Strength Comparison between Bolt and Cendani Bamboo (Bambusa multiplex) as A Shear Connector

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Abstract. Bamboo is a natural material that can replace wood, but the bamboo weakness is easily attacked by powder beetle and a bad connection system. A simple method of bamboo connection system often uses fibbers, ropes or rattan. However, this method cannot guarantee the unity of structural elements, over time the bonds will become saggy because the shrinkage that is affected by temperature changes. Another alternative can be done by using the bolt or the Cendani bamboo (Bambusa multiplex) as shear connector. The purpose of research is to know the ability of the bolt and the Cendani bamboo the shear connector in an element structures of bamboo. The research method is done by combining three pieces of bamboo with mortar filler using the bolt and Cendani bamboo as a shear connector, then apply the load to the ultimate limit. The result showed that use of bolt as the shear connector was stronger than Cendani bamboo. This is available with the results of the higher tensile strength of the bolt compared by the tensile strength of Cendani bamboo.

Keywords: bamboo, shear connector, bolt

1. Introduction

One of the natural building materials known by the public and used for building construction materials is the type of wood material. As one of renewable materials, wood is also used for the construction of earthquake resistant buildings because it is lighter than concrete material. However, the growth of timber that takes a long time to grow big and utilized is not proportional to the needs of the community that continues to increase along with population growth. The bamboo is an alternative to replace wood. Bamboo is a type of natural material, highly strength tensile and bending. The utilize of bamboo as a building material is a heritage of grandmothers. In the past, community has been used it as building materials, household appliances, retaining walls and etc. in a construction, bamboo can be used as structural elements such as; beams, columns, truss, walls, roofs, roof trusses, doors, and windows [1].

Currently, bamboo as a substitute for timber continues to be developed, such as laminated bamboo technology and plybamboo. However, natural bamboo has an interesting artistic value. The characteristics of bamboo has a high flexural strength and provides a very high aesthetic value in a building construction. It is stronger, lighter, and easier to grow than wood. In addition, it is also cheaper material and easier to obtain than wood or other material.

Since a few centuries ago, the tropical community has used bamboo as furniture and building material. The use of bamboo in building construction is used as both structural and non-structural elements. Building elements that can be made from bamboo materials include foundations, floors, beams, columns, walls, roofs, roof frames, doors, and windows. Some of the advantages of bamboo to design the earthquake resistant building, including [2]:

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• Bamboo has a high flexural strength, so when an earthquake occurs, the bamboo can follow the direction of the earthquake force without collapse until the limits of the allowed bending. The high flexural properties of bamboo make bamboo more resistant than steel or concrete that is hard, rigid.

• The shape of a hollow bamboo makes the lighter and the bigger inert moment that can reduce the weight of the building, withstand the direction of earthquake force that is difficult to predict. So it can reduce the influence of earthquake forces and minimize the risk due to building collapse.

• The bamboo connection system is rigid so that the distribution of the load is evenly distributed.

Growing rapidly, bamboo can be cut down and utilized when is three to five years old. The development of research about bamboo technology makes bamboo be a choice of raw materials/building materials. In addition, bamboo is also cheaper than other building materials. Current bamboo technologies currently introduced by researchers include bamboo preservation methods to avoid the attack of powder beetles, lamination methods that make bamboo such as processed wood sheets.

Tensile strength and flexural strength of bamboo can be utilized in unique and interesting architectural designs. Elastic properties of bamboo are good enough to withstand loads, either axial, shear, or bending loads. In contrast, to utilizing of bamboo as a structural element, its problem is the type of shear connector. A simple method that is cheap and often used with fibers. However, this method does not guarantee the unity of structural elements, over time the bonds will become saggy because it is affected by the shrinking due to the influence of temperature. Another alternative is to use the bolt or Cendani bamboo.

This research is done to know the ability of bolt and Cendani bamboo as the shear connector. The specimen is made based on the standard ISO 22157-1: 2004 [3] and ISO 22157-2004 [4].

2. The Connector in Bamboo Construction

Bamboo can be modelled as structural elements such as beams, columns, roof frames or bridge frames. In a bamboo structure, the incorporation of elements is usually done in a simple way e.g.: using rope, palm fiber or rattan. The weakness of the connection system using rope, palm fibre, or rattan is that the strength of the connection is based on the strength of the friction between bamboo and shear connector. Over the time, the connection will be loosened due to the shrinkage that is affected by temperature changes, so the connection strength becomes unstable. As the strength analysis of connector from the rope, fibres, or rattan are still difficult, bolt and Cendani bamboo can be an alternative solution of the shear connector. Many researchers have conducted studies about the connection on bamboo [5-7].

The strength of shear connector using bolts with fillers stated that the shear connector strength was influenced by several related variables [2], such as bamboo diameter (d1), bolt diameter (d2), bamboo thickness (t1), thickness of steel gusset plate (t2), the strength of the filler material (f.), the fulcrum strength of bamboo is parallel to the fiber (f.), the fulcrum strength of steel (f.), and yield stress of steel/shear strength of steel (f.) (see also Fig. 1).

![Figure 1. Installation shear connector at bamboo element](image-url)
3. Research Methods

3.1. Research flowchart

The research was conducted as shown in Figure 2.

![Flowchart of the research](image)

Figure 2. Flowchart of the research

3.2. The Specimens

Specimens used in this study is the *Wulung* bamboo species (*Gigantochloa atroviolacea*) obtained in the Sleman area of Yogyakarta, with a bamboo age of between 3 to 5 years. Test objects are divided into two types, preliminary test and connection model test [3]. The specimen was three bamboo sticks filled with mortar and combined using bolts and *Cendani* bamboo as the shear connector. The size of the bolt and bamboo as the shear connector and the shape of the specimens including test settings [4] are shown in Table 1, Figures 3 and 4.

| Shear Connector | Diameter (cm) | Long (cm) |
|-----------------|---------------|-----------|
| Bamboo          | 2             | 25        |
| Cendani bamboo  | 2             | 25        |
| Bolt            | 0.6           | 25        |

Table 1. The Bolt and *Cendani* bamboo sizes as shear connectors.
Figure 3. The shape of specimens, (a) Cendani bamboo, (b) Specimen with a bolt as shear connector, (c) Specimen with a Cendani bamboo as shear connector, (d) Set-up a bolt as shear connector, (e) Set-up a Cendani bamboo as shear connector.

Figure 4. Setting Up of Testing.
4. Results and Discussion

The result of load strength test which can be accepted a bolt and a Cendani bamboo as the shear connector for 3 specimens test at the ultimate limit and elastic limit [8-9] are shown in Table 2. The result of preliminary test is shown in Table 3.

Table 2. Preliminary test of shear connector specimen

| Shear Connector | Tensile Strength (MPa) | Percentage (%) |
|-----------------|------------------------|----------------|
| Cendani Bamboo  | 131.49                 | 100            |
| Bolt            | 613.26                 | 466            |

Table 3. The results of test use Cendani bamboo as a shear connector

| Shear Connector | Limit Load (N) | Elastic Load (N) |
|-----------------|----------------|------------------|
|                 | Load Average  | Load Average     |
| Bamboo Cendani  | 7200          | 1200             |
| 2               | 4300          | 5666.67          |
| 3               | 5500          | 2100             |
| 1               | 7300          | 3800             |
| Bolt            | 7900          | 4200             |
| 2               | 3833.33       | 3966.67          |
| 3               | 8300          | 3900             |

Based on Table 2 and Table 3, the test to the maximum load and elastic load can be seen that the acceptable boltshear connector is higher than the Cendani bamboo shear connector, but it is not too significant. On the contrary, the difference is significant in the imposition of elastic load. The amount of load that can be carried by bolt and Cendani bamboo shear connector is also affected by the size of the bamboo specimens, diameters, and thickness of bamboo. The percentage comparison of shear connector bamboo and bolt at the ultimate limit and the elastic limit is presented in Table 3 and Figure 5.

Figure 5. Comparison the strength of shear connector bolt and Cendani bamboo, (a) Maximum load, (b) Elastic load

Based on Table 4 and Figure 6 it can be seen that the comparison of load percentage at the ultimate limit increases 38% with the use of a bolt shear connector. In contrast, in the elastic condition, the load increase reaches 164% or 1.5 times the amount of load that can be retained by the bamboo with a bolt-shear connector. Percentage of strength of bolt and Cendani bamboo are significant with tensile strange test. Bolt have tensile strong higher than Cendani bamboo.
Table 4. Percentage comparison of maximum load

| Shear connector | Maximum load | Elastic load |
|-----------------|--------------|--------------|
|                 | P (N)        | Percentage Increase Load (%) | P (N)        | Percentage Increase Load (%) |
| Cendani Bamboo  | 5666.67      | 100          | 1500         | 100                        |
| Bolt            | 7833.33      | 138.23       | 3966.67      | 264.45                     |

Figure 6. Comparison percentage the strength of shear connector bolt and Cendani bamboo, (a) Maximum load, (b) Elastic load

5. Conclusion

From this study, several conclusions can be drawn as follows:

- The use of shear bolt connector is able to withstand larger loads compared to the Cendani bamboo shear link.
- There is no significant difference in load, which can be retained by bolt compared to the Cendani bamboo as the shear connector.
- The Percentage increased the load on the bamboo system using a bolt shear connector is 38%.
- The load that can be retained by bamboo system besides influenced by shear connector also by the diameter and thickness of bamboo.
- The Cendani Bamboo can be an alternative shear connector in the bamboo construction system.

6. References

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