Bamboo Reinforcement Concrete Beam as Innovation for Low-cost Earthquake Resistant House

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Abstract. The aim of study is to know about shape, specification, strength, and reduction bamboo reinforced concrete cost construction percentage against reinforced concrete. This study was conducted with a comparative quantitative method. The comparison examined includes cost reduction that occur when using bamboo. Study was using one of bamboo species called Bambusa Vulgaris which has great growth potential in Tidore City, especially Rum District. Bambusa Vulgaris is a strong and recommended bamboo for application as a construction material. Based on the analysis results, bamboo reinforced concrete has enough strength to replace the type of steel-reinforced concrete construction on slotted beam and ring beam. The use of bamboo as reinforced concrete for simple houses projects could save projects cost up to 10.4 million rupiahs. It reflects that Rum Village and Tidore City has tremendous bamboo potential to be used as a structural material. That fact expected that the results of this study can be empirically tested in the laboratory to determine mechanical properties of bamboo reinforced beams originating from Tidore City. For the long term, it is hoped that the local government can move together with the society of the Tidore City to cultivate bamboo seriously and sustainably.

Keywords: Bamboo, beam, construction, reinforcement concrete

1. Introduction
Indonesia has been listed among the world's most disaster-prone countries, especially for earthquakes. It is caused by geographical location which is on the confluence of several large and small plates, as in Tidore Islands, North Moluccas that often experience earthquakes. This area is located in a meeting point of two large plates along the east of Indonesia. It is in the west of Halmahera island and in the south of Ternate consisting of several districts and villages. Those northern districts and villages have a high risk of earthquakes, such as in Rum Village. As presented in the mapping of earthquake potentials released by SNI 1726-2002, Rum Village is included in zone IV that is prone to earthquake occurrence [1]. The collapsed building contributes as one of the biggest human casualty levels in earthquakes. It urged the government to promote earthquake-resistant buildings in which the Ministry of Public Works and Housing issued the Technical Guide to Earthquake-Resistant Houses in 2006.

In fact, the evaluation of simple houses in Rum Village showed that from 35 houses that had been surveyed, there were 21 houses (60%) categorized as less-earthquake resistant buildings and 3 houses (8%) were not resistant to earthquake. It means that more than half of the simple houses in Rum Village are not resistant to earthquakes. If there is a strong and sudden earthquake, it can make simple houses collapse. Unfortunately, there is no research or reference that is able to predict when sudden Earth events will occur.
The main cause of the houses to be less resistant to earthquakes is due to the absence of reinforced concrete sloof structures as stiffeners in its columns, foundations, and walls. Based on the interviews with the artisan coordinator in Rum Village, it is known that the lack of funds has been the main reason why many houses do not use sloof structures. The high price of sloof is caused by its steel reinforcement. The reinforcing steel costs 34% of the total cost to make 1 m³ of reinforced concrete slabs. In other words, 1/3 from the cost of making 1 m³ of concrete slabs can be used to create reinforcing bars.

Based on the facts above, it urgently requires an innovation of alternative building materials which is more economical but strong to replace reinforcing bars. It may be realized by optimizing the potential of *Bambusa Vulgaris* as an open-clump type bamboo species. Bamboo can be chosen as an alternative of steel by considering 6 criteria of appropriate technology, i.e. technical, economic, ergonomic, socio-cultural, energy-saving, and environmentally friendly. Technically, bamboo has been extensively studied and it meets the requirements for concrete reinforcement, especially those applied to simple building structure systems [2]. Bamboo is considered technical and economical because the price of bamboo is very cheap and easily grown in many areas of Indonesia. It is also ergonomic because it will not damage human safety and health. In case of the socio-culture, bamboo has been widely used for building materials. It also promotes energy-saving since its manufacturing process does not require much artificial energy. Moreover, it is environmentally friendly because it can always be renewable without damaging the environment. Referring to those potential reasons, this research is trying to reveal the strength of this type of bamboo that is available in Tidore.

This research was carried out based on the support of the following research results, such as "A Case Study on Bamboo as Green Building Material". This research shows that in recent years there has been an escalation of interest in the use of bamboo as a construction material and as an alternative building material [3]. In China, contractors use bamboo as scaffolding [4]. Bamboo with a water content of 15% or less has good mechanical properties and reduces the potential of insect attack [5]. The strength of bamboo is influenced by its species and age. For construction purposes, the proper materials are 3-4 years old because in this period bamboo has high strength and is easy to apply to several pieces [6].

In addition, the research has identified the mechanical properties of four types of bamboo including *Bambusa Vulgaris*, *Dendrocalamus Asper*, *Schizostachyum Grande*, and *Gigantochloa Scortechinii*. Based on the results of his research, it is known that the *Bambusa Vulgaris* type obtains a tensile strength of 233 MPa, followed by *Dendrocalamus Asper* with 230 MPa, *Gigantochloa Schortechinii* with 187 MPa, and *Schizostachyum Grande* with 149 MPa respectively. This study shows that bamboo of *Bambusa Vulgaris* type is suitable to be applied as a building structure [7]. The last study which directly tests the samples of reinforced concrete beams get results that the 120 mm x 200 mm beam using bamboo reinforcement produces sufficient strength. The tested beam is able to withstand a nominal moment of 4375000 N mm with a deflection at 2.96 mm [8].

2. Experimental Setup

2.1 Research Type

This study belonged to comparative quantitative research. This type of research was chosen because this study tried to compare the price and the ability of bamboo-reinforced concrete with steel-reinforced concrete. The comparisons were made using the numbers in case of its prices in Rupiah.

2.2 Setting dan research Time

This research was done in Rum village, Tidore Islands, North Moluccas on August 07 – 16, 2019.

2.3 Research subject

The subject of this research was the bamboo type of *Bambusa Vulgaris* which was available in Rum Village. This subject was selected based on the results of direct observations in the highland of Rum Village. The identification step of bamboo selection was based on the research results before on the mechanical properties of bamboo species.

2.4 Data Collection Techniques and Instruments
The process of data collection was done through the combination of observation, documentation, and literature study. The observation was carried out to know the specifications of bamboo species of *Bambusa Vulgaris* in Rum Village, Tidore City. Then, the selected bamboo was documented in the form of a drawing to show the shape and thickness of the cross-section of the bamboo.

After the bamboo data were obtained, simple houses were designed based on the general shape of the houses in Rum Village. The design was arranged in such a way to synchronize the architecture of local values in Rum Village. The building was then analyzed to determine the amount of dead load, live load, and earthquake load. After the load was received, the specification of bamboo-reinforced concrete was planned to withstand the accumulation of dead load, live load, and earthquake load that was working.

### 2.5 Data Analysis Technique

The obtained data on the bamboo specifications were used to determine the size and content specifications of bamboo-reinforced concrete that able to withstand the building loads. The total building load was analyzed using conventional methods and with software assistance. The conventional load calculations were done using the envelope method. Meanwhile, the calculation with the software assistance was done with SAP 2000 v11.

### 3. Results and Discussion

#### 3.1 Specification of *Bambusa Vulgaris* in Rum Village

Based on its potential, Tidore is one of the regions in Indonesia which has the potential of *Bambusa Vulgaris*. With its large area of 10 km² or 26% of the area of North Tidore District, Rum Village provides a great bamboo potential in the forest. Based on observations, the biggest bamboo which is available refers to a type of *Bambusa Vulgaris*. This kind of bamboo was also matched the criteria of bamboo species with a height of 5-10 m, perforated, and yellowish-green color. The illustration of the shape of the bamboo along with the dimensions of the bamboo can be seen in Figure 1 and Figure 2.

![Figure 1(a). The Potential of Bambusa Vulgaris in Rum Village](image1)

![Figure 1(b). The Potential of Bambusa Vulgaris in Rum Village](image2)
3.2 The Plan of Simple House in Rum Village

Types of houses or dwellings can be classified into 4 types. The simple house is defined as a non-tiled house with a floor area of no more than 70 m² [9]. In addition, in Rum Village there is a general culture of building forms which makes the design of most house plans have a common pattern. The similarity of patterns is because there is only one artisan coordinator who is responsible for coordinating the construction of simple houses in Rum Village. The design pattern of the building is presented in Figure 3.
3.3 Analysis of Building Load

3.3.1 Envelope Load System

This method divides the room spaces into several sections that resemble the shape of an envelope. The division of this room is limited by the wall that is connected to form an envelope pattern as shown in the following Figure 4. Based on the picture above, the columns and beams in the red circle receive the biggest load. Total load is differentiated based on accumulation of dead load (D), live load (L) and earthquake load (E). These loads were calculated based on several load combinations that referred to SNI 1726-2012 regulations on building loads, namely:

1. $1.4D$
2. $1.2D + 1.6L + 0.4 (Lr or R)$
3. $1.2D + 1.6 (Lr or R) + (L or 0.5 W)$
4. $1.2D + 1.0W + L + 0.5 (Lr or R)$
5. $1.2D + 1.0E + L$
6. $0.9D + 1.0 W$
7. $0.9D + 1.0E$.

Based on SNI 1727-2013 on the Minimum Load for Building Planning, it is explained that a simple house receives the dead load (D) of 96 kg/m² or 0.96 kN/m² and the live load (L) of 48 kg/m² or 0.48 kN/m². From the results of the analysis on the column that received the largest load, the column received the D load of 14.65 kN and the L load of 4.98 kN. Meanwhile, the beam that received the biggest load obtained the D load of 9.17 kN and the L load of 3.14 kN. In this calculation, it was chosen the combination of loading 2) $1.2D + 1.6L$. Therefore, the accumulated load received by the column was 25.57 kN. Meanwhile, the beam took the accumulated load of 16.03 kN.

3.3.2 The load with SAP2000 version 11

SAP2000 is used as a tool to check the load based on manual calculations. The main reference still uses the results of manual calculations because the results of calculations with SAP2000 devices are only modeling of the actual structure. The determination of the received total load was started by arranging the structural modeling of the floor plan. After that, the load was entered and analyzed, as presented in Figure 5 below, to determine the column that received the biggest load, i.e. 23.86 kN. The total load was approaching the result of manual calculation of 24.62 kN. For safety reasons, the total of a bigger load than the calculation results was chosen.
3.4 Planning Bamboo-Reinforced Concrete

After knowing the total workload and the specifications of the tested bamboo-reinforced concrete, it is followed by planning the beam to obtain the specifications of ring beam and concrete with bamboo reinforcement that are able to withstand the building load. This planning can be divided into two, planning the ring beam and the sloof. Based on this planning results, it was known that reinforced concrete beam rings required a size of 150 x 200 mm with reinforcement area (As) 720 mm2. Therefore, the detailed ring beams can be measured in 150 x 200 mm with 4 bamboo bars installation of 30 x 6 mm. The detailed shape of the bamboo-reinforced ring beam can be seen in Figure 6(a). Meanwhile, from the sloof planning, it indicated the required size of 150 x 250 mm with the area of reinforcement (As) 853 mm2. Therefore, if the sloof beam of 150 x 250 mm was installed, 5 bamboo bars of 30 x 6 mm were also installed. The details of sloof pieces can be seen in Figure 6 below.

3.5 The Comparison of Houses with Reinforced Beams of Bamboo against Iron

In this section, the price difference is presented based on the bamboo application as the substitution of bars reinforcement. Based on the price analysis on the bars-reinforced sloof unit, for 1 m3, it required the fund of Rp 4,327,589.61, while bamboo-reinforced sloof only Rp. 2,685,767.61 that saved more than 38%. Moreover, the bars-reinforced ring beam of 1 m3 spent the fund of Rp 4,558,780.27 and the bamboo-reinforced ring beam for 1 m3 only required Rp 2,916,958.27. So, it can save 36%.
In its application on houses, the construction of earthquake-resistant buildings using bars-reinforced concrete blocks spent Rp. 189,006,000.00. Meanwhile, earthquake-resistant houses using bamboo-reinforced concrete blocks needed Rp 178,592,000.00. This means that houses with bamboo-reinforced beams can reduce the total cost of the building by 5.5%. With its total price, it is able to make the building that can be categorized as earthquake-resistant houses at a relatively cheaper price.

4. Conclusions
Based on the analysis results, several conclusions can be drawn as follows.

a. Bamboo is able to replace bars for ring beam construction and reinforced concrete sloof. Although not as strong as bars, the use of bamboo based on software has been proven safe for use as a construction material.

b. The ring beam structure of reinforced-bamboo concrete has the specification size of 150 x 200 mm and 4 reinforcement with the size of each cross-section of 40 x 6 mm.

c. The sloof structure of bamboo-reinforced concrete can be measured in 150 x 250 mm and 5 bamboo reinforcement with each bamboo cross-section of 40 x 6 mm.

d. The use of bamboo as a reinforcement substitution in the sloof beam can reduce the price in 1 m3 to 38% while the ring beam reduce in 1 m3 to 36% (Rp 1,641,822.00).

e. The use of bamboo in two-beam structures for simple houses can reduce the total construction cost by 5.5% (Rp 10,414,000.00).

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