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The Comparison Between Pull-Out Test And Beam Bending Test To The Bond Strength Of Bamboo Reinforcement In Light Weight Concrete

Nindyawati*, Sri Murni Dewi, Agoes Soehardjono****
*(Doctoral Student At Master And Doctoral Program, Faculty Of Engineering, Brawijaya University, Indonesia and Lecturer At Civil Engineering, State University of Malang, Indonesia)
** (Professor, Department Of Civil Engineering, Brawijaya University, Indonesia)
*** (Professor, Department Of Civil Engineering, Brawijaya University, Indonesia)

ABSTRACT

Bamboo reinforced concrete as a building material is expected to be an alternative to steel reinforced concrete. Due to the fact that steel is not renewable and polluting steel mills are fairly high. The bond strenght is a major concern for the natural fiber used as reinforcement in structural composites.

This paper reports study on the bond strenght of bamboo reinforcement in concrete. To determine the adhesion reinforcement in concrete often do by the pull-out test. The research objective was to compare the bond strenght between pull-out test and beam bending tests . The test used light weight concrete with foam additives klerak. Bamboo slats, coated paint and sprinkled with sand.

The result pull-out test is equal to 0.41 MPa. Bond strenght bamboo in bending test is 1.49 MPa. The results obtained showed that the bond strenght of bamboo pull-out test is smaller than the beam bending test.

Key word : Bamboo, reinforcement, pull-out test, light weight concrete.

I. INTRODUCTION

Bamboo has many unique properties that make it strong and suitable to be used as a construction material. Concrete is used for most building. The most reinforcement material for concrete is steel. Steel needs great energy to produce and can not be renewed. Even some countries do not have the steel. Bamboo however, is more cheap and can renewable.

The usual assumptions in the design and analysis of concrete structures is the bond strenght reinforcement with concrete surrounding it is complete without sliding. Based on that assumption when the bamboo reinforced concrete support surface tension bond between the bamboo and concrete. For beam structures that resist bending moment, bond strenght equivalent to the variation of changes in the value of the bending moment along the beam. Changing the value of longitudinal bending moment resulting interaction between bamboo reinforcement and concrete so that the tension stress along the bamboo reinforcement should be arrested.

The simple pull-out test is widely used to evaluate bonding with concrete reinforcement. In the pull-out test concrete reinforcement is pulled so that the concrete around it stressing. Bond behavior actually occurs in concrete beams reinforcement not like the pull-out test, reinforcement and surrounding concrete experience both tension (Elagroudy, 2003). Strong adhesion to concrete reinforcement depends on main factors (Nawy, 1998) that bond between concrete and reinforcement; effect gripping (holding) as a result of the drying shrinkage of concrete around the reinforcement. Bamboo swells up as it absorbs water. This swells up might cause voids and loss of adhesion between the surface of bamboo and the concrete. When bamboo shrinks and dries, could lead to failure in the concrete structure. To counter this problem is to coat the bamboo with a water resisten coating.

Resistance friction to slip and lock together when experiencing tension reinforcement also increases the resistance to slip. Effects of quality tension stress of concrete influence attached to bond strength bamboo. The bamboo slats coated paint and sprinkled with sand. Sand serves to increase the gripping effect on bamboo reinforcement.

II. MATERIALS

Bamboo culms, paint, cement, sand, klerak foam and water are used in this investigation.

II.1. Bamboo

The brown colour Apus bamboos are selected, which indicates that the plant is at least three years old. The culms seasoned before use so that starch of bamboo will be lost and insect attacks will be minimised which is used for construction. The bamboo culms are split or cut by means of hand knife. Aerated for two days to reduce the moisture content in bamboo.

II.2. Paint

Bamboo receive a waterproof coating to minimise swelling. Paint "MAWAR" is used as water proofing in research.

II.3. Concrete

The concrete mix proportion (cement : sand) is 2 : 3. Water – foam and cement ratio is 0,60. Concrete is expected lightweight concrete. The foam of lerek is sticky, able to keep the bubbles in the concrete mixture.

II.4. Klerak (*Sapindus rarak* Dc)

Klerak seeds foam is often used for washing clothes by the people of Indonesia. Klerak foam is thick and sticky. The sticky bubbles can sustain hollow in concrete. Cavity causing lightweight concrete.

Fig 1. *Sapindus rarak* Dc

III. EXPERIMENTAL PROGRAM

Tests conducted were: concrete compression strength testing, tension testing of bamboo, pullout tests, and beam bending test. Preparation of test specimens and testing using the following tools: stirring concrete compression machine with a capacity of 2000 kg to test the compression strength of concrete, Universal Testing Machine (UTM) 2 ton capacity used for tension testing of bamboo and pullout test . Tests performed on the flexural strength of concrete loading frame equipped with hydraulic jacks and load cells. The number of specimens for each type of test is shown in Table 1, and the test object shown in Figure 2.

Table 1. Objects Test

No.	Type of testing	Number of specimens
1	Concrete compression strength testing	6
2	Tension testing of bamboo	6
3	Pullout test	6
4	Beam bending test	3

III.1. Concrete Compression Strength Testing

Lightweight concrete made from cement, sand, water and foam klerak. The sand used was Malang sand. Specimens were cylinders with a diameter of 150 mm and height of 300 mm. Concrete cylinder covered with plastic for 28 days so as not to get wet. Specimens were weighed before test. The specimens were placed in compression testing machine of capacity 2000 kN. The load is applied parallel to concrete in gradual increments until the specimen failure. Determined compression stress at ultimate load.

III.2. Tension Testing Of Bamboo

Apus type of Bamboo specimens of length 400 mm was used. Bamboo specimen with dimension of 8 mm x 8 mm. Tension test procedure for bamboo is same as that of steel. Load and elongation readings for specimen placed in UTM are recorded.

III.3. Pull Out Tests Specimen

Apus type bamboo of 450 mm length and be split 8 mm x 8 mm are used. Bamboo coated paint and sprinkled with sand. Concrete cylinders of size 75 mm dia and 150 mm length are used for test. The bamboos specimens were placed at center in concrete cylinders while casting.The specimens were tested after 28 days of curing are tested in machine of capacity 15 kN.

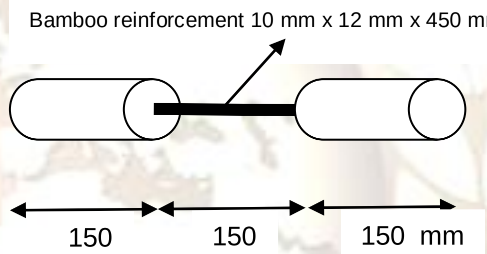

Figure 2. Specimens *pullout* test

Bond length (ld) is the length of bamboo which is in contact with concrete in cylinder. The bond stess is determined from ultimate load using formula,

$$u = \frac{P}{\pi . d_b . l_d} \quad \text{Units are in N/mm}^2$$

Where 'P' is the ultimate load at failure, 'd'is the diameter of specimen.
Bamboo reinforcement can be detached from the concrete because split in the longitudinal direction when the high frictional adhesion or defense. When the bamboo reinforcement can be separated out and leave a hole in the concrete so there is low adhesion or friction.

III.4. Beam Bending Test

The specimens used for bending test are apus bamboo of 650 mm length. Bamboo slats with dimensions of 8 mm x 8 mm x length of bamboo, covered with paint and then sprinkled with sand to improve adhesion. Reinforcement has assembled will casted by lightweight concrete as shown in fig 2.b. The light weight concrete used cement, sand "Malang", water, and foam of klerak (*Sapindus rarak* Dc). The concrete mix proportion (cement :

sand) is 2 : 3. Water – foam and cement ratio is 0,60.

Beams were tested after treatment for 28 days. Specimens tested at Universal Testing Machine (UTM) with a capacity of 2000 kN.

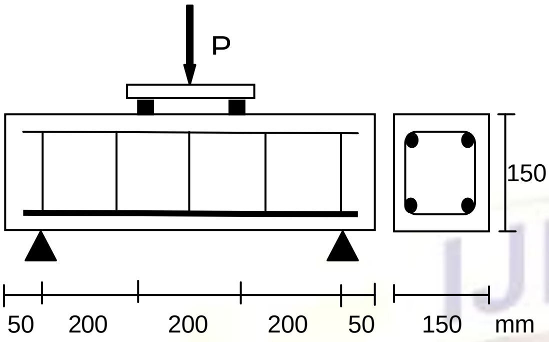

Figure 3. Specimens Beam Bending Test

According to Park & Paulay (1974) the amount of the bond stess flexural beam can be determined from the amount of shear forces that occur.

$$\mu = \frac{V}{\sum o.\, jd}$$

Where 'V' is the shear forces of beam, 'Σ_0'is the nominal surface area of a bar bamboo of unit length, 'jd' is the lever arm of the resultant compression force. The distance between the resultan internal forces, known as the internal lever arm, is given by

jd = (d – ½. a)

Where d, the distance from the extreme compression fiber to the centroid of the bamboo area, is known as the effective depth, 'a' is the depth of the equivalent rectangular stress block.

IV. TEST RESULTS AND DISCUSSIONS

IV.1. Concrete Compression Strength Test

The failure of concrete is observed as compression failure. Curing of light weight concrete is 30 days. The compression test using Universal Testing Machine (UTM). The addition of foam and water klerak 60% of the cement causing low concrete compression strength (Table 2). Klerak foam forming cavities in the concrete so that the concrete compression strength is low. Cavity causing bonding among aggregate reduced. When under pressure, easily spalled concrete as aggregate bonding brittle.

Table 2. Light weight concrete Compression Test

Specimen Number	Compression Stress (N/mm^2)	Weight of Cylinder (N)
1	12.8	68
2	11.9	59
3	13.2	68
4	13.5	69
5	12.9	65
6	11.8	66
Average	12.7	66

Average compression stress of light weight concrete was 12.7 MPa. None of the results of compression stress has a value of less than 0.85 average compression stress of concrete. The advantages of foam klerak is a light weight concrete. Weight concrete cylinders in the study was 66 N. Volume weight concrete cylinder is 1240 kN/m3.

IV.2. Tension Testing Of Bamboo

Bamboo weakness located on the node after the split.The failure of bamboo members are observed mainly as node failure. Selected bamboo with node point at ¼ length from each end (Sakaray:2012). Bamboo coated paint and sprinkled with sand. The failure of bamboo is split failure at middle of specimen. The failure pattern was shown in fig 3.

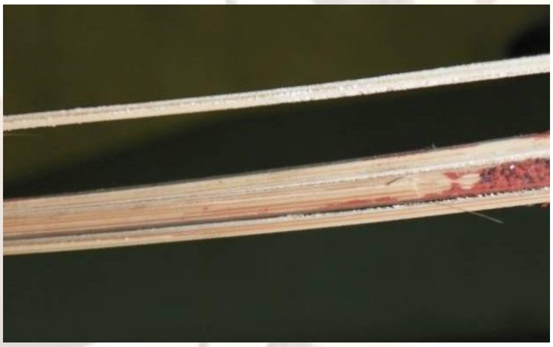

Fig4. Splitting failed specimen in tension test.

Table 3. Tension test for Bamboo

Specimen No	Strain (mm/mm)	Ultimate Tension Stress of Bamboo (N/mm^2)
1	0,0082	135,9
2	0,0080	133,5
3	0,0090	144,0
4	0,0083	136,4
5	0,0084	139,8
6	0,0089	144,2
Average	0,0084	139,0

Bamboo tension test results showed that the average maximum stress that occurs is 139 MPa. Apus Bamboo has a relatively small tension stress than the Bamboo Ori. The advantages bamboo Apus is straight so suitable for the walls. Apus bamboo size average was 8.3 mm x 8.3 mm. The average strain Bambu Apus is 0,0084. Modulus elasticity of bamboo Apus is 16454 MPa.

IV.3. Pull Out Tests

Pull out test results of the testing can be seen in Table 4. The length of reinforcement embedded in concrete is 300 mm. The average maximum load that can be accepted is 318 kg or 3.2 kN. Bond strenght of bamboo to the concrete average is 0.41 MPa.

Table 4. Pull-out Test

S. No	Load (N)	Bond Strenght (N/mm^2)
1	2500	0.33
2	4000	0.48
3	3000	0.39
4	3500	0.45
5	2600	0.34
6	3500	0.45

Reinforcement not yield as well as the concrete had not been spalling. Reinforcement has shifted rapidly over 2.5 mm. Bamboo comes out smoothly from concrete while testing and these values obtained are due to bond failure. Pull-out failure occurred due to the shear strength between the bamboo and the concrete.

IV.4. Beam Bending Test

The results of bending test on a beam can be received by 24,2 kN load. Bending test results of the testing can be seen in Fig 5.

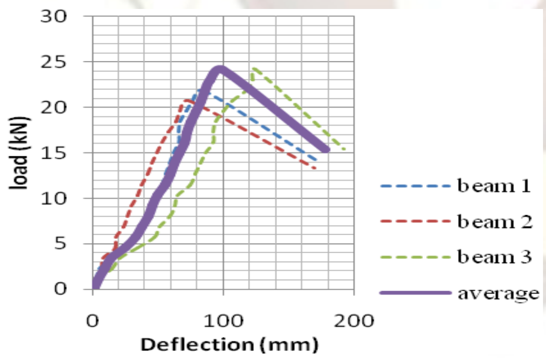

Fig 5. Load-deflection curves for beam loaded in bending.

Theoretically, the load that can be supported by beam is as follows:

$$a = \frac{A_s.f_y}{b.0,85.f_c'} = \frac{128 \; x \; 139}{150 \; x \; 0.85 \; x \; 12.7} = \quad 10.99 \quad mm$$

c = a : 0.85 = 12.93 mm

$M_n = A_b \,.\, f_y \,.\, (d - 1/2a)$

= 128 x 139 x (132-1/2x10,99)

= 2250776,96 Nmm

$$P_{teori} = \frac{6 \, x \, M_n}{l} = \frac{6 \, x \, M_n}{600} = 22507 \text{ N}$$

= 22.5 kN

The result of calculation are known the rated load (P theoretically) equal to 22.5 kN less than the maximum load of 24.2 kN test results. The amount of bond stress to each due to flexural load of 24.2 kN is as follows, Where, b = 150 mm, d = 132 mm, fc' = 12.7MPa, P= 24200 N, and l= 600 mm and, a = 10.99 mm.

jd = (d – ½. a) = (132 – ½. 10.99) = 126,505 mm

$$\mu = \frac{V}{\sum o.\, jd} = \frac{\frac{1}{2}.24200}{(2x4x8)x126{,}505}$$

= 1,49 MPa

From the description above it can be seen that the bond by direct tension pullout bond test less than bond reinforcement on beam. The amount bond by direct tension pullout bond test is 0.41 MPa and bond of beam reinforcement at the rate is 1.49 MPa. Bond direct tension pullout bond test at only 28% of the bond of beam reinforcement. Bond by direct tension pullout bond test is not accurate for use in the calculation of the bond beam reinforcement.

V. CONCLUSIONS

Bond strenght reinforcement calculations based on direct tension pullout bond test is less than bond strenght reinforcement that occurs on the beam. Bond strenght reinforcement by direct tension pullout bond test should be adapted to take account of the real bond strenght reinforcement in beams.

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