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# Experimental investigation of connection performance for prefabricated timber beam

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**Abstract.** This paper presents an investigation of connection performance for a simple supported prefabricated timber beams using Meranti hardwood (Shorea sp.). The good connection is crucial for the proper functioning of the timber structures. The adequate connection condition should be assured to achieve the requirement capacity design and performance of the system. The property of material was tested according to [1]. The proposed design of bolted connections has been evaluated through experimental investigation and compared to the simple supported beam without connection. The results demonstrate the effectiveness of the proposed connection design although the ultimate load of the beam with connection is only half of the beam without connection. The test results obtained the purposed connection should be improved.

## 1 Introduction

One of the important factor to investigate the performance of the wood building structures is by evaluating the performance of its element. The limited length in the market creates the demand of the needs to improve connection technology so the wood structure element can be longer. Many researchers have studied the wood connections [2] but the innovative design remains questionable.

A prefabricated (prefab) building is a building that is manufactured and constructed using prefabrication or factory-made components that are transported and assembled on-site to form the complete building. The prefab can be solution for delivery urban infill housing and residential buildings [3,4] and the wood as material can be innovative systems for carbon reduction and waste avoidance [3,5]. This type of housing is factory made but the dimension and connection are not custom made. The limitation of the dimension and connection in beam usually becomes a limitation of the structure. The beam structure needs to resist moment so the connection needs to distribute a tension force. The simple, easier, faster, strong and precise connection are still the challenges for the wood technology.

The wood is a unique sustainable material with a variation of many external factors as soil characteristic, climate condition, and the age of the timber. The mechanics property of the same type of the wood can be different so the test should be conducted in each experimental investigation to getting know the real characteristics of the element.

In this study, the performance of the bolted connection was investigated in simply and aesthetic way of connection that designed and applied in connection of two beam elements. The main objectives of this study were to investigate the material property of the wood that used for the beam and to evaluate the connection performance of the simple supported beam.

## 2 Material and methods

The material properties were obtained according to [1]. 15 specimens of 50 mm x 50 mm x 50 mm were prepared. Table 1 showed the average results from the specific gravity and water content for Meranti wood (*Shorea sp.*).

Table 1. Material property of the specimen

| Type | No. of Sample | Specific Gravity | | | | | | | Water content |
|---|---|---|---|---|---|---|---|---|---|
| | | min | max | mean | min | max | mean | cov | |
| Meranti | 15 | 0.508 | 0.984 | 0.806 | 0.462 | 0.899 | 0.721 | 0.207 | 11.7% |

Two models of the simply supported beams were investigated. The BEAM-1 was the solid beam without connection and the BEAM-2 was the solid beam with bolted connection fabrication. The length of the beam was 1500 mm support to support and the vertical loading in the middle was setting up until attain its ultimate load as shown in Figure 1.

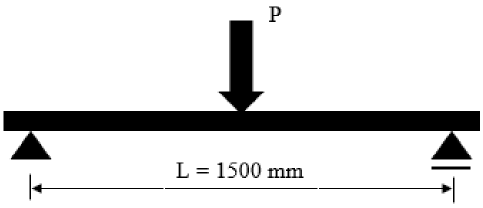
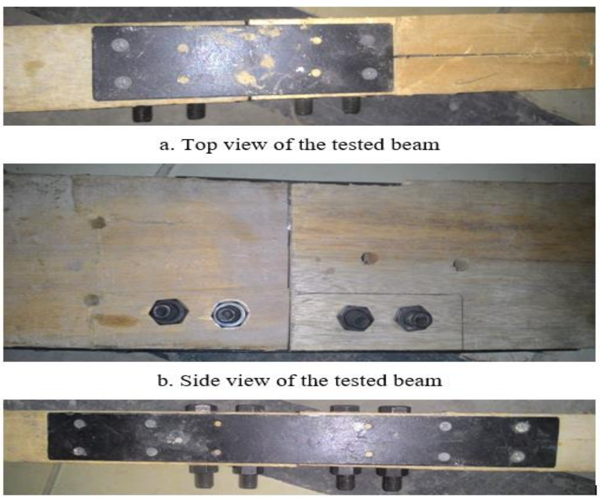



Figure 1. Beam loading pattern

### *2.1 Bolted connection configuration*

The connection was designed to distribute the forces uniformly at the connection with a significant number of bolts. To optimize the testing results, joint test configurations were fabricated in the middle of each specimen. The steel plate was put in the center inside of the wood to cover the tension. The bolted connection was connected horizontal in the side and vertically in the bottom of the wood. The top of the wood also connect with steel plate that strengthened with steel plate. The hole patterns were fabricated and the combination of two rows of bolts. The bolted connection configuration can be seen in Figure 2. The top and bottom connection were using 6 mm diameter bolts and the side connection was using 10 mm bolts with ring.



a. Top view of the tested beam

b. Side view of the tested beam

c. Bottom view of the tested beam

Figure 2. Bolted configuration setup

### *2.2 Test Setup*

The tests were conducted with the setup shown in Figure 3. A monotonic vertical loading was load until failure at a speed to cause failure between 3-5 minutes. A load-deformation curve was obtained using the movement of the head of the testing machine as a measure of deflection.

a. Test Setup for BEAM-1

b. Test Setup for BEAM-2

Figure 3. Test Setup

## 3 Results

### *3.1 Performance of the BEAM-1 model*

Test results for the solid beam without connection (BEAM-1) were shown in Figure 4. The ultimate load can be attained in 30 kN on 17 mm deformation. This test result was the baseline for the designing bolted connection configuration. The result was meet the allowable strength that calculated using the mechanics-based model using Indonesian Standard.

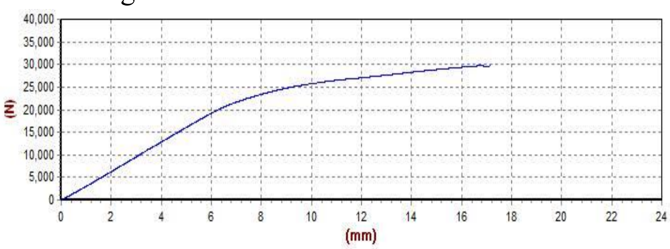



Figure 4. Load-deformation curve of BEAM-1

### *3.2 Connection Test Results*

The results for the beams with connection (BEAM-2) were shown in Figure 5. The maximum ultimate load can be attained was 12 kN in 22.5 mm deformation. Lower value of the ultimate load can be observed if it was compared with the ordinary beam. The performance of the bolted configuration was not as expected. The first failure can be observed on 8 kN loading. This result indicated the configuration should be improved.

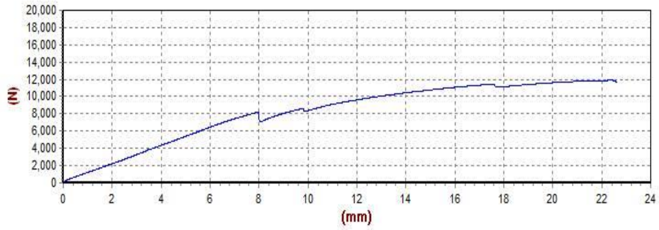



Figure 5. Load-deformation curve of BEAM-2

### 3.3 *Failure Mode*

The flexural failure can be observed for the BEAM-1. The crack pattern in Figure 6 showed a relatively small crack less than 1 mm can be observed in the top and the bottom on the middle of the beam.

Figure 6. Crack patterns of BEAM-1

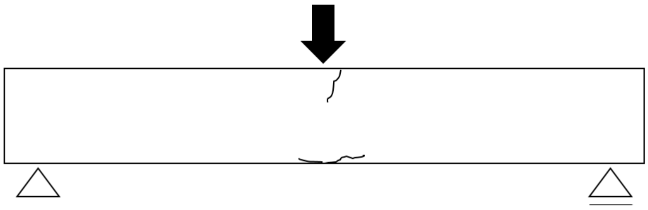


Figure 7. BEAM-1 failure

For the beam with connection, BEAM-2, a large separation in the middle can be observed in Figure 7. The bolted connection was failed with the separated in the bottom of the beam. The bolts and the plate cannot distribute the loading significantly. The separation of the both connected in the beam was larger in the bottom of the beam. The bottom plate was bent and the top of the beam lose its capacity and gain more loading because of the top distance between both elements became small. No crack can be observed on the wood and the plates. The failure was only because of the separation of the both elements due to bending.

## 4 Conclusions

From the experimental investigation, the conclusion can be summarized as below:

1. The connection design for the prefabricated beam only can attained less than half of the capacity from the solid beam without connection;

2. The design of bolted connections was need to be improved. It should accommodate the loading transfer, more bolts and bigger diameter were recommended to use;
3. More research should be conducted on the right bolted configuration so the ultimate load of the connection beam can more than less the same with ultimate load of the beam without connection;
4. To improve the models, it is necessary to perform more tests so the strength can be predicted.

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