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Material Relationship with Nias House Structural System in Response to Earthquake

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Abstract*—Nias Island is located on plates that collide with each other so it is very vulnerable to earthquakes. This is what makes the Nias community built so that they can adapt to the environment by utilizing wood materials in the structural system of the house. This study aims to determine the pattern of loading on Nias houses, as well as the placement of wood types in the composition of the structural elements of the house. This is to answer the formulation of the research problem, namely how is the relationship between the material and the structural system of the house to respond to the earthquake problem. The research was conducted by collecting data from journals and other sources, and making models from the data obtained. Then the data obtained were analyzed quantitatively by comparing the specifications of the wood to its placement in the structure of the house. The placement of the type of wood on the Nias house structure depends on the strength and durability of the wood, the higher the grade of wood, the wood is used as the main structure of the house and in the foundation of the house.*

Keywords: *Nias house; earthquake; wood type; structural system; loading*

I. Introduction

Indonesia has more than 1700 islands with various cultures, customs, characters, languages, behaviors, and history (Septiano, 2014). The form of diversity is reflected in his architectural works. Architectural works in each region vary. Because, the work is the result of a combination of the situation and condition of the location with the identity of a society that has values, culture, images, concepts, characters, and habits. Thus the situation and condition of each region will not be the same because it is influenced by topography, customs, and history factors. (Torabi & Brahman, 2013).

Topography is the most difficult factor in the formation of houses in Nias (Afif, 2010). Nias is located on the Eurasian plate and collides with the India-Australia plate. The impact caused periodic earthquakes in Nias (Mustafa, 2010). Earthquake disasters that occur continuously cause efforts from the community to adapt, especially in the architecture. Nias houses (architecture) that adapt to their environment with local technology and knowledge are known as Nias vernacular houses (Septianto, 2014).

There are several models of Nias vernacular houses, houses of North Nias, Central Nias, and South Nias. All three have different shapes but have similarities in the outline structure of the building. Several challenges were encountered by the people of Nias to build houses in response to earthquake-prone areas. Starting from material knowledge, surrounding natural resources, installation of certain materials, and their strength. However, earthquakes in Nias often occur on a large scale, for example in 1797 an earthquake of up to 8.5 magnitude occurred, after that from 1977 to 2022 an earthquake was recorded at least once a year with a magnitude of 5.5 to 7.6 magnitude (Mustafa, 2010; Armani, 2022; Hatta 2022). Interestingly, these vernacular houses have succeeded in maintaining their existence (Lestari, 2021). Therefore, in this study, researchers want to know more about what and how the material arrangement in the structural system of Nias vernacular houses is. How is the loading pattern for Nias vernacular houses and what is the role of materials in solving the earthquake problem in Nias vernacular houses. That way, the architects can find out more about the loading pattern of Nias vernacular houses, what materials are used and how they are placed in the structural system to solve the earthquake problem in Nias vernacular houses.

II. Literature Review

Nias House and Earthquake

Nias Traditional House is an archipelago traditional house located in the Nias archipelago. Located between 0º 12”-1º 32” North Latitude and 97º--98º East Longitude, Nias Island stands on plates that collide with each other so that tectonic potential arises such as earthquakes that often occur in Nias (figure 1a) (Intan & Nasruddin, 2018). Nias traditional houses are divided into three regions, North Nias, Central Nias, and South Nias, each of which has its own uniqueness and differences in the form and structural system it uses to adapt and respond to earthquake conditions that often occur in Nias (figure 1 b ,CD).

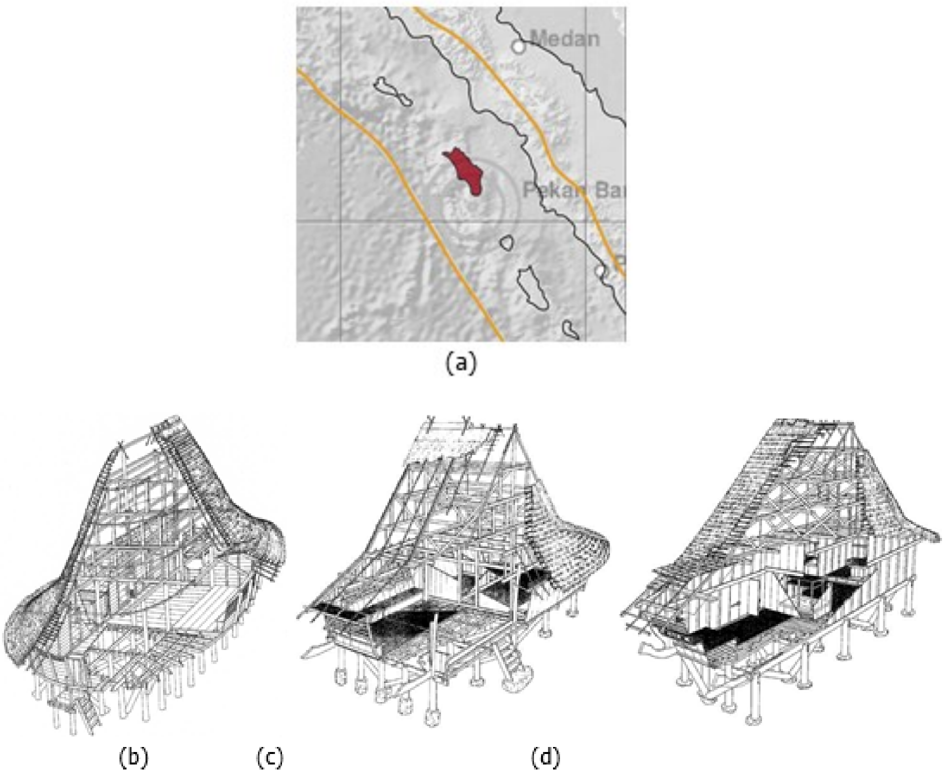

Figure 1. (a) Position of Nias island against the plate (Source: Redrawn from BMKG), (b) North Nias House, (c) Central Nias House, (d) South Nias House (Source: Viaro, 2008)

Nias House Structure

Nias houses are divided into three layers, the lower layer is the building's foundation, the middle layer is the supporting structure for the house, and the upper layer is the roof of the house (Prasetyo, 2014). In each layer there are several types of structural elements that make up the structure of Nias houses in response to the earthquake. This arrangement can be seen in the isometry depicted in figure 2. Each structural element is arranged with local materials with the appropriate number code as attached in table 1-3 (Prasetyo, 2013).

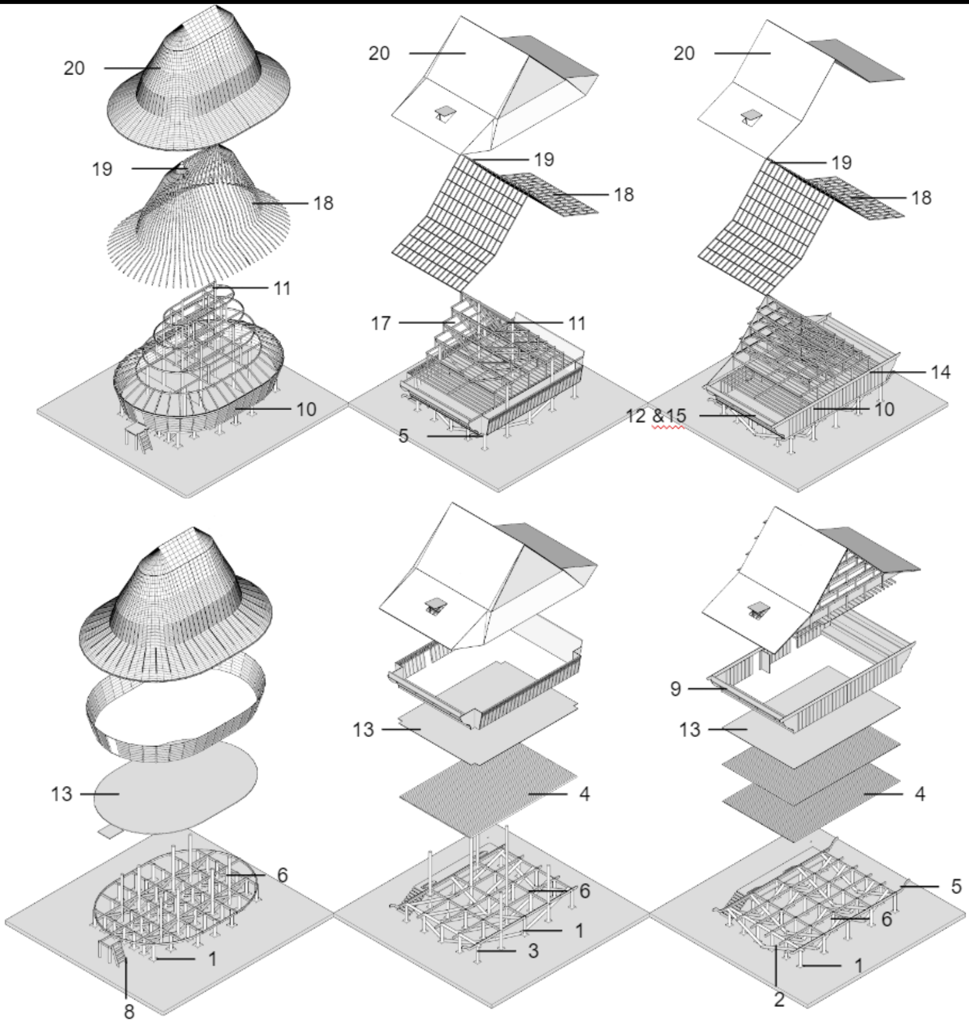

Figure 2. Isometry of North, Central, South Nias Houses
Source: Author, drawn based on Viaro (2008)

Table 1. Structural components of the sublayer/foundation

No.	Structural Components	Description
1	Gehomo Stone / Ndriwa Stone	Square-shaped stone
2	Ndriwa	Diagonal beams that serve as pillars (round)
3	Ehomo	Vertical beam that serves as a support for the main pillar
4	Lali'owo	Longitudinal beams support the floorboard
5	Sikholi	Thick boards that clamp the floor structure on the right and left sides of the building.
6	Siloto	Transverse beam that serves to support the floorboard
7	sirau	Supports/horses/bridges
8	Nora	Staircase
9	Toga/Balo-Balo	Transverse beams covering the ends of lali'owo

Source: Prasetyo, 2013

Table 2. Structural components of the middle layer/support structure

No.	Structural Components	Description
10	Bagolo	Wooden boards used for house walls
11	Ehomo Mbumbu	Pillars made of round wooden poles that serve as roof supports
12	Fafa Daro-Daro	The wooden plank used as a seat
13	Fafa Gahembato	Wooden planks as the floor of the house
14	Lago-Lago	Thick wooden planks located on the right and left sides of the house to clamp the entire structure under the roof of the southern Nias house
15	Tata Daro-Daro	A wooden board that serves as a seat

Table 3. Structural components of the top layer/roof

No.	Structural Components	Description
16	Gaso/Gaso Matua (Fanimba)	Wooden beams that function as roof trusses for southern Nias houses
17	Lasso	Wooden beams that function to form the roof structure of the southern Nias house
18	Bamboo Clamp	A wooden clamp that serves to hold the roof covering arranged in an X . formation
19	Capita	Horizontal structure that serves as a roof support
20	Sago	Thatched roof/thatched leaves

Source: Prasetyo, 2013

As written in the table above, almost all parts of the Nias house structure, from the lower, middle, to upper structural components, use wood. North Nias, Central Nias, and South Nias, the three areas are located on the same island, so the existing trees on the island as a source of wood material have similarities for the three areas. The types of wood used are Berua wood (Mersawa wood), Manawa Dano wood (Laban wood), Afoa wood (Medang wood), and Simalambuo wood (Meranti Putih wood). Each wood has different characteristics, in terms of strength class and durable class. The categorization of wood classes can affect the placement of wood types in the structural layer of the house which has its own role in the distribution of gravity and lateral loads of the house. For example, the walls of South Nias houses are structural walls, while North Nias walls are non-structural walls, so the types of wood used on the two walls have different characters and functions according to their respective needs (Prasetyo, 2013).

Wood Grade Category

Basically, wood has several mechanical properties such as compressive strength, shear strength, tensile strength, hardness and flexural properties of wood which are considered in the selection of wood material as a building structure material. So to find out the category of wood, wood is divided based on several properties. First, wood is classified according to the strength of the wood. The strength of wood is seen from the flexural strength and compressive strength of wood in an air dry state. Usually the stronger the wood, the greater the specific gravity. The category of wood strength class according to the Indonesian Timber Construction Regulation (PKKI) in 1961 is divided into 5 classes in terms of wood specific gravity. This specific gravity can also be seen from the classification of absolute bending stress (kg/cm3) and absolute stress stress (kg/cm3).

Finally, wood is classified based on the durability of wood from the influence of moisture, termites/other insects, climate (to water and sunlight), and the treatment of wood in construction. Based on the Indonesian Timber Construction Regulation (1961), the durability of wood is classified into 5 classes, distinguished by the nature of the use of the wood. These properties are judged by how they are always in contact with moist soil, only influenced by the weather, but still kept from being submerged in water and not lacking in air, located under the roof, not in contact with moist soil and not lacking in air, located under the roof, not in contact with moist soil and no lack of air, and well maintained and regularly painted, Subterranean termite attack, and sawdust attack.

III. Methods

The data collection method used in this study is through data from the literature and other sources, as well as modeling. The data referred to include maps, photos, sketches, and other written information that can sharpen information about Nias Houses. Then the data is compared with each other so that it can obtain correct information and be able to become a research reference. Modeling is done based on data information that has been found previously, so that it can be used for further analysis tools.

The method of data analysis in this study was carried out quantitatively. This stage begins by analyzing the materials used in each Nias House, related to its strength and location on the building. Then, through the model that has been made, an analysis of the loading pattern is carried out. This was done to see how the pattern of laying materials on the Nias House responded to the earthquake.

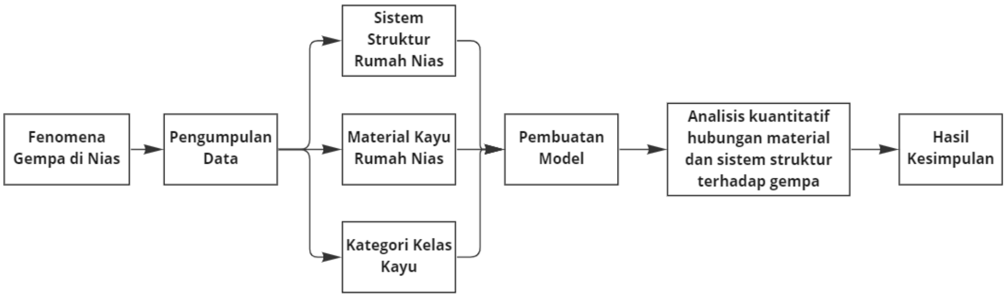

Figure 3. Research framework
Source: Author

IV. Results and Discussion

Following are the results of linking wood materials and their class categories with their use in the Nias house structure system (table 4).

Table 4. Comparison of wood species to wood class categories and their placement

House Structure	Structural Elements	Wood Name	Specific gravity	Strong Class	Durable Class	Laying	Reference
Undercoat/ Foundation	Piling	Gehomo Stone (River stone)	-	-	-	Wooden column support (ehomo), keeping ground water from seeping into the wooden column (ehomo)	Prasetyo (2013)
		Ndriwa Stone (River stone)	-	-	-	Diagonal foundations associated with diagonal columns (driwa)	Prasetyo (2013)
	Floor	Berua Wood (Mersawa)	0.68	II-III	IV	Sitting boards, floor structures (floor boards, laliowo, siloto)	Prasetyo (2013), Zebua (2008), Rumah.com (2020)
		Manawa Dano Wood (Laban)	0.93	I	I-II	Sitting boards, floor structures (floor boards, laliowo, siloto)	Prasetyo (2013), Juniawan, et al. (2015)
Middle Layer/ Supporting Structure	Columns and Beams	Simalambuo Wood (White Meranti)	0.63	II-III	III	The pillars of South Nias	Prasetyo (2013), Putra, et al. (2014)
		Berua Wood (Mersawa)	0.68	II-III	IV	Stairs, ehomo columns, beams, diagonal structures (ndriwa)	Prasetyo (2013), Zebua (2008), Rumah.com (2020)
		Manawa Dano Wood (Laban)	0.93	I	I-II	Ehomo columns, beams, diagonal structures (ndriwa), pillars supporting North Nias & Central Nias	Prasetyo (2013), Juniawan, et al. (2015)
	Wall / Exterior Cover	Berua Wood (Mersawa)	0.68	II-III	IV	Horizontally arranged wooden planks (South Nias)	Prasetyo (2013), Zebua (2008), Rumah.com (2020)
		Manawa Dano Wood (Laban)	0.93	I	I-II	Wooden planks arranged horizontally / slightly tilted (South Nias)	Prasetyo (2013), Juniawan, et al. (2015)
Top Layer/ Roof	Roof truss	Afoa Wood (Medang)	0.83	II-III	II-V	Roof truss structure	Prasetyo (2013), KLHK (nd)

Source: Data processing

To get an idea of how Nias houses responded to the earthquake through their structural elements, an analysis was carried out on the distribution of gravity and lateral loads on each vernacular house in Nias. Distribution of the gravity load is carried through the columns and beams. While the distribution of lateral loads (earthquake) is held by diagonal columns that act as *bracing* . When an earthquake occurs, the diagonal column receives tensile and compressive forces to hold the building structure stable and intact when shaken. Illustrations of loading patterns on each layer of Nias houses are shown in Figures 4a,b,c.

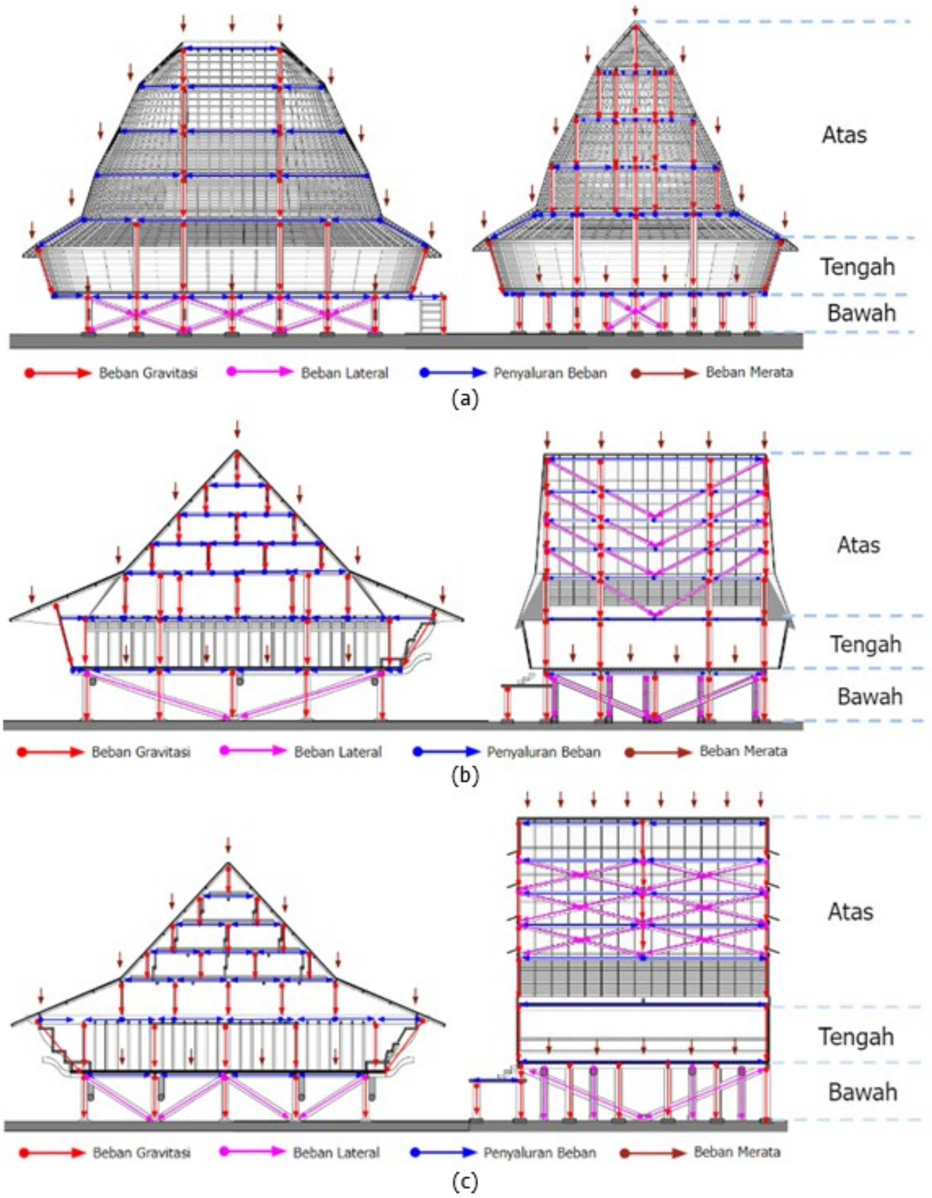

Figure 4 (a) Graph of House Loading in North Nias, (b) Graph of Loading for Central Nias Houses, (b) Graph of Loading for South Nias Houses
Source: Author, drawn based on Viaro (2008)

Based on the results obtained above, it was found that the type of wood with its strength class is directly proportional to the specific gravity of the wood, the stronger the wood, the greater the specific gravity. The strongest types of wood (Manawa dano wood and Berua wood), are widely used in the underlays/foundations of houses. It can be seen from the number and dimensions of the diagonal columns in the foundation layer of each house, the house foundation plays the biggest role in the house's resistance to earthquakes, so wood with a higher density is placed at the bottom to withstand the greatest lateral loads as well as gravity. Likewise with the wood durability class, the higher the wood durability class, the more wood is used as the main structural material (Berua wood, Manawa Dano wood, Simalambuo wood). Berua wood is used when Manawa Dano wood is not available, so its nature is as a substitute. Although Berua wood is classified as durable class IV, it can still be used as a structural material due to the geographical condition of the Nias House which is located in the mountains so that the wood is rarely exposed to rainwater puddles and the wood is also not planted in the ground and does not stick directly to the ground because there are pedestal stones. , so the wood can still last long enough.

Simalambuo wood has a strong class II-III (medium). In North Nias and Central Nias houses, Manawa dano wood is used as the main pillar of the house (ehomo mbumbu) which is large in size, consisting of 4 main pillars (figures 4a and 4b). Meanwhile, the South Nias house does not use truss, but a structural wall made of Simalambuo wood.

Because Simalambuo wood is not as strong as Manawa dano wood, this wood, with smaller dimensions but with a larger number of structures, acts as a support for houses in the structural walls of South Nias (figure 4c). The middle structure/support plays a role in supporting the roof to stand up, so that the middle structure also withstands gravity and lateral loads but is not as large as the load received by the foundation. In addition, Simalambuo wood has a class III level of durability, but because of the characteristics of Simalambuo wood, which is strong and hard, it is also known as termite-resistant wood (Rumah.com, 2020). In contrast to South Nias, the walls of houses in North Nias and South Nias are non-structural, so the wood material used is Afoa wood with a lower strength class (specific gravity).

Then for the roof structure of the three types of Nias houses, a type of wood with a lower strength class is used, namely Afoa wood. Because the roofs of Nias houses withstand the least gravity and lateral loads, lighter wood types, smaller dimensions, but in larger quantities are used. Afoa wood functions as a roof truss material that supports the load of the roof covering (thatch leaves) and functions as a storage area for goods in the roof layer of the house. Afoa wood has a lighter density than Manawa dano wood, but its strength is still strong enough (class II-III) so that Afoa wood can still be used as a construction material that can withstand gravity and lateral loads from earthquakes or wind. In addition, Afoa wood has the lowest durable class (durability class III-V), therefore the use of Afoa wood is located at the top (roof) where the environmental conditions are less humid and there is no lack of air.

V. Conclusion

The results of the study concluded that the strength class and wood durability class influenced the placement of wood species on the Nias house structure system in response to the earthquake. Types of wood with a strong class and high durability class such as Manawa dano wood, Berua wood, and Simalambuo wood are used as the main structural system material and are placed on the foundation layer or the middle layer of the house, because these woods support the largest gravity and lateral loads. Wood with a strong class and low durability class is used as a roof truss material because it supports lighter gravity and lateral loads with less humid environmental conditions and there is no shortage of air for the wood material.

This study further analyzes the placement of wood species in the Nias house structure system which has not been found in previous studies. By studying the strength class and wood durability class, the study obtained more objective results in the relationship between the material and the structural system of the house on the issue of earthquakes. This means that the people of Nias have paid attention to the characteristics of the wood that are suitable for each element found in Nias houses. However, this research still has shortcomings because the methods used are only limited through literature studies. For further research, it is hoped that laboratory tests can be carried out on the strength and durability of each type of wood used in Nias houses.

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