



Plagiarism Checker X Originality Report

Similarity Found: 23%

Date: Friday, April 28, 2023

Statistics: 630 words Plagiarized / 2685 Total words

Remarks: Medium Plagiarism Detected - Your Document needs Selective Improvement.

The development of traditional wooden house using local coco wood waste as strategy for facing earthquakes R Rumbayan¹, C D E Kandou¹, M M Wala¹, and B A Tombeg¹
¹Department of Civil Engineering, Manado State Polytechnic, Manado, Indonesia E-mail: rilyarumbayan@sipil.polimdo.ac.id <mailto:rilyarumbayan@sipil.polimdo.ac.id> Abstract. The consideration of ecological quality is an approach for environmentally friendly house construction by utilizing waste material. This paper discusses a current study into developing local coco wood waste as an alternative construction material to build an earthquake-resistant wooden house.

The aims of this research are 1) to identify the engineering properties and strength classification of local coco wood; 2) to design and analyse the structural elements for a traditional wooden house through a seismic approach; and 3) to demonstrate the construction method of a coconut timber house prototype. Research methods include 1) laboratory testing of the physical and mechanical properties comprising density test, compression test parallel to the grain, and flexural test. All tests were performed according to the American Standard Testing Material (ASTM) D143-09; 2) identification of strength classification of coco wood based on SNI 03-3527-1994; 3) design of the structural components and analyse structural performance using ETABS simulation; and 4) construction of a prototype earthquake-resistant coconut-timber house.

Results from this research are expected to support the beneficial usage of local coco wood waste as a construction material for timber houses in an effort to mitigate the risk of earthquake hazard. 1. Introduction The building material of timber has been used for house construction since it is a sustainable material [1] and has a high resistance to earthquakes. The use of timber can contribute to leveraging a shift towards a more emission-efficient production of construction material [2]-[4]. Timber is also a natural

product that degrades after its life cycle without impacting the environment [5], [6].

In addition, building construction made of timber offers many advantages, including low weight and high structural stability. This is due to the fact that timber has a higher strength-to-weight ratio compared to concrete and steel [7]. Timber's flexibility produces it a safe material to use in earthquake zones. These properties have caused timber to become alternative building material for earthquake-prone areas, including Indonesia. Coconut is one of the many potential plantation crops commodity grown in North Sulawesi, Indonesia. However, about 10% of coconut tree plantation areas are not productive due to their declining fruit productivity. The total area of 17.259 hectares of coconut tree plantation with coconut trees aged over 50 years and needed to be replanted. The largest waste from the replanted area of coconut trees is the logs from old coconut trees.

If the logs are left unprocessed, they can become breeding places for diseases that could strike coconut seedlings, bringing disadvantages to the local farming communities [8]. The characteristics of coconut wood are different from 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.

In addition, coconut-timber also cannot regenerate, which can be observed from the existing footholds made during the harvesting of coconut that never disappear. Also, the density of coconut-timber varies depending on depth and height of the trunk. The density increases from the centre of the trunk to the edge and decreases with increasing trunk height. More toward the centre of the trunk, coconut-timber is softer. Moreover, the density of coconut-timber also varies according to variety, location, and age of the coconut tree [9], [10].

Processing and utilization of the unproductive coconut wood as a construction material for timber houses can be very potential for building material. The objectives of this study are: 1) to identify the engineering properties and strength classification of local coco-wood; 2) to design and analysis of the structural elements for a traditional wooden house through seismic approach; and 3) to demonstrate construction method of a coconut timber house prototype. 2. Materials and Methods This research was conducted by an experimental method with laboratory research as shown in Figure 1.

Experimental tests were performed at the Civil Engineering Material Testing Laboratory, Polytechnic of Manado. Materials used were 81 pieces of 50 years coconut logs in 25-35

cm diameter and 2500 cm length taken from unproductive coconut trees located in South Minahasa, North Sulawesi Province. Samples then tested for the engineering (physical and mechanical) properties including density test, compressive test parallel to the grain, and flexure test, as shown in Figure 2.

Test methods were based on the American Standard Testing Material (ASTM) D143-14 [11]. Figure 1. Research Method Figure 2. Material and testing methods: (A). Specimens of density test (before testing); (B). Specimens of compressive test parallel to grain (after testing); (C). Specimens of flexure test (after testing); (D). Compressive test parallel to grain; and (E). Flexure test The strength classification of coco-wood is determined according to SNI 03-3527-1994 [12], as shown in Table 1. Table 1.

Strength classification of wood [12] Absolute Flexural Absolute Compressive Next, the results from this experimental stage were used as references in design the structural elements of a 6 m x 6 m model of a traditional wooden house. The design stage includes the drawing of design plan and 3D modelling of the timber house. The design stage was performed in accordance to design principles, standards, and construction methods of building model by considering earthquake load. Preparation of dimensions of coconut-timber house components which consist of column, beam, floor board, wall panel, and roof was presented after the structural analysis calculation.

The structural analysis calculation was performed by using structural software for building analysis and design (ETABS) simulation. The structure performance was simulated under earthquake load. The study of Nasution, et al [13], who conducted study on analysis of earthquake structure on a traditional wooden house of Mandailing using SAP2000 simulation, was used as a reference to observe and analyse the structure of the house through seismic approaches. 3. Results and Discussion 3.1.

Engineering properties and strength classification of cocowood The experimental test results of engineering properties including density test, compressive test parallel to the grain, and flexure test of coconut-timber are presented in Table 2. Table 2. Test results from the mechanical properties tests in the laboratory No. Characteristics of coconut-timber Test result 1 Density 0.91 gr/cm³ 2 Compressive strength parallel to grain 399.3 kg/cm² 3 Flexural strength 458.7 kg/cm² The result showed that the density of coco-wood reaches 0.91 gr/cm³. Mechanical properties of specimen consist of compressive strength parallel to the grain reaches 399.3 kg/cm², and flexure strength reaches 458.7 kg/cm².

Another study by Rangkang, et al [14], who conducted a study on the mechanical properties and physical properties of coconut tree from several locations in North

Sulawesi and North Maluku found that the density, compressive strength parallel to the grain, and flexural strength were 0.97 gr/cm³, 533.3 kg/cm², and 887.7 kg/cm², respectively, for the outer bottom part of the coconut tree. This finding confirms that the characteristics of coconut wood vary according to location of the coconut tree. The timber strength can be seen in the engineering properties test including density, compressive strength, and flexural strength.

According to SNI 03-3527-1994 [12], the categories of wood strength classification, the strength class of coconut-wood is as follow: 1) based on the air-dry density, the coco-wood is in the range of strength class I and II, therefore can be used as structural timber, which usage requires calculation of load; 2) based on the compressive strength parallel to the grain, the coco- wood is in the range of strength class III, therefore can be used as non-structural timber, which usage does not require calculation of load; and 3) based on the flexural strength, the coco-wood is in the range of strength class III to IV, therefore can be used as temporary building material. 3.2.

Design and analysis of traditional wooden house Results of structural design of traditional wooden house with a floor plan size of 6 m x 6 m are presented in Figure 3 and Figure 4. (A) (B) (C) Figure 3. Design of traditional wooden house: (A). Floor Plan; (B). Portal Frame X-axis; and (C). Portal Frame Y-axis. The design and analysis of timber houses have been developed to protect the house from earthquake load. Moreover, timber house design and construction has been developed in considering the characteristic of Minahasa culture.

The Minahasa timber house traditionally was only one floor placed with 3 meter of height from the ground and supported by structural column. The house designed only has a floor plan on the second floor. The first story was an open plan design with no walls and stairs as access to the second floor. The frames, beams, and columns were made of coco- wood. The floor consists of wooden boards. Its wall was built from wooden board. Figure 4. Design of traditional wooden house in 3D The dimensions of the coconut-wood house structural components are designed as shown in Table 3. Structural computation of coconut-wood house includes roof frame, ceiling, floor, columns, and beams.

The roof structure design consists of compression and tension members. The ceiling and floor design consist of main beam, secondary beam, floor boards, and floor beam. Determination of the dimensions of coconut-wood house structural elements was performed in accordance with standards, design principles, and guidelines of construction methods by considering seismic load. Table 3. Result of the dimensions of coconut-timber house structural elements No.

Construction Element Dimension 1 Roof truss Compression Tension 8 cm x 12 cm 8 cm x 12 cm 2 Ceiling Main beam Secondary beam Floor beam Floor boards 10 cm x 18 cm 10 cm x 18 cm 5 cm x 10 cm 25 cm x 2,5 cm 3 Floor Main beam Secondary beam Floor beam Floor boards 15 cm x 20 cm 15 cm x 20 cm 5 cm x 10 cm 25 cm x 2,5 cm 4 Upper columns 15 cm x 15 cm 5 Lower columns 15 cm x 15 cm Performance of the coconut-wood house structural elements is done by simulation of structural model of structure under earthquake load. The software used for this simulation process is ETABS (Structural software for building analysis and design). The result of displacement mode on the frame structure of coconut-wood house caused by earthquake is introduced in Figure 5.

According to SNI 1726-2012 [15], the determination of inter-floor displacement should not exceed the level of permits inter-floor, which is $0.020 \times h_{xs}$, where h_{xs} is the height of the house. Since the height of the house is 600 cm, inter-floor displacement of permit for all other structures has inter-floor displacement permits for earthquake risk category I or II is $0.020 \times 600 \text{ cm} = 12 \text{ cm}$. Based on the calculation of ETABS analysis, the highest part of the coconut timber house obtained a displacement about 7.0981 cm.

This maximum value obtained from the simulation shows that the displacement occurred in construction did not expose the safety limits. It means that the construction is safe under earthquake load. Figure 5. Displacement mode due to earthquake load acting on the frame structure of coconut- timber house (generated with ETABS) 3.3. Construction method of a Traditional Wooden House Prototype The final outcome of this research is a 6 m x 6 m coconut-timber house prototype.

The construction of this prototype was based on the results of the model design and the dimensions of the structural elements calculated previously. Figure 6 shows the construction process of the earthquake-resistant coconut-timber house prototype. Figure 6. The progress of construction process of the earthquake-resistant coconut-timber house prototype: (A) 10%; (B) 20%; (C) 30%; (D) 60%; (E) 80%; (F) 100% The construction of timber houses follows the principle of building strength and characteristic of coco-wood as the main material. All structural components were prefabricated and assembled with fitted wood joints by carpenter.

The construction methods were divided into three parts: substructure (foundation), main structure (beam, column, floor, and wall), and upper structure (roof). The foundation was made by concrete. Its height is about 50 cm from the ground to avoid termite and decaying by groundwater. The height of the main structure is 300 cm. The floors consist of thick transverse wood boards, which are supported by horizontal beams. Walls are

made of timber panels. The roof of the house has corrugated iron sheet attached to a timber truss frame. The house covers a total area of 36 m² with additional 36 m² of space below. The space under the house is utilized for various activities including relaxation and storage.

4. Conclusions It can be concluded that coconut wood can be used as structural construction timber according to the categories of wood strength classification in SNI 03-3527-1994. The testing result of the air-dry density characteristic indicated that the coconut-wood strength is in the range of strength class I and II. Therefore, the calculation of load is required in terms to determine the structural members. Design and analysis of the structural members for the wooden house were performed in accordance with standards, design principles, and guidelines by considering earthquake load.

In addition, the house design and construction has been developed in considering the characteristic of Minahasa culture. Performance of the traditional coconut-wood house structural elements is done by simulation of the structural model in ETABS. Based on the calculation of ETABS analysis, the highest part of the coconut timber house obtained a displacement about 7.0981 cm. This maximum value obtained from the simulation shows that the construction is safe under earthquake load. Then, the construction of the coco-wood house prototype was build based on the results of model design and structural analysis.

These findings confirm that the local coconut-timber waste from unproductive coconut trees can be used as a construction material to build earthquake-resistant timber houses. Therefore, these research results are expected to support the local economy's empowerment by utilizing potential sustainable local natural resources. References [1] Sodangi M and Kazmi Z A, 2020 Integrated Evaluation of the Impediments to the Adoption of Coconut Palm Wood as a Sustainable Material for Building Construction Sustainability 12, 18 p. 7676.

[2] Mitterpach J and Štefko J, 2016 An Environmental Impact of a Wooden and Brick House by the LCA Method Key Eng. Mater. 688 p. 204-209. [3] Hildebrandt J Hagemann N and Thrän D, 2017 The contribution of wood-based construction materials for leveraging a low carbon building sector in europe Sustain. Cities Soc. 34 p. 405- 418. [4] Gerilla G P Teknomo K and Hokao K, 2007 An environmental assessment of wood and steel reinforced concrete housing construction Build. Environ. 42, x p. 2778-2784.

[5] Tsai M T and Wonodihardjo A S, 2018 Achieving sustainability of traditional wooden houses in Indonesia by utilization of cost-efficient waste-wood composite Sustainability 10 p. 1718. [6] Ramage M H et al., 2017 The wood from the trees: The use of timber in

construction Renew. Sustain. Energy Rev. 68, October 2016 p. 333-359. [7] Rumbayan R and Rumbayan M, 2019 A Study on The Utilization of Local Coconut Timber Waste as Sustainable Building Material in Proceeding of 5th International Exchange and Innovation Conference on Engineering & Sciences (IEICES) p. 1-3.

[8] Rumbayan, R.; Taju, D.; Mait R, 2018, THE FUTURE OF ASIA?: Toward the Future of Asia?: My Proposal ??????, (The Japan Times, Ltd), p. 185-190. [9] Sudarna N S, 1990 Anatomi Batang Kelapa (Cocos Nucifera L.) J. Penelit. Has. Hutan (Forest Prod. Res. Journal) 7, 3 p. 111-117. [10] Rahayu I S, 2001, Sifat Dasar Vascular Bundle dan Parenkim Batang Kelapa Sawit Dalam Kaitannya dengan Sifat Fisis, Mekanis serta Keawetan, Insitut Pertanian Bogor (IPB). [11] ASTM D143-14, 2014 Standard Test Methods for Small Clear Specimens of Timber West Conshohocken, PA: ASTM International. [12] SNI 03-3527-1994, Mutu Kayu Bangunan National Standardization Agency of Indonesia.

[13] Nasution I N Alvan S and Winata H A, 2019 Analysis of earthquake structure on a traditional IOP Conf. Series: Earth and Environmental Science 739 (2021) 012032 doi:10.1088/1755-1315/739/1/012032 wooden house of Mandailing IOP Conf. Ser. Mater. Sci. Eng. 615, 1 p. 012079. [14] Rangkang J Sondakh F and Saerang E J, 2016 Karakteristik Kayu Kelapa di Berbagai Zona di Indonesia Timur Berdasarkan Sifat Fisis dan Mekanisnya J. Tek. Sipil 23, 2 p. 89-98. SNI 1726:2012, Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Non Gedung National Standardization Agency of Indonesia.

INTERNET SOURCES:

1% - jglobal.jst.go.jp > en > detail
2% - ui.adsabs.harvard.edu > abs > 2021E&ES
6% - iopscience.iop.org > article > 10
<1% - iopscience.iop.org > 1755/1315/739-1 > 012032
1% - www.researchgate.net > publication > 312491602_An
<1% - www.thomasnet.com > articles > other
<1% - www.fao.org > in-action > restoring-coconut-farmers
4% - www.researchgate.net > publication > 356713394_The
1% - www.researchgate.net > publication > 361432600_The
1% - www.researchgate.net > figure > Strength
<1% - quizlet.com > 13990447 > the-product-design-process
<1% - ui.adsabs.harvard.edu > abs > 2019MS&E
1% - www.scribd.com > document > 28334325

<1% - www.nature.com › articles › s41598/021/03524-0
1% - www.researchgate.net › figure › Result-of-the
<1% - studentlesson.com › etabs-structural-software-for
<1% - www.researchgate.net › figure › Displacement-values
1% - www.researchgate.net › figure › Displacement-mode
1% - www.researchgate.net › figure › The-progress-of
<1% - www.nilaeslit.com › coconut-wood-a-viable-source
1% - www.mdpi.com › 2071/1050/12-18 › 7676
1% - sci-hub.se › 10 › j
1% - en.ad.ntust.edu.tw › meng-ting-tsai-2
<1% - www.semanticscholar.org › paper › The-wood-from-the
<1% - standards.globalspec.com › std › 3854285
1% - www.ijcaonline.org › archives › volume177