# The Flexural Strength of Wood Connection using Different Lengths of Waste Plastic Bottle as Connector

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Abstract: Various types of wood processing produce wood waste beside indeed the wood products. Wood waste can be re used by joining it using wood connector, which was in this current study used waste plastic bottle by heating the plastic using a hot air gun at a certain temperature. The length of the connector could be influence to the strength of the wood connection. Therefor this study was conducted to observe the flexural strength of the wood connection using waste plastic bottle as connector in some different lengths by doing an experimental study. Thirty samples with 5x5x76 cm in dimension were prepared from five variations of the connection length that were 5, 10, 15, 20, and 25 cm. Eight samples made for each variations of length. The results indicate that the length of the connector significantly influence in the flexural strength of the wood connection. The length of the plastic connector which met the highest flexural strength was 20 cm which was reach 65.091 kg / cm2 or 7.58% of the undamaged wood or wood without connection.

## 1 INTRODUCTION

Muhi (2011) states that global warming is basically a phenomenon of global temperature increase from year to year due to the greenhouse effect caused by increased emissions of gases such as carbon dioxide (CO2), methane ($CH_4$), dinitrooxide ($N_2O$) and chloro fluoro carbon (CFC) so that solar energy is trapped in the Earth's atmosphere. According to the Green Building Council Indonesia 2009 in Utomo (2012) all $CO_2$ emissions in the world, 30-40% are produced by buildings, so that any reduction in emissions in buildings will be of great leverage to anticipate global warming.

The building sector has the potential to anticipate damage to the earth, which is one of them by implementing a concept of environmentally friendly buildings or commonly referred to as the concept of "green building", where the concept demands a building with attention to environmental aspects, starting from the planning, development process, selection building materials, installation up to the operational period. One effort that can be made by humans to reduce $CO_2$ emissions using wood material so that the Green Open Space is maintained, so that the balance goes well.

Various types of wood processed to meet the needs of construction, furniture and decorations that produce products and waste. Wood cut waste is found mostly in the timber sector processing. Wood pieces can be used to increase the value of the function by connecting. The connector that can be used is a plastic bottle. Its presence in the environment is very large and has not been utilized optimally, especially in the field of wood connections.

Based on Jambeck (2015) Indonesia ranks the 2nd largest country producing plastic waste. Whereas plastic waste specifically, Baruno (2015) stated that consumption of bottled drinking water in Indonesia throughout 2014 was recorded at 23.1 billion liters. It can be estimated that the number of plastic bottles in Indonesia in 2014 is 15.4 billion bottles if all bottles are 1.5 liters. Plastics used in bottled drinking water generally from PET (Polyethylene Terephthalate) plastic types. Quoted from Derucher et al 1981 in Shinta (2008) states that PET has tensile strength (1.5-1.8) x $10^3$ psi, modulus of elasticity 0, 19 x $10^3$ psi and impact strength <16 psi. While the resistance to plastic bottles for weathering is estimated to be 500 years to 1,000 years until decomposition (Juniarta, 2016). So it is very necessary to do research on plastic bottles used as wood connectors.

Plastic bottle connectors are made using a hot air gun to heat the plastic until the entire surface of the



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plastic bottle shrinks and attaches to the wooden surface of the connected part. This connection technique was first exhibited in 2016 by Micaella Pedros, an artist from London. Therefor this study was conducted to observe the flexural strength of the wood connection using waste plastic bottle as connector in some different lengths by doing an experimental study.

## 2 RESEARCH METHODLOGY

The flexural test based on the standard wood bending test at the SNI 03-3959-1995 laboratory. The sample used is 6 samples in each variation, while the number of variations is 5 variations in connection length. wood type is local teak wood from Kaliyoso, Central Java with a size of 5 x 5 x 76 cm. The total sample used is 30 samples.

The plastic bottles used are PET bottles (Terephalate Polyethylene) with a capacity of 1500 ml. PET plastic bottles are used all from only one brand. Variations in joint length were 5 cm, 10 cm, 15 cm, 20 cm and 25 cm. Plastic bottles are connected to the center of the wood to be joined. The samples of the connection for each variation can be seen in Figure 1. The independent variables were the length of the plastic bottle connector and the dependent variable in this study was the flexural strength.

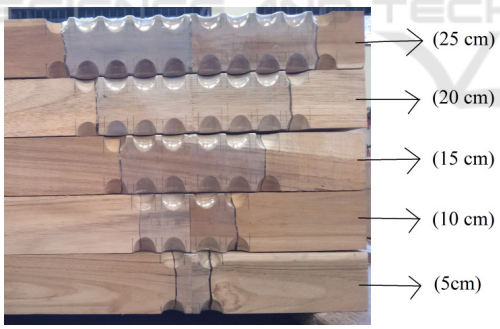


Figure 1: Wood joinned with plastic bottle in different connector length variations.

The moisture content test was done so that the test requirements are met. The maximum moisture content for flexural strength test is 20%. Calculation of water content according to ASTM D 4442-92-2003. When wood moisture content requirements were met, the wood were processed to a dimension of 5 x 5 cm and a length of 38 cm with 60 bars to be connected, and 6 bars without being connected along 76 cm.

The wood bars were then given notches on each corner of the wood crossing with the first notch edge distance with a 0.5 cm from connection. The shape of the semicircular notch is 2 cm in diameter with a distance of 0.5 cm from the notch edge. The detail projection is shown in Figure 2.

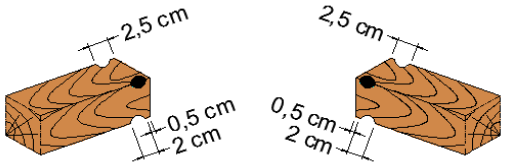


Figure 2: Projection of wood with semicircular notch.

The length of the plastic bottles were adjusted to the length of the connection variation. The wood that has been notched is then installed with plastic bottles according to the length of the variation by means of being heated using a hot air gun. The distance of the hot air gun to the plastic bottle when the heating process was around 7-10 cm. Plastic bottles were heated to the entire plastic surface attached to the wooden surface that was connected.

Excessive heating can make plastic bottles whitening or melting should be avoided during heating the plastic bottles. If both things happen, then the strength will be different.

Test specimens that have been prepared were then tested for flexural strength using the GoTech U60 type UTM (Universal Testing Machine). After testing, the data were obtained maximum load or maximum load received by the test spsciment (P). Furthermore, calculating the flexural strength has the following Equation (1).

$$\sigma lt = \frac{3PL}{2bh^2} \qquad (2)$$

Where, σlt is flexural strenght (kg/cm$^2$), P is maximum load (kg), L is support distance (cm), b is speciment widht (cm) and h is speciment hight (cm).

The data obtained from the test were then processed by doing outlier detection, i.e. cleaning data from outlier data. Outlier data in this study were data that have a z-score outside the range for data less than 80 that is -2.5 to 2.5. If outlier data were found, the data should be discarded because it cannot be used. This data were then analyzed using simple linear regression analysis using the SPSS application. Before performing regression analysis, normality and linearity tests were used as prerequisites.

# 3 RESULTS AND DISCUSSION

The wood moisture content testing based on ASTM D 4442-92-2003 produces an average moisture content of 15.90%. The moisture content had met the requirements of flexural testing.

Relative strength is a comparison of the flexural strength of original wood (without connection) with joinned wood in percentage form. Flexural strength test results can be seen in Table 1.

Table 1: Flexural strength test result.

| Connector Length (cm) | Flexural Strenght (kgf/cm$^2$) | Relative Strenght (%) |
|---|---|---|
| 5 | 22.881 | 2.666 |
| 10 | 37.759 | 4.400 |
| 15 | 50.799 | 5.919 |
| 20 | 65.091 | 7.584 |
| 25 | 61.662 | 7.185 |
| Wood without connection | 858.228 | 100 |

Figure 3. Stretched plastic.

Figure 4. Torned plastic.


Figure 5. (A) Broken wood and (B) Torned plastic.

Plastic bottle as connector behave along the testing deforming, streching and torning slowly. It torn at the wood edges near the bottom connection. Meanwhile, it strech shown when the plastic detached from the semicircular notch. In line with Stoebe's (2007) statement that if polyethylene is stretched, the molecule moves so that it becomes longer and inherence with the direction of attraction. With a load speed of 2.5 mm per minute with ± 25% deviation allowed (SNI 03-3959-1995), the plastic will stretch as long as it receives the load in the form of tensile force (bottom section) and will tear if it is no longer able to stretch.

In addition to plastic, wood breaks at the cross-sectional angle of the upper joint (compressive force). When the wood is broken, the flexural strength decreases drastically and will rise again as long as the plastic is still able to withstand the load. The cause of this break in wood is estimated because the distance of the notch is too close to the connection. As quoted from Handayani (2009) states that there is a minimum distance between connecting devices, so that the wood can avoid the possibility of rupture.

The value of the wood flexural strength of this connection can also be affected by the number of connection layers. The number of connecting devices greatly affects the strength of the connection (Sadiyo et al, 2012). A connection layer that uses only one layer less contributes to good flexural strength. It is proven that only one layer of plastic connection will be easier to stretch and the plastic part that in the notch is easy to return straight because the size of the thickness of the plastic bottle is very thin.

This plastic bottle connection is also compared to other types of connections obtained from Safitri & Gunawan (2010) study of flexural testing of wooden beams in the cross section of 6 cm x 12 cm with phenol epoxy adhesive consisting of two types of components, namely adhesive components (resin) and hardener component with finger joint connection 1: 2 slope ratio of 115,541 kg / cm², 1: 4 equal to 151,014 kg / cm² value of woodless joint flexural strength of 537,268 kg / cm². Whereas based on research (Aji & Dermawan, 2013) from testing the flexural strength of wood beams 6 cm x 12 cm with ALF Epoxi Adhesive adhesive material, hooked bevel lip connection (BSBMB) has decreased flexural strength of 91.14% or has flexural strength 8.86% of timber without connection. Graph comparison of the percentage of flexural strength can be seen in Figure 6.

In Figure 6, PBC (Plastic Bottle Connection) is a wooden connection that uses plastic bottle connectors that tested in this study, SLC (Sloped Lip Connection)

is a wooden connection using ALF Epoxi Adhesive glue joint, FJC 1: 2 (Finger Joint Connection with a slope ratio of 1: 2) is a wooden connection using Phenol Epoxy glue joints and FJC 1: 4 (Finger Joint Connection with a slope ratio of 1: 4) is a wooden connection using Phenol Epoxy glue joints.

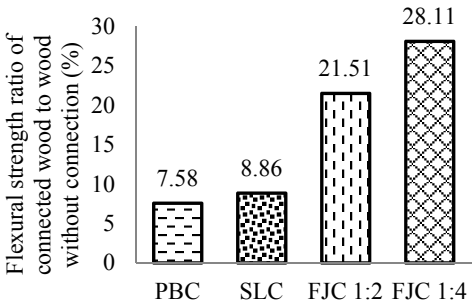


Figure 6: Flexural strenght rasio comparison of various connected wood to wood without connection.

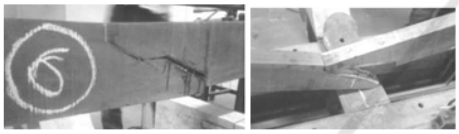


Figure 7: SLC wood speciment when collapsed (Aji & Dermawan, 2013).

Figure 8. FJC Design (Safitri & Gunawan, 2010).

Based on Figure 6 plastic bottle connection is the lowest strength type of connection compared to other types of connections. So it can be concluded that the innovation of plastic bottle joints is not good enough to be used in the construction of dominant wood withstand bending forces. But this plastic bottle connection has advantages, including easy to get, easy to make, elastic and shaped according to the shape of wood. However, its use is still limited to connecting longitudinal wood so that new innovations are needed.

# 4 CONCLUSIONS AND RECOMMENDATION

The results indicate that the length of the connector significantly influence in the flexural strength of the wood connection. The length of the plastic connector which met the highest flexural strength was 20 cm which was reach 65.091 kg / $cm^2$ or 7.58% of the undamaged wood or wood without connection.

From this study, several recommendations can be stated. The need for further research on how much plastic bottles shrink so that the connection can be installed according to the plan. Hereafter, notch design as shear connector and the distance to the edge of wood connections need to be observe to get condition that between wood and plastic bottles can collapse simultaneously, so that it can provide maximum flexural strength. In order to get better flexural strength, wood connections using plastic bottle connectors need to be combined with other connection devices such as glue.

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