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An Experimental and Theoretical of Shear Connector Strength with Void Filler Material on Layers Full-Bamboo beam

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Abstract —The development of the use of bamboo showed increasing as non-wood material. The bamboo of *Gigantchloa atroviolacea* of the most popular has been used as a construction material in Yogyakarta region of Indonesia. Bamboo has a low elasticity modulus and has a cross-section in the hollow. One of the efforts can be conducted to improve the strength and rigidity of bamboo by making of layers full-bamboo beam. One of the factors that affect the strength and stiffness of beam is kind and distance of shear connector with or without of void filler material. The shear connector can be determined with theoretically and ekaperimental. Application of theory of the European Yield Model could be developed into theory of connection lateral strength of bamboo with void filler material. Factors that affect the strength of shear connector is bamboo thickness, kind of shear connector and void filler material. Besides to improve strength connection, the void filler material can be expected to increase the strength and stiffness of layers full-bamboo beam. The four equation of connection strength base on European Yield model can calculated of according to the yield modes of accurred, The connection strength is specified from the value of the smallest of the four of the equation of connection yield modes.

Keyword—Bamboo, Gigantochloa atroviolacea, mortar, shear connector, strength

I. INTRODUCTION

Currently, bamboo has become the most popular as non-wood material in the developing of contruction engineering on especially bamboo building. Besides, bamboo is highly renewable, the fast growth and can be harvested of 3 to 5 years old. Bamboo can utilized as building component such column, beam, floor, ladder, truss, scaffolding, bridges lightweight and furniture. Bamboo of Gigantochloa atroviolacea is favorit as construction material in a city Yogyakarta, Indonesia because has high strength to weigth rasio, relative low cost and already burning can regrow [16}.

The application of bamboo as the structural component of a building, then informasi of mechanical properties of bamboo is very needed. Factors affecting of mechanical properties of bamboo is species and age, green or conditioned, moisture content, form and size of the specimen, node or internode, position along the culm and testing speed respectively[13]. The strength and rigidity of beams can be increased by way of arranging the culms of single with shear connector with or without void filler material. Its influenced by the bamboo diameter, the bolt diameter, the bolt distance and the bamboo component number.

This study was aimed at evaluating some important of the strength of bamboo connection with void filler material. The properties of support were assessed such as bamboo embedment strength, filler material embedment strength and yield moment of shear connector. The strength of the one shear connector from eksperimental and theoritical, then it can be determined of the need of shear connector of beam.

II. MATERIALS AND METHODS

The connection lateral strength can be predicted by applying European Yield Model (EYM) [15], then can be used for computing of bamboo joint strength with void filler material. The method EYM was first proposed oleh Johansen based on the principle of mechanical from inner forces equilibrium to work on the system joint. The joint yield can be defined with the yield of bamboo embedment strength under

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the bolt or the plastic hinge formed on bolt or combination of both. The connection yield models can be obtained an equation of connection lateral strength and the strength of the connection is the smallest resistance values [2].

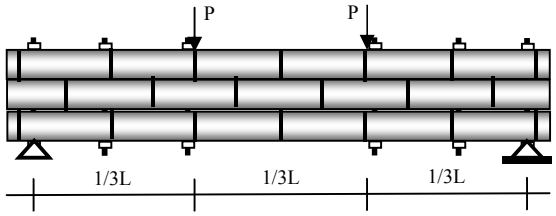

Figure 1 The model of three layers full bamboo beam

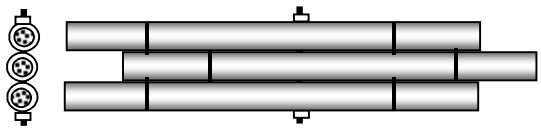

Figure 2 The model connection of bamboo component three

A. The Connection Yield Model

The yield model in use analytically identifies four basic yield modes for the connection of bamboo three component in double shear connection as depicted in Figure 3[2]. The yield model of I_s occur due to yield embedment strength of the component bamboo side with a material of the filler, in Figure 3(a). The yield model of I_m was caused due to yield embedment strength of the component bamboo middle with a material of the filler, in Figure 3(b). On of the yield models due I_s and I_m of shear connector has not experienced of yielding or still behaves elastic. The yield model of III_s was caused due to yield embedment strength of the component bamboo side with a material of the filler and accompanied by one the plastic hinge on shear connector of bolt, in Figure 3(c). The last is of the yield model of IV of the establishment of two hinge plastic or more on shear connector of bolt.

B. The lateral connection resistance

The yield model of I_s

$$Z_1 = f_{em}\, dt_{ms} + f_{eb}\, d(2t_{bs}) \qquad (1)$$

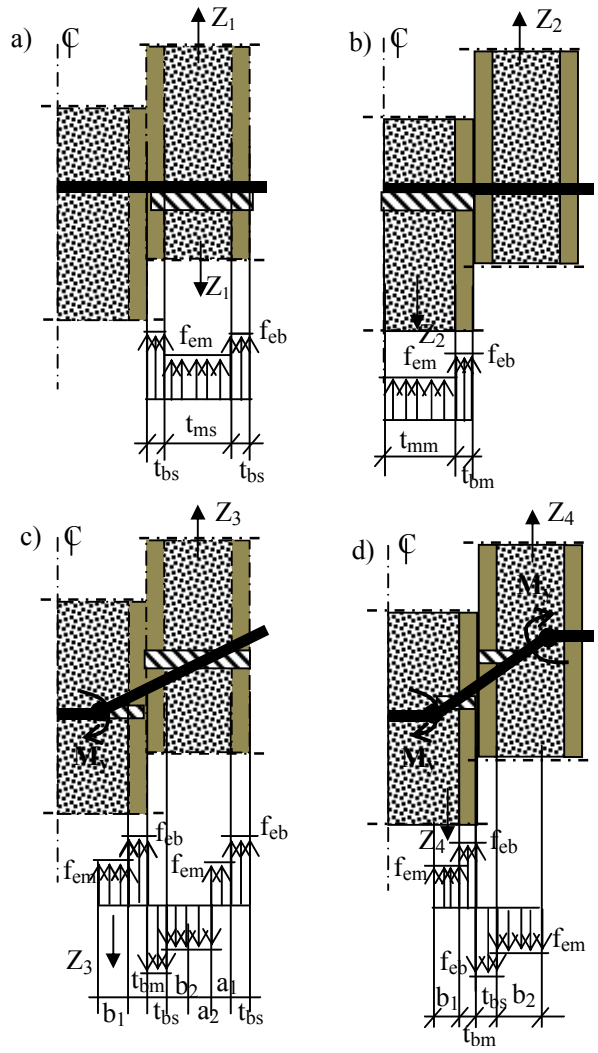

Figure 3 The connection yield models of the three component of bamboo

The yield model of I_m

$$Z_2 = f_{em}\, dt_{mm} + f_{eb}\, dt_{bm} \qquad (2)$$

The yield model of IIIs

$$Z_3 = f_{eb}\, dt_{bs} + f_{em}\, db_2 \qquad (3)$$

in which b_2 obtained by two-order polynomial equation as follows.

$Ab_2^2 + Bb_2 + C = 0$

$A = 0.75$

$$B = ?2 + \frac{3}{2}R? t_{bs} + (1 - R)t_{bm} + \frac{1}{2}t_{ms}$$

$$C = ?\frac{3}{4}R^2 - R? t_{bs}^2 + ?\frac{R^2}{2} - \frac{R}{2}? t_{bm}^2$$

The yield model of IV

(4)

in which b_2 acquired by two-polynomial equaition as follows.

C. The embedment strength of bamboo

Bamboo of *Gigantochloa atroviolacea* was used in this study. This bamboo has been commercially known as one of the materials of construction in Yogyakarta city of Indonesia. The bamboo embedment strength influenced by specific gravity, moisture content, bamboo grain direction and diameter of shear connector of bolt [2]. As a result, some researcher have tested of bamboo embedment strength [1], [4]. The determination of the bamboo embedment strength uses off-set 5% method. The bamboo embedment strength can be determined with an equation as follows.

(5)

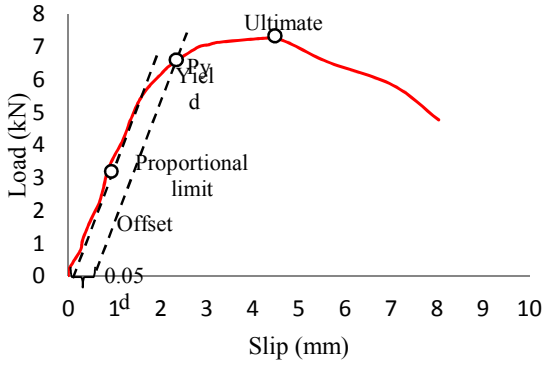

Figure 4 Determine of yield embedment load of bamboo

D. The embedment strength of void filler material

Bamboo void filler material can be either mortar. Mortar is a mixture of sand, cement and water. The mortar was used in this study with comparisons between the cement and sand (1:3), while water-cement ratio was 0.50. To increase the strength of the bamboo connection is filled with void filler material, so that is the structure of composite locally [16]. A cross section in hollow bamboo, the force on the connection was detained by void filler material and partly was countered the bamboo. The yield load of void filler material can be obtained via testing of cube compression strength of 50 x 50 x 50 mm^3 , in Figure 5. The strength embedment of the void filler material (mortar) can be specified with an equation as follows [1].

(6)

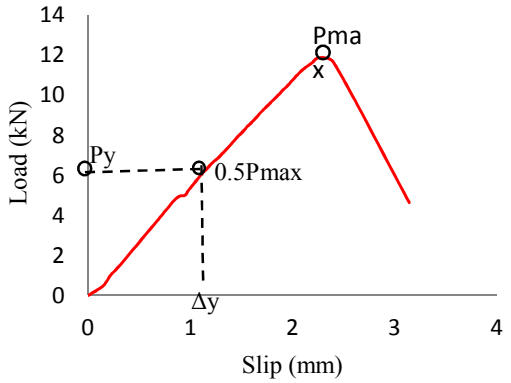

Figure 5 Determine of yield embedment load of void filler material

E. The yield strength of bolt

The determination of the yield bending strength of the bolt is conducted by three-point bending method. Bolts to be used in this test has a diameter of 12.7 mm (diameter actually 12.33 mm). The yield bending load is determined with off-set 5% method. The yield bending moment of bolt can be determined with an equation as follows [5].

(7)

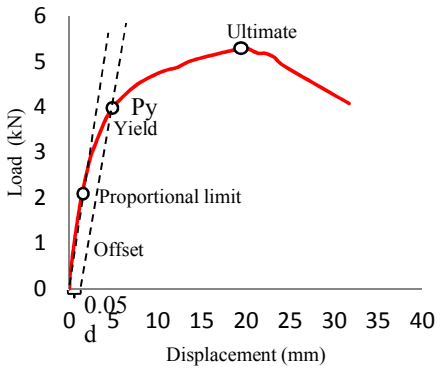

Figure 6 Determine of yield load of bolt

III. RESULTS AND DISCUSSION

From 9 bamboo specimen, it was found that the bamboo embedment strength of specimens varied from 22.34 to 36.64 MPa with an average 27.23 MPa. The average value on height position at bottom, middle and top was used to estimate the bamboo embedment strength in direction of parallel to grain. The typical load-embedment curve of loading parallel to the grain obtanined from the experiments is showed in Fig.4.

Experimental and estimated of the strength embedment of void filler material (mortar) are shown in Fig 5. The average values was discovored that the strength embedment of void filler material of specimens varied from 5.20 to 20.57 MPa with an average 12.61 MPa. The typical load-embedment curve of loading of void filler material obtained from the experimental. The yiel load of void filler material acquired from 0.5 P_{max} of typical load-embedment curve [6].

The determination of the yield bending strength of the bolt is conducted by three-point bending method [7]. Bolts to be used in this test has a diameter of 12.7 mm (diameter actually 12.33 mm) with the number of specimens of 5. The yield bending load is determined with off-set 5% method. Typical load-displacement curve was procured from experimental. The yield bending moment was found of the specimens varied from 74321.63 to 92017.25 Nmm with an average 87062.48 Nmm.

From 15 specimens of three-component bamboo were expressed in Figure 7. The theoretical and eksperimental results presented in Table 1 for shear double connection (SDC) on height position at bottom (B), middle (M) and top(T). Results of connection strength of theoretically represented by the yield modes. Four kinds of yield modes of analyzed can be concluded a three-component bamboo reviewed which the smallest value is given by the yield mode IV. The yield model of IV of the establishment of two hinge plastic on shear connector of bolt was showed in Figure 8.

TABLE 1 RESULTS OF THEORITICAL AND EKSPERIMENTAL OF CONNECTIONS

Specimens Label	The Connection Lateral Strength						
	Theoritical					*Eksperimental*	
	Z_1	Z_2	Z_3	Z_4	Z	Py	Pu
SDC.12.B1	31.23	16.0	15.66	13.06	13.06	11.60	27.16
SDC.12.B2.	28.62	15.3	14.48	12.75	12.75	12.40	26.33
SDC.12.B3.	26.35	13.4	13.14	11.97	11.97	11.80	15.18
SDC.12.B4.	30.64	15.5	15.25	12.80	12.80	12.20	25.39
SDC.12.B5.	28.11	14.4	14.36	12.64	12.64	12.40	27.57
SDC.12.M1.	28.36	12.9	13.56	12.07	12.07	11.40	14.28
SDC.12.M2.	27.17	13.1	13.22	12.29	12.29	12.10	19.24
SDC.12.M3.	28.41	13.4	13.69	12.28	12.28	12.20	20.87
SDC.12.M4.	26.75	12.6	13.33	12.12	12.12	10.80	20.74
SDC.12.M5.	28.54	13.4	13.65	12.20	12.20	11.20	22.12
SDC.12.T1.	24.55	11.5	12.01	11.80	11.80	8.80	10.58
SDC.12.T2.	25.90	11.7	12.61	11.85	11.85	10.40	14.68
SDC.12.T3	25.87	11.9	12.51	11.86	11.86	10.20	17.68
SDC.12.T4.	26.61	12.5	12.89	11.93	11.93	10.20	25.31
SDC.12.T5	27.73	12.6	12.78	11.88	11.88	9.40	22.15
Results average					12.23	11.13	20.62

Figure 7 Specimens of three-component bamboo

Figure 8 The hinge plastic of bolt

IV. CONCLUSION

A study on the connection lateral resistance of *Gigantochloa atroviolacea* under a double-shear test configuration is reported. The average connection lateral resistances of theoretical and eksperimental were found to be 12.23 kN and 11.13 kN, respectively. Analysis of theoretical was 8.99% lower than eksperimental of a double-shear connection. Appication of European Yield Model (EYM) on analysis of connection lateral resistance can be used in counting the number of shear connector on layers full-bamboo beam. The four equation of connection strength base on European Yield model can calculated of according to the form the yield that accurred, The strength of the connection is specified from the value of the smallest of the four of the equation of connection yield modes.

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