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On behalf of the orginizing committee The II International Multidisciplinary Conference 2016, here, we are pleased to present the Conference Proceedings, which consist of varieties papers that had been presented on The II IMC 2016.

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STRUCTURAL EFFICIENCY AND FLEXURE STRENGTH OF MIX-GLULAM TIMBER BEAMS ARE COMPOSED OF SENGON AND COCONUT WOOD AS GREEN MATERIAL CONSTRUCTIONS

Kusnindar Abdul Chauf, Sri Murni Dewi

Brawijaya University, Indonesia

kus_untad@yahoo.co.id

Abstract

Wood is a green materials that has a low level of embodied energy. Production of sawn timber is very efficient because it can reduce; reuse and recycling. Two species of wood that could be developed is sengon and coconut wood. The problem is that sengon wood have not an adequate mechanical performance. On the other hand, coconut wood has a good mechanical properties, but the heavy weight becoming an obstacle. Therefore, it is necessary to increase the performance of them. The improvement is achieved by a mix-glulam system that will be produced a lightweight structural timber beams. This research was conducted through a three and four point bending test according to ASTM:D 198 – 02. The coconut wood was placed as the outer zone of glulam. The beams size is 55mm in width, 155 mm in depth and 1740 mm in span. As a control parameter used the mechanic behavior of clear specimen as initial strength. The experimental results showed that the mix-glulam system can increase the flexure strength and stiffness by 6.1% and 8.4% respectively. In addition, the lamination process could be to improve the flexure strength and modulus of elasticity sengon-wood by 8.4% and 26% respectively. On the other hand the lamination process causes a decrease in ductility of 14%, so the glulam beams failure that occurred tend to be more brittle. In terms of structural efficiency, mix glulam has a level much better than concrete and almost equivalent to steel.

Keywords: Coconut Wood, Mix-glulam, Sengon-wood, Timber Beam.

INTRODUCTIONS

Wood is naturally renewable building material that one of the oldest known materials of construction. Simplicity in fabrication, lightness, reusability, and environmental compatibility, have made this material one of the most popular in light construction. Today wood remains important to the engineer by reason of improved technology. Modern technology has increased the durability of wood. Although many construction products using wood as the raw material have been introduced into the construction market in the last 20 or more years and are presently being used extensively the dominant use of wood is still in the form of lumber which are pieces of wood cut from tree trunks (Issa & Ziad, 2005)..

Using more wood in construction has the potential to store more carbon in the building materials than is emitted. The manufacture of wood products results in low emissions compared with other materials. In addition, the carbon stored in wood products is substantially greater than the emissions from their initial manufacture. The carbon stored in wood products as an offset to emissions was shown to be significant. Comparison of various building materials wood, steel, and concrete showed that wood was more environmentally friendly (Lippke et. al, 2010). Table 1 shows that the use

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of wood as a construction material to produce environmental impact index is smaller than steel and concrete (Perez-Garcia et. al, 2005).

Table 1. Environmental Performance Indices for Residential Construction

Mineapolis Design	*Wood*	*Steel*	*Difference*	*% Change*
Embodied Energy (GJ)	651	764	113	17%
Global Warming Potential (CO_2 kg)	37047	46826	9779	26%
Solid Waste (total kg)	13766	13641	-125	-0.9%
Atlanta Design	*Wood*	*Concrete*	*Difference*	*% Change*
Embodied Energy (GJ)	398	461	63	16%
Global Warming Potential (CO_2 kg)	21367	28004	6637	31%
Solid Waste (total kg)	7442	11269	3827	51%

Source: Data adapted from Perez-Garcia et.al (2005:12)

In addition to having an index lower environmental impact, wood also has a good level of structural-efficiency. Based on the structure capacity and mass ratio, the structural-efficiency level of timber is almost equivalent to the steel. Table 2 presents a comparison of the structural-efficiency level of wood, steel and concrete as building material (Thelandersson & Hans, 2003).

Table 2. Strength and Density Rasio of Building Construction Materials

Material	Density (kg/m^3)	Strength (MPa)	Strength /density (10^{-3} $MPa.m^3/kg$)
Structural steel	7800	400-1000	50-130
Aluminium	2700	100-300	40–110
Concrete, compression	2300	30-120	13-50
Clear softwood, tension	400-600	40-200	100-300
Clear softwood, compression	400-600	30-90	70-150
Structural timber, tension	400-600	15-40	30-80

Source: Data Adapted from Thelandersson & Hans (2003:16)

Two species of wood that potential to be developed as a construction material is sengon and coconut wood, although both has disadvantages in terms of mechanic properties and achievement dimensions. The availability of two types of wood is perfectly adequate and does not depend on the logging of natural forests. The low performance of sengon wood and achievements of dimensions can be overcome by applying a mix glue laminated timber systems. Glued laminated timber beams is one of derivative product from wood. The glulam manufacturing process consists in the gluing of overlaid lamellae of timber.

In compare with sawn solid beams, glulams have more advantageous. When the span becomes long, the use of sawn lumber may become impractical. Glued laminated timber can be a good choice for use in this kind of situations. Glued laminated timber beams are highly engineering components manufactured specially selected and positioned lumber laminations of varying strength and stiffness properties (Homas & Williamson, 1976). High quality lumber is required only for the outer laminations and lower quality lumber can be used in the core laminations (Van-Green & Jean, 2001).

In this research, the mixed-glulam system is applied through the placement of coconut wood as the outer lamina to obtain an increase in the flexural strength of the beam. In addition, the limited dimensions can also be solved with this system. Thus will be obtained laminated timber beam

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structure that is lightweight with an adequate flexural strength. However, note the flexure strength generated by the application of the system. Likewise with flexural behavior changes when compared with solid beams. Therefore, in this paper will discuss about comparisons bending strength and ductility of the mix-glue laminated timber beams with sengon-solid wood beams. In addition, also discussed the structural-efficiency level of the glue laminated timber beams compared to concrete and steel.

In order to predict the behavior of glulam, it is essential to understand the effect of the strength increase of laminations as a result of bonding them, the so-called laminating effect. This is a formal definition linked to the assumption that the load-bearing capacity of a glulam beam is essentially governed by the tensile strength of its outer laminations. Furthermore it is assumed that the stiffness and the strength of the laminations are positively correlated (Falk & Colling, 1995).

Material and Methods

The materials used in this study are sheets of board from sengon wood (*Albizia falcatara*) and coconut wood (*Cocos nucifera*). The size of the boards is the thickness = 3 cm, width = 6 cm and length = 200 cm. Before being used as a laminate material, both dried naturally so as to achieve ± 12% moisture content. Sengon wood density used is 320 kg/m^3 and coconut wood density is 551 kg/m^3. The sheets of the board was then leveled using knives planner-machine, in order to reach net dimensions thickness = 2.5 cm, width = 6 cm and length = 200 cm. Then do the manufacturing of wooden beams (solid and glulam) as a specimen, according to the type and dimensions of which are presented in Table 3 and Figure 1.C. Especially for laminated beams, the adhesive used is a urea formaldehyde resin powder (UF-100) which is mixed with water. Its composition is water: UF-100 = 1: 2. Pressure force applied is 2 MPa with a duration of clamping for 24 hours.

Table 3. Geometry and Dimensions of Timber Beam Specimens

Beam Type	Method	Load Type	*b* mm	*h* mm	*L* mm	Repe tition	Density (kg/m^3)
Sengon-Solid	ASTM: D143–2000		25	25	360	3	320
Sengon-Glulam	ASTM: D198 – 02	Three point bending	55	155	1740	3	-
Mix-Glulam (sengon-coconut wood)			55	155	1740	3	-
Coconut-Solid		Four point bending	45	90	1350	3	551

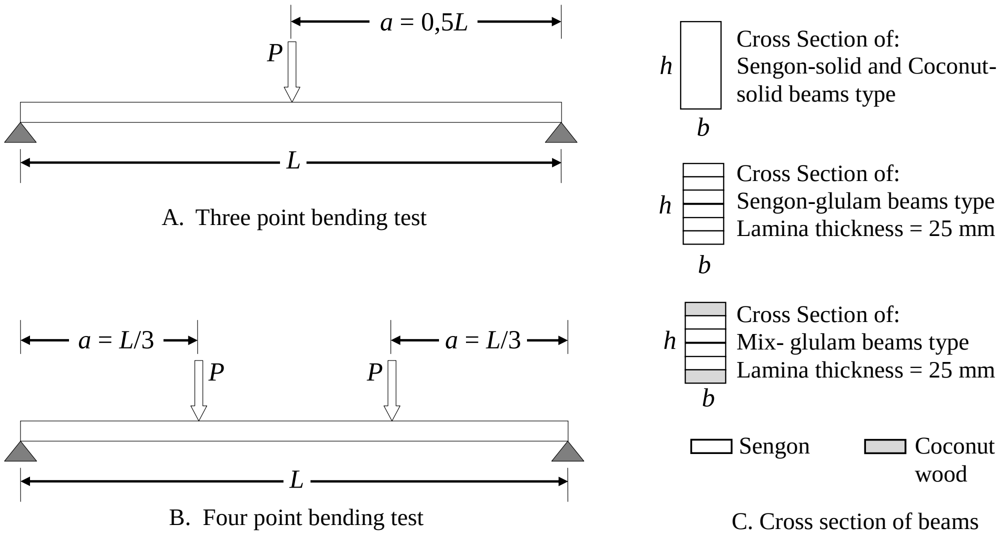

Figure 1. Setting Up of Bending Test and Beams Geometry

Load-deflection data collection is carried out through a static bending test against three types of beams, as Table 3 and Figures 1A and 1B. For each type of laminated beams used uniform lamina thickness of 25mm. Lamina thickness does not make any statistically significant difference in the flexural properties. Laminated beam with the same lamina thickness have no significant difference in the flexural properties. The wood adhesive bond strength and the wood failure percentage are appreciable (Nadir & Praveen, 2014).

The test results is then processed and analyzed to determine the mechanical properties and performance of timber beams. The beam performance criteria determined by the modulus of rupture (MOR), modulus of elasticity (MOE), ductility (D_u) and structural efficiency (ρ / MOR). All parameters were determined by Equation 1 to Equation 5 (ASTM D198-02, 2002).

$$MOE = \frac{P_e L^3}{48\delta_e I} \quad \text{(for three point bending test)} \quad \text{.................................. (1)}$$

$$MOR = \frac{1{,}5\, P_u L}{bh^2} \quad \text{(for three point bending test)} \quad \text{.................................. (2)}$$

$$MOE = \frac{P_e a}{24\, \delta_e\, I}\left(3L^2 - 4a^2\right) \quad \text{(for four point bending test)} \quad \text{.................................. (3)}$$

$$MOR = \frac{1{,}5\, P_u L}{b\, h^2} \quad \text{(for four point bending test)} \quad \text{.................................. (4)}$$

$$D_u = \frac{\delta_u}{\delta_y} \quad \text{.. (5)}$$

Where:

MOE	=	modulus of elasticity (MPa)
MOR	=	modulus of rupture (MPa)
P_e, P_u	=	elastic and ultimit load (N)
δ_e, δ_y, δ_u	=	elastic, yield and ultimate deflection respectively (mm)
L	=	span of beam (mm)
a	=	load distance to the supported (mm)
I	=	moment of inertia (mm^4)
D_u	=	ductility index

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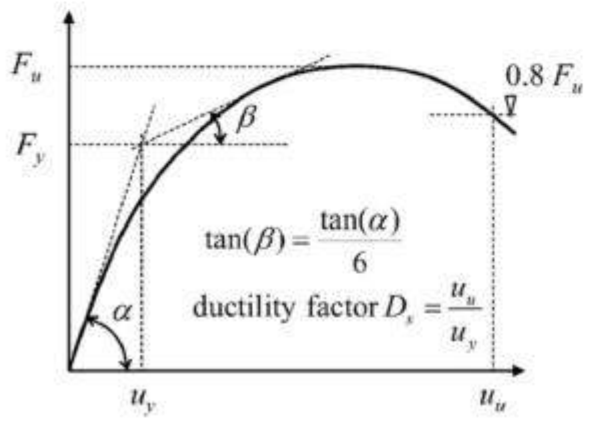
Because the determination of the yield point of the load-deflection curve is difficult, then used the approach as Figure 2 (SIA 265, 2003). Most timber structures are not able to develop full plastic mechanisms at failure. The plasticization only develops in timber under compression. In this case, the currently relative definitions of ductility, as a ratio between an ultimate deformation/displacement and the corresponding yield quantity (Jorissen & Massimo, 2011).



Source(s): SIA 265. 2003

Figure 2. Definition of Ductility Factor, Yield and Ultimate Deformation

RESULTS AND DISCUSSIONS

Flexure Strength and Stiffness of Glue Laminated Timber Beams

The results of the three-point bending test on laminated timber beams are presented in Figure 3. There are two phases to the load-deflection curve of each beam, namely the phase of linear and non-linear phase. Mix glue laminated timber beams by compose sengon-coconut wood (type II.11) has a linear phase firmer and longer. The maximum load is reached after all laminated beams through a non-linear phase. Based on Figure 3, the apparent decrease in the maximum deflection is achieved due to the placement coconut wood on the outer lamina. Bending strength and stiffness changes also occur due to the placement of coconut wood on the outermost lamina (mix-glulam method).

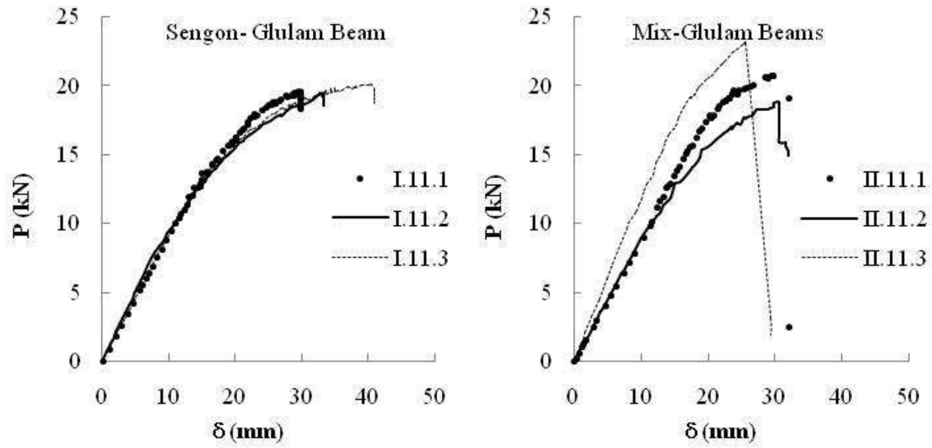


Figure 3. Load-Deflection at Mid Span of Glue Laminated Timber Beams

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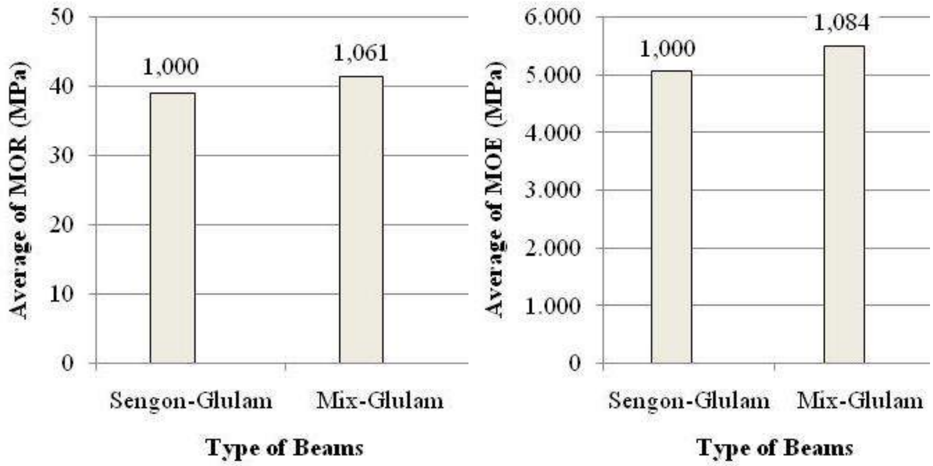

Figure 4. Flexure Strength and Stiffness of Sengon-Glulam and Mix-Glulam Beams

In this case, the mix glulam method produce flexural strength and modulus of elasticity which is higher than the uniform laminated timber beams (uniform glulam method). Figure 4 shows an increase in flexure strength and stiffness by application of the mix glulam method is 6.1% and 8.4% respectively. Both occurred because of the strength increased in the outermost lamina (laminating effect). In this case the tensile strength of coconut wood is higher than the tensile-strength of sengon wood. This is in line with the statement that the bending strength of laminated timber beams is determined by the strength of the outermost lamina (Falk & Colling, 1995).

The laminating effect are shown in Figure 5. By comparison of flexure strength (MOR) and modulus of elasticity (MOE) of the sengon-solid beams and sengon-glulam beams showed an increase. The increase in flexural strength of 8.4% caused by the lamination process applied to sengon wood. Likewise, the modulus of elasticity of sengon-wood increased by 26%. This increase occurred due to the densification effect of the lamination process. There is also a weak zone deployment of the lamina. In solid timber beam, the weak-zone concentrated in one location. But in laminated beams, the weak zone (wood defect) will be spread along the beam.

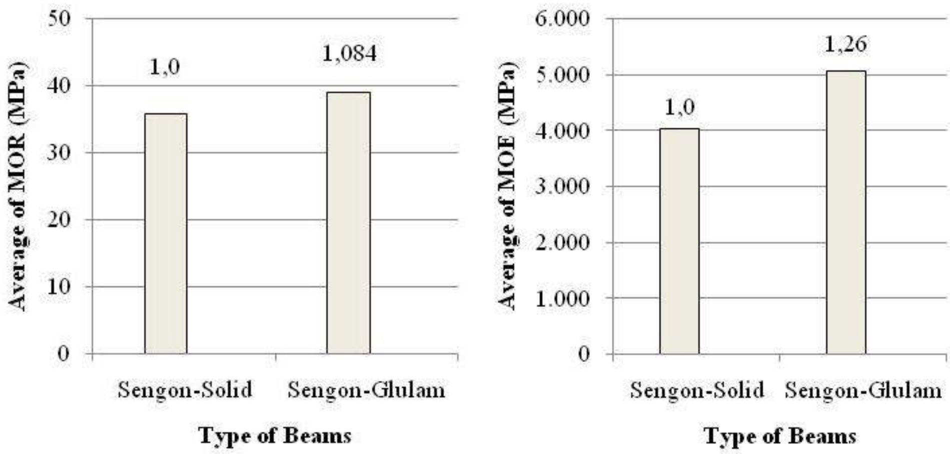

Figure 5. Flexure Strength and Stiffness of Sengon Solid and Glulam Beams

Ductility and Structural Efficisy of Beams

In terms of ductility, the lamination process and placement of coconut wood in the outer zone of glulam beams produces the ductility index smaller than the sengon-solid beam as Figure 6. Its means a solid beam (sengon-solid beam) is more ductile than laminated timber beams (sengon-glulam beam).

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The decrease of ductility index is 14% and 27%, respectively for sengon-glulam beams and mix-glulam beams. The ductility index is closely associated with the failure mode of the beam. If the beam ductility index is smaller, so the beams failure that occurred tend to be more brittle. In this research, the application of lamination methods contribute to an increase in flexural strength (MOR) and modulus of elasticity (MOE) of the beam, while also contributing to changes the failure mode from ductile to more brittle, as shown in Figure 7.

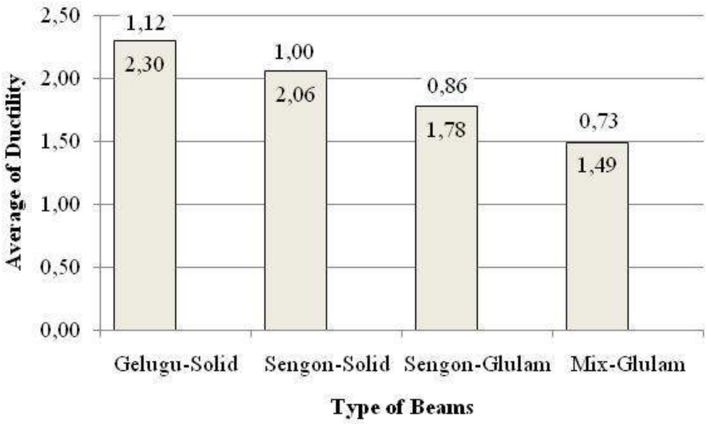

Figure 6. The Ductility Factor of Solid and Glulam Beams

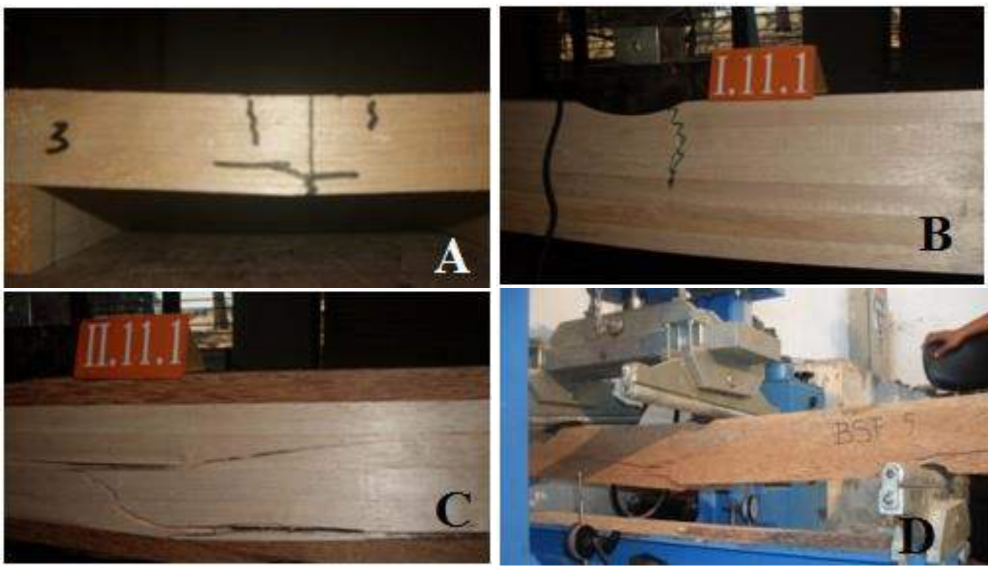

Figure 7. Failure Mode of Solid and Glue Laminated Timber Beams
Where: A. Ductile failure of sengon-solid beam
B. Ductile failure of sengon-glulam beam
C. Brittle failure of mix-glulam beam
D. Brittle failure of coconut wood-solid beam

The brittle failure is one of the shortcomings of building construction if it is associated with ductility requirements on the earthquake structural design. Therefore need to be treated in addition to the glue laminated timber beam structure to improve the ductility, for example by application the external reinforced. However, when viewed in terms of strength and structural-efficiency, then the glue laminated timber beam structure of are still very good.

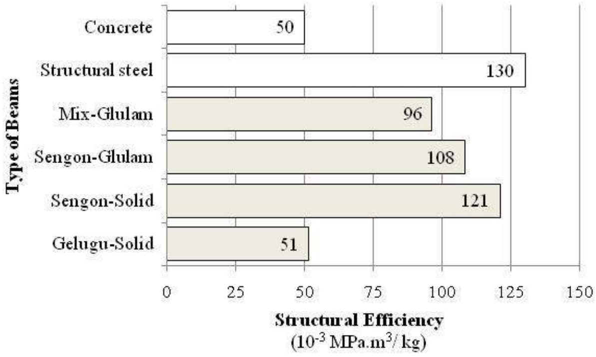

Figure 8. The Comparison of Structural-Efficiency of Wood with Steel and Concrete as Constructions Materials

The use of wood as a construction material has an structural-efficiency level is very adequate. In this case, the system of laminated beams (sengon-glulam, mix-glulam) have a level of structural-efficiency approximately two times better than concrete, and almost equivalent to steel (Figure 8). So with a combination of flexure strength and structural-efficiency, the glue laminated timber beam system are viable to developed. Furthermore, if the environmental impact factors involved included as a consideration in the selection of construction materials, the use of laminated timber beam structure would provide benefits. By compared with concrete and steel, as presented in Table 1, the mix-glulam system is very suitable to be applied for green-construction.

CONCLUSIONS

The mix-glulam method can increase flexure strength and stiffness of glue laminated timber beams by 6.1% and 8.4% respectively. This increase occurred due to laminating effect and strengthening the outer zone by placement of coconut wood. The lamination process resulted in increased bending strength and modulus of elasticity wooden beams sengon 8.4% and 26% respectively.

The lamination process and placement of coconut wood in the outer zone of laminated beams causes a decrease in ductility of 14% and 27%, respectively for laminated beams-sengon and mix-glulam. This means that the solid beam sengon more ductile than laminated beams. Thus, the increase in flexural strength and modulus of elasticity of the beam actually causes changes in the pattern of collapse ductile (solid beam) into a brittle failure (laminated beams). Therefore, the external reinforcement in laminated timber beams was needed to improve the ductility.

Nevertheless, the laminated timber beams structure have a structural-efficiency level that approximately two times better than concrete and almost equivalent to steel. Therefore, the glue laminated timber beams structure could be developed as green-material construction purposes, especially in terms of the carbon emissions and storage.

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ABOUT THE AUTHORS

Kusnindar Abdul Chauf, ST., MT.: Lecturer in the Department of Civil Engineering Tadulako University. A master's degree in Civil Engineering Department of the University of Gadjah Mada in 2004, and now is a student in Civil Engineering Doctoral Program of Brawijaya University. Research interest in the structural of timber building. E-mail: kus_untad@yahoo.co.id

Prof. Dr. Ir. Sri Murni Dewi, MS: Proffessor in the field science of concrete/steel structure in the Departement of Civil Engineering, Faculty of Engineering, Brawijaya University. Research interest in the bamboo material and finite element analysis. E-mail:srimurnidewi@ub.ac.id

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Muhtar, Bond-slip improvement of bamboo reinforcement in concrete beam using hose clamps: 385-393
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BOND-SLIP IMPROVEMENT OF BAMBOO REINFORCEMENT IN CONCRETE BEAM USING HOSE CLAMPS

Muhtar, Sri Murni Dewi, Wisnumurti & As'ad Munawir

Department of Civil Engineering, Faculty of Engineering,University of Muhammadiyah Jember, Jember 68121, Indonesia

muhtar@unmuhjember.ac.id

Abstract

Failed of bond-slip interaction between bamboo reinforcement and concrete are main factors of flexural failure at bamboo's reinforced concrete beams. To increase bond-slip interaction between surface of bamboo reinforcement and concrete has been done using coating treatments with water-resistant material, the addition of hooks, wire rope wrapping, and others. With the treatments, concrete beams with bamboo reinforcement able to increase capacity, but the pattern still shows slip failure. The aim of this research is to improve bond-slip interaction between bamboo reinforcement and concrete to reform the flexural behavior pattern of concrete beam using a hose clamp. This research used bamboo petung (Dendrocalamus asper) 2-3 years. Dimension of bamboo reinforcement is 15 mm x 15 mm. Dimension of concrete beam is 120 mm x 200 mm x 2100 mm, with percentage of tensile reinforcement (ρ) about 4.68% and compression reinforcement (ρ ') about 1.875%. Shear strength reinforcement using steel bar with diametre of 6 mm. Four beam specimens casted with four different treatment, i.e: normal reinforcement, reinforcement with hose clamp, reinforcement with water-resistant coating, and reinforcement with water-resistant coating and hose clamp. Beam tests performed using four-point load. The test results showed flexural capacity, ductility, and stiffness of the beam with bamboo reinforcement which coated by water-resistant material and hose clamp has increased compared to the other beam. All beams shows crack and collapse by slip failure, but beams with bamboo reinforcement which were coated by water-resistant materials and hose clamp has many spread crack before it collapses

Keywords: *Bamboo reinforced concrete, hose clamp, bond-slip interaction, flexural capacity.*

INTRODUCTION

Bamboo can be used as alternative of reinforcement in concrete structure because of several advantages. Tensile strength of bamboo can reach 370 MPa (Ghavami, 2005) and even up to 417 MPa (Morisco, 2005). As concrete reinforcement, bamboo should be treated, i.e soaked, dried, or coated with a waterproof coating, and sprinkled with dry sand. Bamboo bar can be coated with an adhesive waterproof layer such as: Araldite, Tapecrete P-151, Anti Corr RC, and Sikadur 32 Gel (Agarwal et al, 2014); Araldite layer, Epoxy Resin, and Coal Tar (Siddhpura et al., 2013); epoxy layer and fine sand coating (Kumar et al., 2014); paint and fine sand coating (Nindyawati et al, 2013); and asphalt layer and sand (Bhonde et al., 2014)

Although treatments has been done, concrete bond with bamboo not as good as concrete with steel. Load test of bamboo beam reinforcement with no treatments shows that there only one or two lines crack and then bamboo straight slip detached from the concrete. After adhesive strength of bamboo enhanced with paint layers and sand, bending crack is increasing at bamboo beam and it has increasing load capacity. Lack of bond slip at bamboo can be seen from test results of some

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researchers that only reach 35% of capacity, if tensile strength of bamboo is full (Khare et al., 2005; Terai et al., 2011). If adhesion is enhanced, it is expected that flexural capacity of bamboo beam can be increased.

Rudeness modification research of bamboo reinforcement has done with notch treatments (Budi S., 2013) and additional hooks (Lestari et al., 2015). This method can increase beam capacity, but still many shortcomings, such as notch process can weaken bamboo reinforcement. Concept of using hose clamp on bamboo reinforcement is same with concept of using deformed steel reinforcement at concrete, where this concept is happened at interaction of frictional force and pivot force between concrete and reinforcement. In order to increase bond-slip of bamboo reinforcement in concrete beams, this study will use hose clamp ring at bamboo reinforcement which installed after the first waterproof coating.

MATERIALS AND METHODS

Materials

Bamboo

This research using "petung" bamboo (Dendrocalamus asper) 2-3 years. The bamboo trunk which is used as concrete reinforcement along 3-6 meters taken from the base. Bamboo divided or cut according to size plan and then soaked to issue a starch content (Morisco, 2005) about one month. After soaking, bamboo was dried or aerate for approximately one month. Then bamboo is coated by a water-resistant coating to minimise swelling.

Water-resistant coating

The water-resistant coating "Sikadur®-752" use as water-resistant coating as in research of Agarwal et al. (2014). Sikadur®-752 is a solvent-free, consist of two component super low viscosity-liquid, based on high strength epoxy resins. Especially for injected into cavities and cracks in concrete, increasing the bond strength and restoring its structural integrity.

Hose clamp

This research is using hose clamp ring at bamboo reinforcement to improve bond between bamboo and concrete reinforcement. Hose clamp ring size is ¾" made in Taiwan as shown in figure 1a.

a. Hose clamp

b. Test setup

c. Bamboo speciment

Figure 1. Hose clamp, bamboo speciment and tension test setup.

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Experimental Program

The following tools are used for the experiment: 2000 kN compression machine of concrete test for compression strength test of concrete, 500 kN Universal Testing Machine (UTM) for bamboo tension test and pullout test. The loading frame with hydraulic jacks and load cells are using for flexural strength test. Several specimens for each type of test is shown in Table 1.

Table 1. Objects test speciment

Type of testing	Number of specimens
Concrete compression strength testing	14
Tension testing of bamboo	6
Pullout test	15
Beam flexural test	4

Concrete compression strength testing

Material for normal concrete was cement, sand, coarse aggregate, and water. Sand and coarse aggregat was taken from Malang. Specimen test was cylinders with 150 mm diametre and 300 mm height. Concrete cylinder covered with gunny sack for 28 days. Specimens were weighed before test. The specimens were placed in compression testing machine. The load is applied to concrete in gradual increments until the specimen failure. Compression stress is determined at ultimate load.

Tension testing of bamboo

Bamboo specimens with length of 300 mm use as shown in figure 1c. The procedure of tension test for bamboo is same as for steel. Load and elongation readings for specimen which placed in UTM are recorded.

Pull out tests specimen

The dimension of Bamboo reinforcement are 15mm x 15mm x 400mm. Concrete cylinders of 150 mm diametre and 300 mm length are used for test. Bamboo reinforcement were inserted at the center of concrete cylinders with 200 mm depth when casted. Speciment were tested after 28 days curing. Several treatment has made to measure their performance in improving the interaction bond-slip strength between bamboo and concrete. Total 15 cylinders are casted for the comparison purpose, which includes three cylinders for each different treatment, i.e., bamboo reinforcement with (a) normal reinforcement, (b) hose clamp with span 100 mm, (c) Sikadur®-752, (d) Sikadur®-752 and hose clamp with span 100 mm, and (e) Sikadur®-752 and hose clamp with span 50 mm. The typical sectional detail and pull out test setup is shown in figure 2.

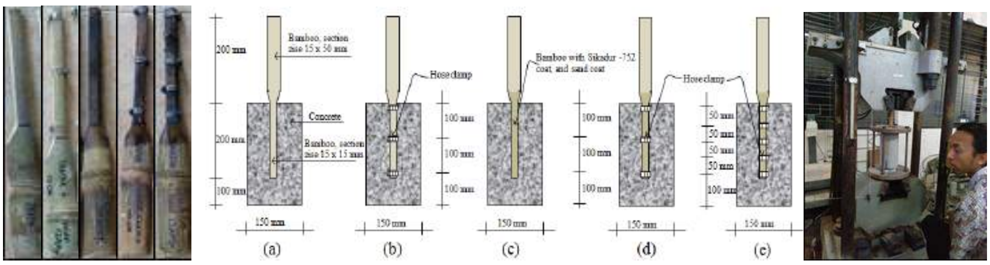

Figure 2. Typical sectional detail of pull out tests and test setup

Speciment bond stress (τ_b) is calculated using equation (Agarwal et al., 2014):

$$\tau_b = \frac{F}{SL} \quad (\text{N/mm}^2) \qquad (1)$$

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where F is pulling out load, S is perimeter of bamboo reinforcement and L is length of bonded interface. Bamboo reinforcement can be detached from concrete because of split in the longitudinal direction when the high frictional adhesion or high defence. When bamboo reinforcement could be pulled out and leave a hole in the concrete, it means low adhesion or small friction.

Beam flexural test

This research used bamboo petung (Dendrocalamus asper) 2-3 years. Dimension of bamboo reinforcement is 15 mm x 15 mm x length of bamboo. Dimension of concrete beam is 120 mm x 200 mm x 2100 mm, with tensile reinforcement (ρ) about 4.68% and compression reinforcement (ρ') about 1.875%. Reinforcement for shear strength using steel reinforcement with 6 mm diametre. Four beam specimens were casted with four different treatment of bamboo reinforcement, i.e. : (B1) normal reinforcement, (B2) with hose clamp, (B3) with water-resistant coating, and (B4) with water-resistant coating and hose clamp as shown in Figure 3. Table 2 show the dimensions and cross section of sample beams. The resulting concrete is poured in cylindrical moulds of 150 mm diameter and 300 mm height. After casted, concrete beams are kept in wet place and de-moulded at 24 hours age. Beams were tested after 28 days treatment. Specimens tested at loading frame with capacity of 150 kN and load cell with capacity of 100 kN. During the loading test, load (P) was measured by load cell. Speciment displacements externally measured by displacement transducers instrument at the bottom of specimens. Beam tests performed using four-point load as shown in Figure 4.

Table 2. Dimension and cross section of beam specimen

Beam Specimens	Longitudinal Reinforcement		Stirrup at		Using Hose Clamp	
	Upper	Lower	Position of shear field	Position of no shear field	Upper	Lower
(B1) Normal	2□15x15	5□15x15	Ø 6 - 5	Ø 6 - 20		-
(B2) Hose Clamp	2□15x15	5□15x15	Ø 6 - 5	Ø 6 - 20	_	Ø ¾” - 10
(B3) Sikadur®-752	2□15x15	5□15x15	Ø 6 - 5	Ø 6 - 20		-
(B4) Sikadur®-752 + Hose Clamp	2□15x15	5□15x15	Ø 6 - 5	Ø 6 - 20		Ø ¾” - 10

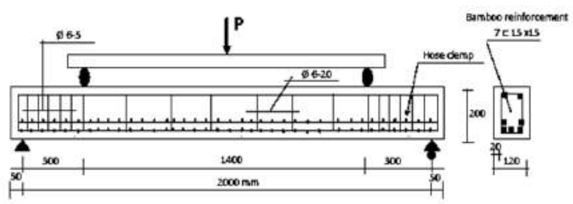

Figure 3. Details of beam specimens

Figure 4. Four-point loading test set up for beam

RESULT AND DISCUSSION

Concrete compression strength test

Compressive strength test was performed according to ASTM C 39 at 28 days using Universal Testing Machine with a constant loading rate. In order to ensure uniform loading on the cylinder, each

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Specimen was capped with sulfur. Average compression stress of normal concrete was 31.31 MPa and average weight concrete silinder in the study was 122.78 N.

Tensile testing of bamboo

Tensile test is conducted to understand the ultimate strength and elasticity parameters of the bamboo reinforcement. Test procedure for bamboo reinforcement is same as for steel. Total six specimens are tested for this purpose. Bamboo is more vulnerable for failure at the nodes. All six samples considered for the study were having one node. The physical dimensions of samples and corresponding test results are given in Table 3. Measurement of width and thickness done at six different location on the speciment and their average value is considered as strength estimation. From Table 3, average tensile strength is 126.68 N/mm^2. The average strain value is 0.0074. The modulus of elasticity is 17118.92 MPa.

Table 3. Details of tensile test results

Specimens	Length (mm)	Width (mm)	Thickness (mm)	Area (mm2)	Ultimate load (kN)	Failure stress (MPa)
1	300	16	14	224	38	169.64
2	300	15	15	225	20	88.89
3	300	14	14	196	28	142.86
4	300	15	13	195	30	153.85
5	300	16	12	192	18	93.75
6	300	15	12	180	20	111.11
Average =						126.68

Pull out tests results

The Pull-out test for bamboo reinforcement with layer of sikadur 752 and hose clamp ring embeded in concrete cylinders shows that the increasing the adhesion stress about 364% to 411% of the bamboo without treatment with the distance of hose clamp about 100 mm and 50 mm in a row. While the failure patterns shows the bond failure, concrete cone failure and bamboo failure of nodes as shown in Figure 5b and Figure 5c. It shows that influence of hose clamp installation on bamboo reinforcement are work well and the bamboo reinforcement still attached to the concrete.

For specimens without hose clamp ring, the collapse bond-slip failure are shown in Figure 5a. However, in a few cases, bamboo samples have broken during the slippage despite of fact that tensile strength of bamboo sample is much higher than the maximum bond stress which obtained between bamboo reinforcement and concrete. This due non-alignment of the samples in testing machine leading to unnecessary eccentricity. Details of 15 cylinder test and the results are shown in Table 4.

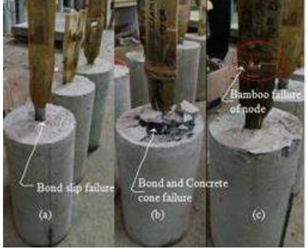

Figure 5. Modes failure of pull out test

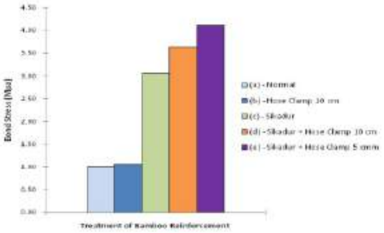

Figure 6. Variation of Bond stress of Bamboo reinforcement

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Beam flexural test

Flexural analysis of bamboo's reinforced concrete beam in this study refers to the research of Ghavami (2005). The balance between the compressive force on the concrete (C) with a tensile force (T) must be fulfilled. Tensile on bamboo reinforcement (T) is obtained by multiplying the stresses by juxtaposition (Pull out test results) with an area of shear reinforcement, because based on the research of bamboo reinforced concrete beam collapse caused by the loss of bond between bamboo and concrete. Flexural test results and calculations on bamboo reinforced concrete beams can be shown in Table 5.

Table 4. Details of pull out test results

No	Treatment	Bamboo width (mm)	Bamboo thickness (mm)	Depth (mm)	Contact area per unit height (mm)	Pull out load (kN)	Bond stress (MPa)	Average Bond Stress (MPa)	Modes of Failure
1	(a) Normal	15	15	200	60	12	1.00	1.00	Bond slip failure
2			15		60	12	1.00		
3			10		50	10	1.00		
4	(b) Hose clamp	15	15	200	60	12	1.00	1.06	Bond slip failure
5			15		60	13	1.08		
6			10		50	11	1.10		
7	(c) Sikadur®-752	15	15	200	60	40	3.33	3.06	Bond slip failure
8			15		60	33	2.75		
9			15		60	37	3.08		
10	(d) Sikadur®-752 + Hose clamp 10 cm	15	15	200	60	42	3.50	3.64	Bamboo failure of node
11			15		60	44	3.67		
12			15		60	45	3.75		Bond and Concrete cone failure
13	(e) Sikadur®-752 + Hose clamp 5 cm	15	15	200	60	49	4.08	4.11	Bamboo failure of node
14			15		60	49	4.08		
15			15		60	50	4.17		Bond and Concrete cone failure

Table 5. Comparison of flexural test results and theoretical calculations

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. Specimens	Theoretical calculations		Flexural test results			Bond stress flexural beam (μ) (MPa)	Bond stress pull out test (u) (Mpa)
	First crack load (kN)	Ultimete load (kN)	First crack load (kN)	Failure load (kN)	Deflection at failure (mm)		
B1-Normal	21.64	78.32	16.00	60.00	28.57	0.75	1.00
B2-Hose clamp 10 cm	21.64	82.54	16.50	52.50	29.60	0.66	1.06
B3- Sikadur®-752	21.64	183.60	20.00	98.30	33.26	1.62	3.06
B4- Sikadur®-752 + Hose clamp 10 cm	21.64	198.57	19.50	86.50	28.24	1.57	3.64

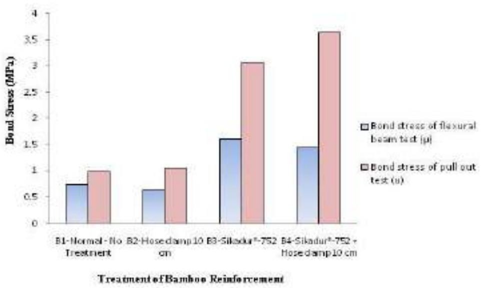

Figure 7. The comparison graph of bond stress of pull out test and flexural beam test

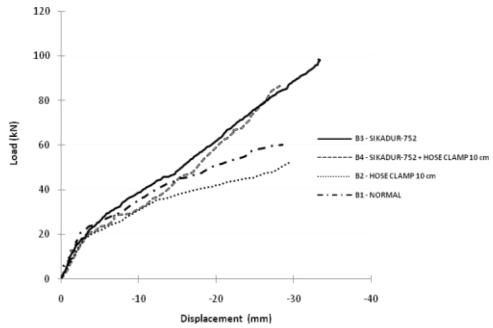

Figure 8. Load-deflection curve for beams under four-point loading test

Comparison of bond stress of pull out test and flexural beam test

The bond-stress of pull-out test (u) is greater than flexural stress of bond-beam test (μ). From Figure 7 and Table 5, it shows that the value of the bond-stress for specimens of bamboo reinforcement-Normal B1 and B2-Hose clamp with distance of 100 mm is lower than the speciment reinforcement with layers of water-resistant bamboo-Sikadur®-752 B3 and B4-Sikadur®-752+ hose clamp with distance of 100 mm. However beams with bamboo reinforcement of Sikadur®-752 + hose clamp with distance of 100 mm tend to be more rigid, it is caused by the installation of a less optimum hose clamp.

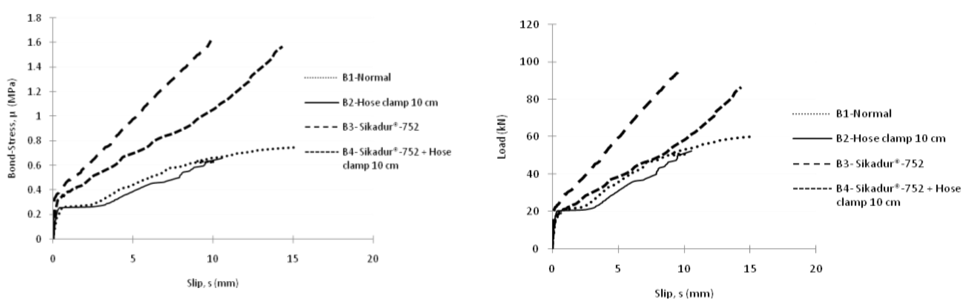

Figure 9. Bond stress–slip relationships and Load–slip relationships of bamboo reinforced concrete beam speciments

Bond-slip of bamboo reinforcement

In general, Load-slip relationship is characterised by small slippage at initial loading stage, then followed by rapid increase when load reaches the maximum support load. At initial loading stages, there were the well bonding performance are observed in these four beams, and their load–slip curves

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almost linear. At this stage, chemical adhesion between concrete and bamboo reinforcement governs bond mechanism, and slippage is avoided. After lost chemical bond, the friction between the concrete and bamboo reinforcement takes effect. With load increase, bond–slip between bamboo reinforcement and concrete develops, friction diminishes and contact surface is damaged, and when applied load reaches maximum support load, sudden decay is recorded. The peak loads for both beam B1 and B2 attained quickly and at comparatively low slip values and their maximum support loads are 60 kN and 52.50 kN respectively. This is due reinforcement of bamboo which has properties hygroskopis and slippery surface.While for beams B3 and B4 with bamboo reinforcement layered of water-resistant reinforcement Sikadur®-752 and bamboo with layered of water-resistant Sikadur®-752 + hose clamp, showing bond-slip behavior better. B3 and B4 beams exhibits better bond–slip behaviour. A well bonding performance with very little slippage is recorded till around 98.30 kN dan 86.50 kN, and the load–slip curves are almost linear as shown in figure 9. Achievement of maximum load beams B3 and B4 is much larger than achievement of maximum load beams B1 and B2. It can shown that bamboo reinforcement surface condition is very important to bond–slip behaviour between bamboo and the surrounding concrete.

CONCLUSIONS

Calculation of the bond-stress reinforcement of bamboo based on direct bond pull-out test is greater than bond-stress reinforcement that occurs on the beam. The bamboo reinforcement's surface condition is very important in the bond-slip behavior between bamboo reinforcement and the surrounding concrete. Installation of hose clamp can increase stiffness and bond-slip bamboo reinforcement, but the not optimum installation in hose clamp, can decrease ductility of bamboo's reinforced concrete beam. All beams shows cracks and collapse due to failure of slip, but concrete beam with bamboo reinforcement which coated by water-resistant material and hose clamp has many spread crack before collapses.

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ABOUT THE AUTHORS

Muhtar, ST., MT., Lecturer in the Department of Civil Engineering, Faculty of Engineering, University of Muhammadiyah Jember. Doctoral student at the Civil Engineering Department, Engineering Faculty, University of Brawijaya. Research interest in the material and structural analysis of concrete structures. E-mail: muhtar@unmuhjember.ac.id

Prof Dr Ir Sri Murni Dewi, MS: Professor in the field science of concrete/steel structure in the Department of Civil Engineering, Faculty of Engineering, University of Brawijaya. Research interest in the bamboo material and finite element analysis. E-mail: srimurnid@ub.ac.id

Dr. Ir. Wisnumurti, MT.: Lecturer in the Department of Civil Engineering, Faculty of Engineering, University of Brawijaya. Research interest in the Inspection Method for Concrete Structures. E-mail: wsmurti@ub.ac.id

Dr. Ir. As'ad Munawir, MT.: Lecturer in the Department of Civil Engineering, Faculty of Engineering, University of Brawijaya. Research interest in the Inspection Method for Concrete Structures. E-mail: a_munawir@yahoo.com

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BOND CAPACITY IN PIPE AND GROUTING CONNECTION

Ninik Catur E.Y[1,2], Sri Murni Dewi[2], Wisnumurti[2], Ari Wibowo[2]

[1]*Department of Civil Engineering, Faculty of Engineering, Merdeka University of Malang, Malang 65145, Indonesia.*

[2]*Department of Civil Engineering, Faculty of Engineering, University of Brawijaya, Malang 65145, Indonesia*

Author(s) e-mail: nien_cey@yahoo.com ; ninik.catur@unmer.ac.id

Abstract

One of the requirements that must be met in the design of reinforced concrete construction is to achieve a perfect bonding between reinforcement and concrete. A perfect bonding ensured a composite action between reinforcement and concrete. The Implementation of the precast construction method leads to a mechanism that is not a monolith between steel and concrete. This condition can affect the lack of coherence which can lead to slip. In this study, the 30 concrete cylinders in 150 x 300 mm are used as pull out test specimens. On each specimen grown mounted on a steel reinforced sleeve pipe. In the sleeve pipe is inserted grouting material. Specified variables are the length of embedded, grouting thickness, and surface roughness of the sleeve pipe. The results of the study showed that the length of embedded of reinforcement a strong effect on the bond capacity. In undefined reinforcement, failure occurs due to slip between the reinforcement with a layer of grouting. While the grouting thickness and roughness together a strong effect on the bond capacity. The best results are given by specimens that grouting reinforcement with a layer thickness of 35 mm with a rough surface of the sleeve. Failure happens to resemble a failure on deformed steel reinforcement which is embedded directly in the concrete, reinforcing steel that is breaking up after passing the yield stress limit and the ultimate stress.

Keywords*: bond capacity, grouting, pipe sleeve, reinforced concrete*

INTRODUCTION

Composite action between the steel and concrete in reinforced concrete construction is determined by the bond between steel and concrete. Therefore bond stresses are a major factor that will determine the performance of reinforced concrete construction when receiving either static load and dynamic load. Not achieving the perfect bonded between the steel and concrete will lead to a decrease in the performance of reinforced concrete construction. Bond is defined as ‘the adhesion of concrete or mortar to reinforcement or to other surfaces against which it is placed’, and bond strength is defined as ’the resistance to separation of mortar and cement from reinforcing steel and other materials with which it is in contact’. Bond describes the total interaction of the reinforcement with the surrounding material.

Some parameters related to the bond stress of them is friction between the steel reinforcement and concrete around the steel embedment length that will determine interlocking mechanism. If there is a failure or adhesion bond between the steel and concrete, the possibility of failure due to the construction of slip becomes very small. The interlock mechanism will prevent the occurrence of cracks along the embedded reinforcement due to tensile stresses that occur (Albarwary, 2013)

In the reinforced concrete construction is carried out with precast system, bonded factor becomes a serious problem because each precast components are not cast monolith. This study aims to

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determine the bond stress occurs between the concrete reinforcement that is not directly related. Bonded given by reinforcement with grouting material that is inserted into the pipe sleeve are embedded directly when casting concrete. In this condition, bond strength of reinforcement is strongly influenced by the bond between the pipes with concrete around and the bond between the steel reinforcement with grouting material in the pipe sleeve. Model installation of reinforcement in this method is expected to be put into one model of connection between precast components.

Bond stress between reinforcement and concrete is influenced: a. bond between the concrete and steel reinforcement; b. gripping effect (holding) concrete around reinforcement; c. prisoners friction against slip and interlock when experiencing tension reinforcement; d. Compressive strength of concrete; e. effect end anchorage reinforcement; and f. diameter, shape and spacing of reinforcement (Nawy, 1990).
The magnitude of the bond stress occurs can be determined by equation 1 below (SNI-2847, 2013):

$$u = \frac{P}{\pi . d_b . l_b} \tag{1}$$

Where u = bond stress (MPa), P = maximum tensile strength (N), d_b = diameter of steel reinforcement, and l_b = length of reinforcement embedment.

Research on the bond stress of steel reinforcement has been done with a variety of models. According to (Anis Rosyidah, Januari 2011) in the study about a pull-out test, the thickness of the grouting material is very decisive and strong adhesive bond failure model on a pilot test. This research was conducted with laboratory experimental methods, and used deformed steel bars 10 mm in diameter grown on cylindrical concrete specimens. Variations in the length of embedded are 100 mm and 200 mm. Variations in the thickness of Sikadur® 31 CF Normal are 2 mm, 3 mm. While (Ginting, 2008) states that the strong adhesion by direct tension reinforcement pullout bond tests should be reduced to take account of the strong adhesion real reinforcement in the beam.

An Experimental Program

Materials Research

In this study, the materials used are compressive strength of concrete fc '= 20 MPa, the diameter of deform steel threaded ф 13 mm , ф steel pipe 25 mm and 35 mm, and grouting materials. Thirty-diameter cylindrical test object 150 mm and high 30 mm. In concrete cylinders embedeed in the steel casing pipe centric. Further into the steel pipe mounted 13 mm diameter deformed bar steel . Installation is done centric. Then into the steel pipe filled material grouting, as shown in Figure 1 and Figure 2. The variables specified in the form of long anchorage (150 mm and 300 mm), the diameter of the casing pipe steel (25 mm and 35 mm), and the roughness of the pipe sleeve (rough and smooth).

Each variable was made 3 specimens. The test results will be compared with the test results bond strength to the steel reinforcement which is directly embedded in concrete without using pipe sleeve and grouting. The material used for grouting should be considered, among other requirements: a. Easy to use, simply by adding water; b. Has the characteristics of easy-flowing; c. Good adhesion to the structural elements; d. Early strength very quickly; e. High compressive strength. f. Resistant to shrinkage; g. Resistant to shock and vibration; h. Do not cause corrosion, and i. non-toxic.

Details of the test specimens specifications are as follows:

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Table 1. Details of the test specimens specification

Code of specimen	Θ pipe sleeve (mm)	Roughness of the pipe sleeve	Length of reinforcement embedment (mm)
A1 A2 A3	25	Smooth	300
B1 B2 B3	25	Smooth	150
C1 C2 C3	25	Rough	300
D1 D2 D3	25	Rough	150
E1 E2 E3	35	Smooth	300
F1 F2 F3	35	Smooth	150
G1 G2 G3	35	Rough	300
H1 H2 H3	35	Rough	150
I1 I2 I3	-	-	300
J1 J2 J3	-	-	150

Figure 1. Making test specimen

Figure 2. Test specimens of bond pull out

RESEARCH METHODOLOGY

The study was carried out experiments in the laboratory. Tests carried out on 30 pull out cylindrical specimen measuring 150 x 300 mm which is referred ASTM 234-91a. Bond pulls out tested was performed using Universal Testing Machine (UTM) against specimen that has been aged 28 days. Bond pulls out tested was performed by giving a tensile force to the reinforcing steel embedded in concrete cylinders.

The data obtained is an increase in tensile force to achieve the maximum tensile force that is required until a failure occurs. In the testing process also noted that the extension occurs in the steel as a result of the withdrawal and the data on the condition of slip that occurs. Data on the magnitude of the increase in the load until the load was achieved as a powerful test object reaches its limit further processed in order to describe the behavior of the test specimen due to pull out bond. Bond stress testing mechanism as shown in Figure 3.

Figure 3. Seting Bond Pull Out Testing

RESULT AND DISCUSSION

Bond Strength

Based on the test results shown that the diameter of the pipe sleeve, the length of embedded of reinforcement, and the type of surface of a pipe sleeve effect the bond stress of reinforcement and the model of the failure. Model of the failure can be divided into two kinds, they are slip of the pipe sleeve

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and broke the steel reinforcement. The relationship between bond stress to the diameter of the pipe sleeve, the length of embedded of reinforcement, and the type of surface the pipe sleeve shown in Figures 4 and 5. The test results show a variety of bond pull out failure pattern as shown in Figure 6 and Figure 7.

The test results indicate that the bond strength that is generated by the grouting system is unbelievably influenced by the mean diameter of the pipe sleeve and the grouting material thickness, the length of embedded of steel reinforcement in concrete / grouting, and the type of surface of pipe sleeve. The use of grouting material produces bond streets approximately equal to the results generated by the bond stress are directly cast steel reinforcement in concrete. This suggests that the grouting material used in this study can be recommended for use as a grouting material in the precast construction system. The results obtained from testing the bond pull out also reinforce the results of research conducted by (Ahmad Baharuddin Abd. Rahman, 2015) which states that the thickness of the layer of grouting a significant influence on the bond strength.

Based on Figure 4 shows that the diameter of the pipe sleeve to contribute significantly to the bond stress increase of steel reinforcement. The larger the pipe sleeve, then grouting layer that surrounds the thicker the steel reinforcement so that the adhesion between the surface of the steel reinforcement and grouting material is great and can increase the required pull tension of force.

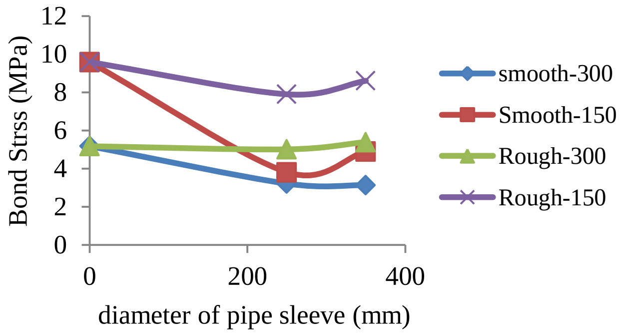

Figure 4. The relationship between the diameter of the pipe sleeve with bond stress

Figure 5 shows that the type of surface of the pipe sleeve affects the amount of bond stress occurs. On the rough surface of the sleeve provides greater friction so as to provide resistance to the pull tension of force required when compared to the smooth surface of the pipe sleeve.

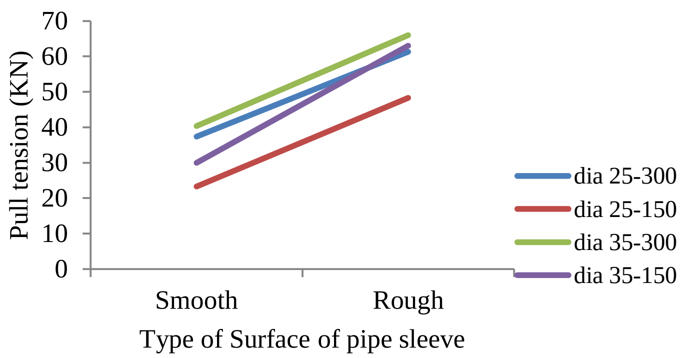

Figure 5. The relationship between the type of surface sleeve with pull tension of force

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Model of Collapse

Model of collapse happened due to pull out the test also determined by the thickness of grouting or diameter of pipe sleeve, the length of the embedded and the type of pipe sleeve surface. The type of pipe sleeve, smooth surface produces a smaller bonded compared with rough surfaces due to friction between the surface of the concrete pipe becomes smaller. As a result, the model failures are slipping on the surface of the pipe with concrete.

As for the rough surface of the pipe sleeve, the failure model is also influenced by the length of embedded of reinforcement and the thickness of the layer of grouting. The best results are given by the specimen with a steel pipe diameter of 35 mm, the type of rough surfaces, and the planting of 300 mm length. This is determined by its failure model test, which broke on the steel reinforcement after passing the limit of its melting and adhesion tension value large enough. The test results show a variety of bond pull out failure pattern as shown in Figure 6 and Figure 7.

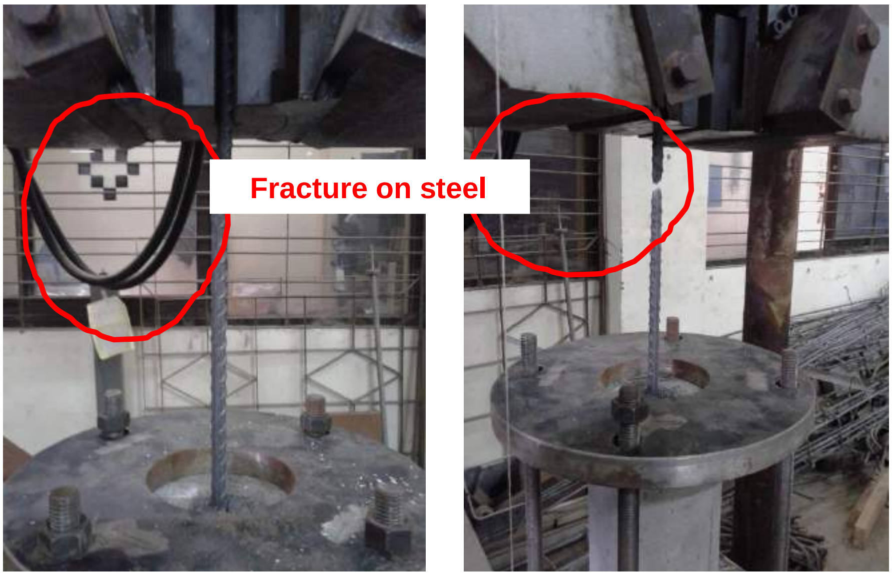

Figure 6. The test results fracture the steel reinforcement

Figure 7. The test results slip on pipe sleeve

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CONCLUSSIONS

Based on the analysis of the test results can be concluded that the strong adhesion between the steel reinforcement in the concrete is cast monolith, can be modified by means of grouting system. The grouting system could be developed for construction of precast concrete components. Modifications grouting system usage by embedded pipes sleeve into the concrete as shells and filled with grouting material after mounted steel reinforcement.

This modification should be done with attention to the factors that influence the amount of bond strength and model of the failure. The factors that determine the diameter of the pipe sleeve is thick layers of grouting, the length of embedded of steel reinforcement into the grouting material and the type of pipe surface.

In this study, the best results are given by the specimen with a steel pipe diameter of 35 mm, the type of rough surfaces, and the embedment of 300 mm length. This is determined by its failure model test, which broke on the steel reinforcement after passing the limit of its melting and the tension force pull out greatest.

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ABOUT THE AUTHORS

Ninik Catur E.Y., ST., MT : Lecturer in the Civil Engineering Departement, Faculty of Engineering, Merdeka University of Malang. Program Doctoral student at the Civil Engineering Departement, Faculty of Engineering, University of Brawijaya. Research interest in the structural analysis of concrete structures. E-mail : nien_cey@yahoo.com ; ninik.catur@unmer.ac.id

Prof. Dr. Ir. Sri Murni Dewi, MS : Professor in thr field science of concrete/steel structure in the Department of Civil Engineering, Faculty of Engineering, University of Brawijaya. Research interest in the bamboo material and finite element analysis. E-mail : srimurnid@ub.ac.id

Dr. Ir. Wisnumurti, MT : Lecturer in the Civil Engineering Departement, Faculty of Engineering, University of Brawijaya. Research interest in the Inspection Method for Concrete Structures. E-mail : wsmurti@ub.ac.id

Ari Wibowo, ST., MT., Ph.D : Lecturer in the Civil Engineering Departement, Faculty of Engineering, University of Brawijaya. Research interest in the Concrete Structures and Seismic. E-mail : ariwibowo@ub.ac.id

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Cc: "Siti Hamidah Rustiana" <siti.rustiana@umj.ac.id>, "Zaitun" <zaitun@umj.ac.id>, "iwan sumantri" <iwan.sumantri@umj.ac.id>, <ozifachrulrozi@yahoo.com>, "sabrina dien" <sabrina.dien@umj.ac.id>

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