Beam-Column Timber Joint Connection Behavior Due to Nail and Modified-Washer Reinforcement Tests

Yosafat Aji Pranata, Anang Kristianto, and Olga Catherina Pattipawaej

Abstract

Timber connection capacity, in case of beam-column joint connection provides significant impact on the wooden building structures. Strength and stiffness of timber connections using reinforcement technique of wooden building structures have not been studied intensively. This paper studies the use of nails and modified-washer to improve wood connection's performance. The experimental tests were conducted in the laboratory by comparing the partial connection between test specimen timber without reinforcement (standard type) and the reinforcement (PRP type). The testing was conducted based on partial connection beam-column joint test using Universal Testing Machine's with a modified holder. Wood studied includes Meranti (*Shorea* spp.) and Mersawa (*Anisoptera* spp.). PRP type connection was using nails and modified-washer strengthening, and standard type connection was using a classic washer. Parameters studied were strength and stiffness of the connection, reviewed both: proportional limit load and ultimate limit load conditions. Result obtained from this research indicates that the use of nails and modified-washer make a positive contribution to improving the performance of the beam-column timber joint connections, in terms of strength capacity (both of proportional limit and ultimate limit loads) and stiffness capacity (displacement ductility ratio). Meranti beam-column timber joint is more brittle than Mersawa beam column timber joint, it has an impact on the results. PRP-type of Mersawa timber connection produces a higher ductility than the standard type, while the PRP-type of Meranti timber connection produces a similar ductility to the standard type.

Keywords: Partial test, beam-column joint, timber, nail and modified-washer, behavior.

Introduction

Connection performance of wooden house building structure plays an important role with regard to the overall performance of the building structure. Ductile connection systems are expected to contribute in the behavior of the strength and stiffness of the building structure positively. Fig. 1 and Fig. 2 show the beam-column joint connection in a traditional house of Minahasa, North Sulawesi, Indonesia. The observed connection is in the exterior residence (Fig. 1) and in the interior residence (Fig. 2). The wood joints were connected using nails.

Figure 1. Beam-column joint connection of Minahasa traditional house: Exterior joint.

In order to review the connection system performance, it is necessary to limit the burden of disproportionate amount of information that could be retained by connection. It is helpful in designing the timber connection to calculate lateral resistance (Z) in accordance to Indonesian National Standard (SNI 7973: 2013) (Badan Standardisasi Nasional 2013).

Figure 2. Beam-column joint connection of Minahasa traditional house: Interior joint.

Information on the load-slip curve relationship of timber connection, moment-curvature curve timber connection and ideal model approachs are also an important empirical data in relation to the numerical modeling of the wood building structure. The accuracy of numerical modeling relies heavily on modeling parameters or idealization of the connection structure elements. The mechanical properties of the material parameters and of the cross section dimensions size of structural elements.

This study is a continuation of previous research development reported by Pranata *et al*. (2014) who mentioned that there is related research capacity of the axial tensile connections of standard type and of the nail and modified-washer reinforcements, as well as research capacity of the beam-column joint connection (Pranata *et al*. 2015). The study of standard type connection and strengthened connections using the reference of ASTM test methods (ASTM 2000).

The testing specimen concept used in this study differs from previous studies particularly in a model specimen partial connection (Pranata *et al*. 2015). In this study, the nails and modified-washer was used to improve performance of timber connections. Experimental tests i the lab were conducted by comparing partial connection between test specimens timber without reinforcement (standard type) and the reinforced specimens (PRP type). Partial beam-column joint connection test was conducted to test Meranti (*Shorea* spp.) and Mersawa (*Anisoptera* spp.) wood using Universal Testing Machine (UTM). PRP types were counducted using nails and modified-washer strengthener. Parameters studied were the strength and stiffness connection and proportional limit of loading as well as ultimate limit loading conditions. The testing method used is the monotonic loading pattern.

Due to the limited length of timber that is in-trade, then for a long timber construction timber is needed for the connection of two wooden trunks or more mutually connected to one another so that a single piece of wood long. Understanding the relationship is two sticks of wood or more interconnected with each other at a certain point that it becomes a part of the construction. Please note the terms of wooden ties, among others: as simple as possible but sturdy, attractive avoid deep wood, placement of connection, will withstand the forces acting on it. Mechanical connection can be used, among others tools connecting bolts or nails.

Basic Theory

Kobel (2011) studied the effect of strengthening, especially for connections that resist lateral loads (hereinafter referred pull axial connection) for a long-span truss. There are four types of reinforcement are studied, namely the retrofitting of type A2 + B2, strengthening 02 + A2, inclined reinforcement and Dywidag strengthening. Retrofitting is done by adding a dowel in the direction intersecting with the mechanical connection.

Noguchi *et al*. (2006) also studied the timber connection (beam-column connections), as well as developing new connection models to bolster the performance of the strength of the beam-column connections.

The thickness of the ring having an impact as well as the influence of pretension effect of the bolts. Pretension effect thus will not increase the capacity of joint significantly, however, a positive effect is to improving connection's ductility. Another effect is by the initials pretension then bolt becomes more difficult to bend or fail flexibly, so that it is suitable to be applied to high quality of wood with high bearing strength. Pretension with a note that the amount does not exceed the compressive strength perpendicular to the wood fibers (Awaludin *et al*. 2008a; Awaludin *et al*. 2008b).

One indicator to know stiffness is displacement ductility ratio, which is calculated by the Equation 1,

$$\mu = D_u / D_y \quad (1)$$

where μ is displacement ductility ratio, D_u is deformation due to ultimate limit load, and D_y is deformation due to proportional limit load.

Methods

The study was divided into four main stages. The first stage was the study of literature. The second stage is to study secondary data and preparation of test specimens. The third stage is the experimental testing in the laboratory. The fourth stage is processing the data to get the results of the discussion and conclusions.

The research method uses empirical methods, namely experimental testing in the laboratory. The total number of test specimens are 6 (six) specimens, which are 2 (two) specimens for Meranti timbers and 4 (four) specimens for Mersawa timbers.

Fig. 3 shows a schematic model of partial connection test object for laboratory test. Fig. 4 shows the partial connection standard type of timber connection. Fig. 5 shows the partial connection for the connection with the reinforcement (named PRP type).

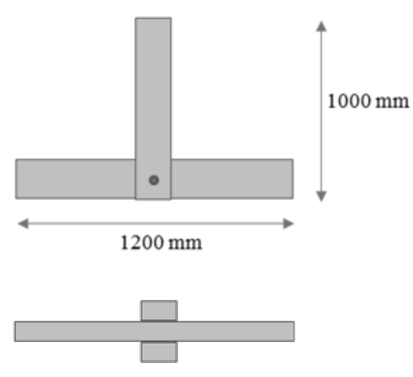

Figure 3. Schematic model of the specimen.

Specimens that used in this research are tested using a Universal Testing Machine (UTM). UTM used to apply a monotonic loads from zero load to the specimen failure. For this purpose it would require additional equipment in the form of a holder for placement of the test object. Setups of the test specimen are shown in Fig. 6.

Figure 4. Example for the standard type of the Beam-Column Timber Joint Connection.

Figure 5. Example for the PRP type of the Beam-Column Timber Joint Connection.

Figure 6. UTM and setup of the specimen.

Results and Discussion

Testing is done by applying a load, from zero loading to the test specimen failure and could not withstand the load again. Fig. 7 shows the process of testing the specimen.

While Fig. 8.a and Fig. 8.b show an example of the failure of the test specimen during an ultimate load is reached.

Figure 7. Testing process of the Meranti Timber Beam-Column Joint Connection.

(a). Meranti timber specimen.

(b). Mersawa timber specimen

Figure 8. Failure mode of the specimens.

Test results for the Beam-Column Timber Joint Connections (six specimens) are shown in Fig. 9 (Meranti Timber specimens), Fig. 10 and Fig. 11 (Mersawa Timber specimens). The test results are a curve of the load vs deformation, which represents the behavior and capacity of the beam-column joint.

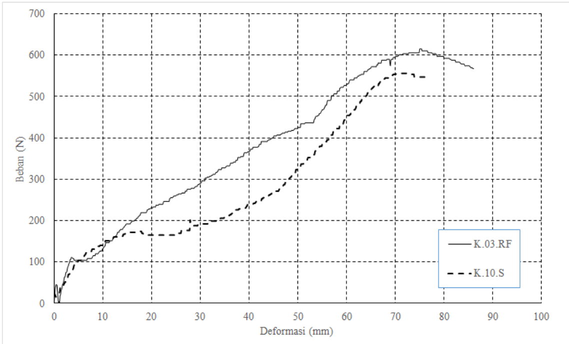

Figure 9. Meranti wood connections test results: Comparison of Load-Deformation Relations curve for the standard type and the PRP type connections.

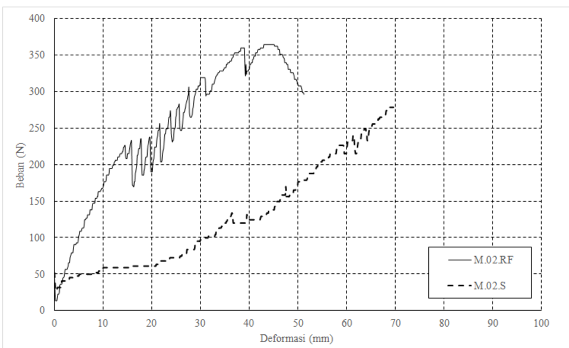

Figure 10. Mersawa wood connections test results: Comparison of Load-Deformation Relations curve for the standard type and the PRP type connections, Specimen M.02.

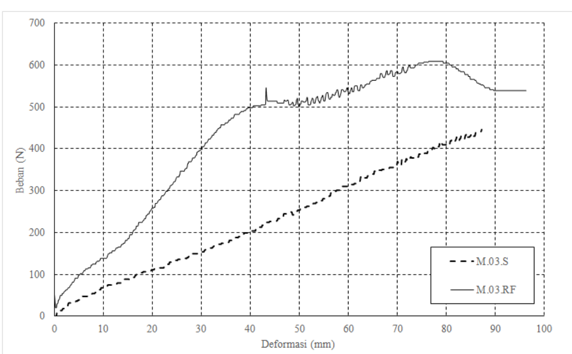

Figure 11. Mersawa wood connections test results: Comparison of Load-Deformation Relations curve for the standard type and the PRP type connections, Specimen M.03.

Fig. 9, Fig. 10, and Fig. 11 generally show test results of the load vs. deformation curve for both Meranti (Fig. 9) and Mersawa specimens (Fig. 10 and Fig. 11), which indicates that the overall capacity of the standard type lower than the PRP type.

Table 1 shows results of the timber joints made with Meranti wood, which are the idealization of the load vs. deformation curve, while Table 2 shows results of the timber joints made with Mersawa wood, i.e with reviewing the conditions of the proportional limit and ultimate limit. Method that used to determine both the proportional (P_y) and ultimate (P_u) limit loads using Yasumura and Kawai (Y&K) Method, namely a method for determining proportional limit loads and ultimate limit loads, specifically for wood material (Munoz *et al*. 2010).

Proportional limit load is a condition when there is a change from elastic to plastic behavior, while ultimate limit load is a peak load or peak capacity of the joints. Displacement ductility ratio is calculated using Equation 1.

Table 1. Summary of experimental results: Meranti specimens.

Specimen	P_y	D_y	P_u	D_u	μ
	(N)	(mm)	(N)	(mm)	(mm/ mm)
S (Standard)	526.49	66.40	555.86	72.60	1.09
RF (PRP)	571.68	66.10	605.57	74.40	1.13
%-difference	8.58%		8.94%		2.94%

Note: S = standard type, RF = PRP type.

Table 2. Summary of experimental results: Mersawa specimens.

Specimen	P_y	D_y	P_u	D_u	μ
	(N)	(mm)	(N)	(mm)	(mm/ mm)
S (Standard)					
M.02.S	178.78	51.10	278.35	68.90	1.35
M.03.S	350.76	67.50	441.28	86.70	1.28
Average	264.77		359.82		1.32
RF (PRP)					
M.02.RF	224.04	15.50	364.35	43.10	2.78
M.03.RF	468.44	35.90	604.22	79.40	2.21
Average	346.24		484.29		2.50
%-difference	30.77		34.59		89.62

Note: S = standard type, RF = PRP type.

The test results show that the beam-colum joint connection with the strengthening of the PRP type is more ductile than the Standard (S) type connection, both for Meranti and Mersawa wood connections.

In general the beam-column Mersawa timber joint connection type of PRP produce higher strength capacities ranging from 30.77% to 34.59% compared to the standard beam-column joint connection (in terms of Proportional Limit and Ultimate Limit Loads), while the beam-column Meranti timber joint connection of type PRP also produce higher than standard type ranging from 8.58% to 8.94%.

The stiffness capacity, in term of Displacement Ductility Ratio of the Mersawa PRP type is 89.62% higher than standard type, while the Meranti PRP type is 2.94% higher than standard type.

Conclusions

This result indicates that the use of nails and modified-washer make a positive contribution to improving the performance of the beam-column joint connections, in terms of strength capacity (both of proportional limit and ultimate limit loads) and stiffness capacity (displacement ductility ratio). Meranti beam-column timber joint is more brittle than Mersawa beam column timber joint, it has an impact on the results. PRP-type of Mersawa timber connection produces a higher ductility than the standard type. While the PRP-type of Meranti timber connection produces a similar ductility to the standard type.

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