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Rumbayan, Rilya
Manado State Polytechnic

Rumbayan, Meita
Sam Ratulangi University

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A Study on The Utilization of Local Coconut Timber Waste as Sustainable Building Material

Rilya Rumbayan[1], Meita Rumbayan[2]
[1]Manado State Polytechnic, [2]Sam Ratulangi University.
rilya.rumbayan@gmail.com

Abstract: *This paper performs a study into the use of local coconut timber waste as an alternative building material to build earthquake-resistant timber house in Indonesia. The goals of this research are: (1) to design a model of earthquake-resistant house made of local coconut timber waste, and (2) to present structural analysis of the house under earthquake load. Research methods include design of an earthquake-resistant local-timber house, estimation of the dimensions of structural elements of earthquake-resistant local-timber house; and analysis of the performance of the timber house under earthquake load with structural software for building analysis and design. Outcomes from this study are expected to promote the beneficial usage of the potentially of local timber waste as construction material for timber house in an effort to mitigate the risk of earthquake hazard.*

Keywords: Local coconut timber; earthquake-resistant; building material, design and analysis

1. INTRODUCTION

Indonesia is located on the Pacific Ring of Fire that has a high degree of tectonic activity. North Sulawesi Province is one of the regions in Indonesia that has a high risk of earthquake. Based on the map of earthquake regions used as a reference for structural building design, the province is located in Earthquake Region 5 which is categorized as a high-risk zone with earthquake scale between 5-7 Richter.

Building construction made of timber presents many advantages such as relatively higher structural stability and integration. This is due to the fact that timber has higher strength-to-weight ratio compared to steel and concrete. This weight or mass of construction has a linear correlation to the lateral force sustained by the construction. These characteristics have caused timber to become an alternative building material for earthquake prone areas such as North Sulawesi [1].

According the Indonesian standard about the quality and dimensions of construction timber, SNI 03-3527-1994 [2], timber can be classified into 5 strength classes based on the physical properties, flexural strength and compressive strength as shown in Table 1.

Table 1. Mechanical properties of timber

Strength Class	Air-dry Density	Flexural Strength (Kg/cm^2)	Compressive Strength (Kg/cm^2)
I	≥ 0.90	≥ 1100	≥ 650
II	0.90 – 0.60	1100 – 725	650 – 425
III	0.60 -0.40	725 – 500	425 – 300
IV	0.40 – 0.30	500 -360	300 – 215
V	≤ 0.30	≤ 360	≤ 215

The long-term goal of this study is to produce a prototype of earthquake-resistant timber house made of coconut-timber. The particular objectives of this research are to design a model of earthquake-resistant house made of local coconut timber waste, and to present structural analysis of the house under earthquake load.

This study is significant as an effort to utilize the use of local timber waste as a construction material to build earthquake-resistant timber house. Additionally, results of this study are believed to support the utilization of potential sustainable local natural resources.

2. MATERIALS

Coconut is one of the many potential plantation crops commodities grown in North Sulawesi. The main waste from the rejuvenation of coconut trees are the trunks from old coconut trees aged over 50 years and needed rejuvenation because of their decreasing fruit productivity. Utilization of the unproductive coconut trees as a building material for timber house can be an alternative solution to the handling of coconut tree trunks after the rejuvenation, which will be useful to the local communities [1].

The characteristics of coconut-timber are different to the characteristics of other hardwoods. There is no cambium in a coconut tree therefore the diameter of the tree does not increase. Moreover, coconut trees do not form the annual circle because there is no annual growth to the diameter of the trunk and coconut trees do not have branches, which means that they are free of knots. In addition, coconut-timber also cannot regenerate, which can be observed from the existing footholds made during the harvesting of coconut that never disappear [3].

In previous study by the author was obtained the mechanical properties of coconut timber as shown in Table 2 [1]. The timber waste was obtained from unproductive coconut trees from Minahasa Selatan region in North Sulawesi. It was found that conform the SNI 03-3527-1994 classification, the strength class of coconut-timber can be used as structural construction timber, of which usage requires the calculation of load. Results from the previous study were used as references in design stage of a 8m x 12m model of timber house.

Table 2. The mechanical properties of coconut timber

No.	Characteristics of coconut-timber	Test result
1	Modulus of Elasticity (kg/cm^2)	67000
2	Flexural strength (kg/cm^2)	458.66
3	Compressive strength parallel to grain (kg/cm^2)	399.3
4	Compressive strength perpendicular to grain (kg/cm^2)	179.79
5	Shear strength parallel to grain (kg/cm^2)	65.13
6	Density (gr/cm^3)	0.9
7	Moisture content (%)	15.95
8	Tensile strength – parallel to the grain (kg/cm^2)	44760.1
9	Toughness (kgf)	424.74

3. RESEARCH METHOD

Research methods include design of an earthquake-resistant local-timber house, estimation of the dimensions of structural elements of earthquake-resistant local-timber house; and analysis of the performance of the timber house under earthquake load with structural software for building analysis and design as shown in Figure 1.

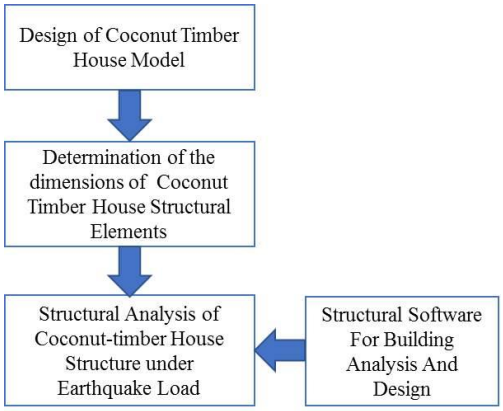


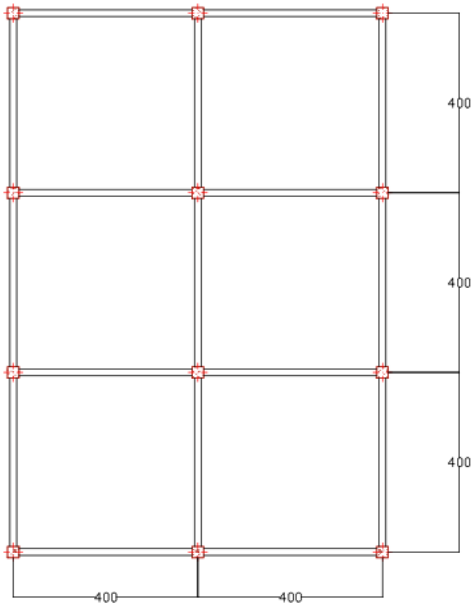
Fig.1. Research Method

The design phase of the coconut timber house model includes the drawing of design plan of the timber house and calculation of timber structural elements. The design phase was implemented principles and standards of building model by considering earthquake load. The dimension determination of the house structural elements including beam, column, floor panel, wall panel and roof. Simulation of structural performance test was done by analysis of the structure under earthquake load using structural software for building analysis and design.

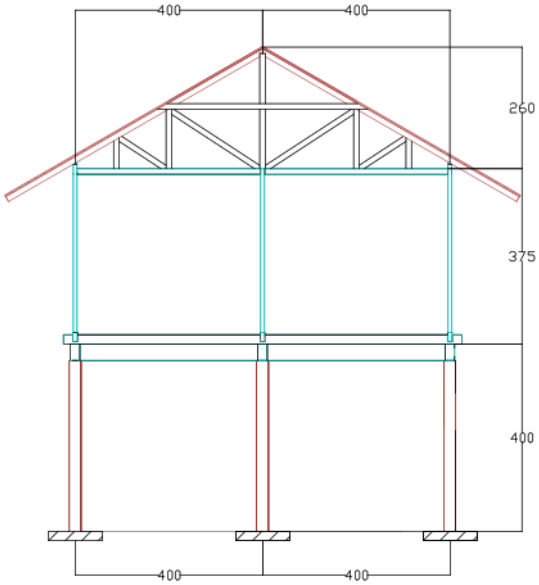
4. RESULTS DAN DISCUSSION

Results of structural design of a coconut-timber house with a floor plan size of 8m x 12m are shown in Figure 2. The result of the design of a coconut-timber house model is shown in Figure 3.

Structural calculation of coconut-timber house includes roof frame structure, ceiling structure: main beam, secondary beam, floor beam and floor board, floor structure: main beam, secondary beam, floor beam and floor board, and columns. Determination of the dimensions of coconut-timber house structural elements was performed in accordance to design principles, standards and implementation methods building model construction by considering earthquake load. Design results of dimensions of the timber house structural elements are presented in Table 3.



(a)



(b)

Fig.2. Design of coconut-timber house (a). Floor Plan; (b) Portal Frame

Structural performance test is done by analysis of structure under earthquake load with simulation of structural model. The software used for this simulation process is ETABS (Structural software for building analysis and design). The sway mode caused by earthquake on the frame structure of coconut-timber house generated by ETABS software can be seen in Figure 4. Results from the structural analysis of the coconut-timber house frame structure under earthquake

loading using ETABS software show that the house is safe.

Fig.3. Design drawing and model of timber house

Table 3. Calculation result of the dimensions of coconut-timber house structural elements

No.	Construction	Element	Dimension
1	Ceiling	Main beam	b=8 cm and h=15 cm
2	Floor	Main beam	b=15 cm and h=25 cm
		Secondary beam	b=12 cm and h=20 cm
3	Upper columns		b=12 cm and h=12 cm
4	Lower columns		b=20 cm and h=20 cm

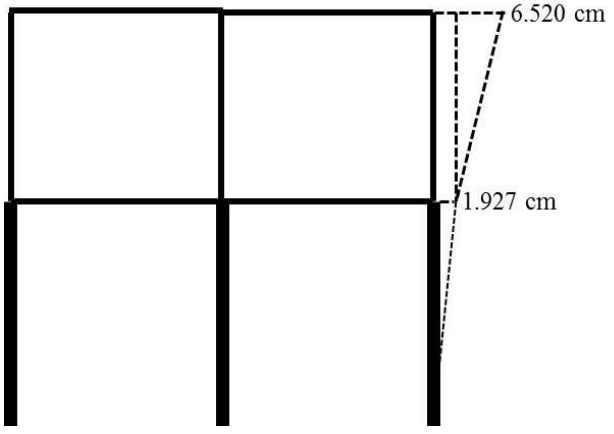


Figure 4. Sway mode due to earthquake load acting on the frame structure of coconut-timber house (generated with ETABS).

Outcomes from this study are expected to promote the beneficial usage of the potentially of local timber waste as construction material for timber house in an effort to mitigate the risk of earthquake hazard.

5. ACKNOWLEDGEMENTS

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