT

Table. II Maximum Load and Bond Stress Result

Sr. No	Description	Days	P_{max}	Average stress (N/mm^2)
1	Without any coating	7	26.2	0.85
			26.5	
			24.3	
		14	24.0	0.93
			25.7	
			22.6	
		28	23.1	0.97
			25.0	
			22.6	
2	With Solution coating	7	19.2	1.14
			25.2	
			30.0	
		14	18.9	1.28
			23.2	
			27.4	
		28	18.4	1.40
			23.1	
			26.1	
3	Coating with Solution and sand	7	21.9	1.05
			23.8	
			20.2	
		14	25.2	1.15
			24.3	
			22.2	
		28	27.4	1.25
			26.5	
			24.8	

Result discussion

As time increases bond strength of bamboo slightly increase with time.

Band strength of bamboo with coating is considerably increases.

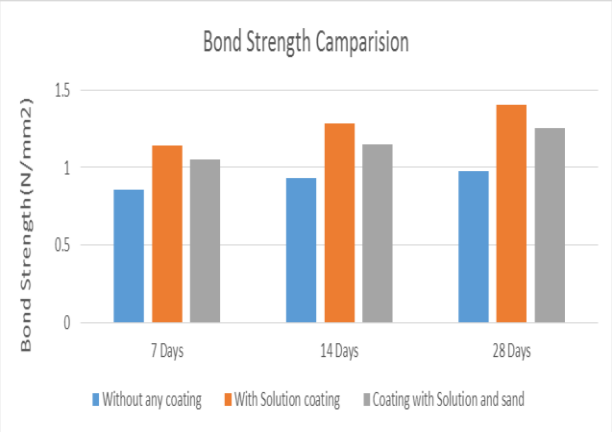

Fig. IV Bond strength Comparison

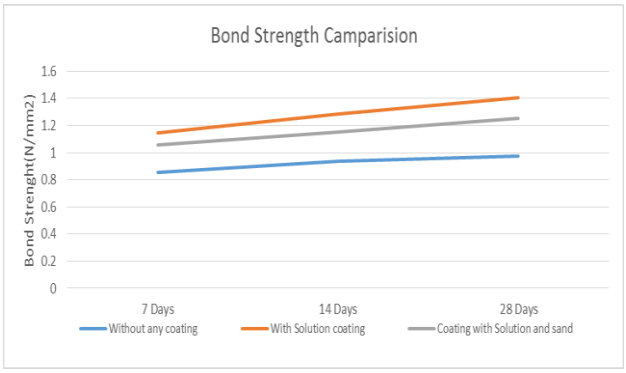

Fig. V Day Wise Bond Strength Comparison

Table. III Increase in bond strength for various coating

Days	Increases in strength With Solution coating (%)	Average increase in strength (%)	Increases in strength with Solution and sand Coating (%)	Average increase in strength (%)
7	33.907	38.621	23.450	25.139
14	37.520		23.393	
28	44.437		28.573	

Result discussion

Bond strength of bamboo is increased by 38.621 % with solution coating.

Bond strength of bamboo with sand and solution coating is increased by around 25.139%.

IX. CONCLUSION

Solution coating improves the life of bamboo as it avoids the insect's attacks.

Solution coating on Bamboo improves Bond strength of bamboos by 38.621 % as solution coating avoid expansion and contraction of bamboo due to moisture absorption. The value of bond strength with solution coating is more than design strength of plain steel.

Similarly, the coating of sand and solution avoid expansion and contraction of bamboo since bond strength of bamboo is increased by around 25.139% but there is weak bond in-between sand and bamboo so no greater effects observed in sand and solution coating. The value of bond strength with coating of sand with solution is nearly equal to design strength of plain steel.

This study suggest a PVC

solution coating is improve band strength of bamboo almost by 40 percent.

This can improve the use of bamboo as reinforcement in various structure as it overcome major problem in Bamboo.

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AUTHORS PROFILE

Amol Ashok Kamble is Assistant Professor in Smt. Kashibai Navale College of Engineering Pune, Maharastra. He is Research Scholar in Vel Tech, Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai. He is doing research in Bamboo Reinforced Concrete.

Dr. Suppiah Subramaniam is Professor in Vel Tech, Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai. Dr. S. Suppiah. is a member of many international affiliations. He has successfully completed his Administrative responsibilities. He has authored many research articles/books related to Civil Engineering.