The Existence of Stilt Houses Post-Disaster

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Abstract. Stilt houses are one of the architectural identities of the archipelago that are still commonly found in Indonesia. Stilt houses have proven to be sustainable products because they still exist today after going through various natural disasters. This is inseparable from the stilts house building techniques, including the process of finding and determining the form and implementation of adat (philosophy). So, this research aims to show the existence of post-disaster stilt houses which include tsunami disasters in Aceh and Palu. This research is a case study that uses a comparative analysis method to show the influence factors of the existence of stilt houses after disaster in Aceh dan Palu. Based on the results of the study, it is known that the stilt houses in Aceh and Palu have stilt buildings that are sturdy and stable in accepting the force load when a disaster occurs. The key of building sturdiness lies on building structures such as connection systems, foundation type, material type, and the buildings proportion. These factors caused the stilts houses to not suffer severe damage, and in some cases did not show any damage to the buildings after being affected by natural disasters.

Keywords: Stilt house; disaster; building structures; Aceh; Palu

1. Introduction

Indonesia is an area located on the Pacific Ring of Fire, which is an area with a lot of tectonic activity. So, Indonesia continues to face the risk of volcanic eruptions, earthquakes, floods, and tsunami. In several incidents during the last 20 years, Indonesia made headlines in the world because of its terrible natural disasters that have caused millions of people and animals were dead, as well as destroying its land area, including a lot of infrastructures, and resulting in economic losses. Natural disasters are the most terrible events on earth because they cannot be predicted. Natural disasters can have a major effect on human life, can destroy the infrastructure of a city, and claim many lives, such as the Aceh earthquake and tsunami in 2004 and Palu in 2018. The location of Indonesia is at the junction of three earth plates that are constantly pushing and rubbing against each other. The more plates can be complicated and dangerous the fault is. This fault is the source of the earthquake. Earthquake energy from faults is not as big as earthquakes generated by collisions between plates. However, the dangers cannot be taken lightly because many of the faults are located right underneath the city, under people’s houses.

Facing this situation, the archipelago people have long been trying to mitigate disasters by building earthquake-resistant traditional houses. One of the major earthquake events that occurred was in Minahasa in 1845 which damaged thousands of houses. After this incident, the Minahasa people started building houses with designs that minimize damage in the event of a similar disaster. Since this incident, people’s houses have been built in small sizes, the poles are shortened and reduced and the frames of the houses are made in such a way so that they do not collapse easily.
The concept of a stilt house will be helping release earthquake energy so it doesn't hit the floor of the building directly. Damage and safety threats to residents can be smaller. This underlies the implementation of this research, to identify and recognize the concept of a stilt house and to know how it can survive and remain strong until now from the attacks of natural disasters, especially in the major tsunami disasters that occurred in Aceh and Palu.

2. Method
This research using the case study method, which is a research strategy, an empirical study that investigates a phenomenon in a real-life setting. The study locations chosen were the post-tsunami areas in Aceh and Palu. Research data were collected from various sources such as relevant previous research studies and the results of their observations. The data collected from the results of the investigation at the two locations were then compared to get conclusions about the concept of a stilt house (the criteria for the robustness of a building) that could withstand natural disasters. The variables studied were the stilts house which included the construction system, materials, and dimensions.

3. Result and discussion
The results of this study explain the condition of traditional buildings (adat) that survive after natural disasters. The description is done separately.
3.1. The existence of stilt house in Aceh
The tsunami occurred on 26 December 2004 in Aceh. The tsunami triggered by an earthquake measuring 9.3 SR occurred at a depth of 30 km below the seabed and 100 km from the west coast of Aceh. The earthquake caused a tsunami wave as high as 9 meters which then swept across Aceh. This disaster killed more than 220 thousand people in Indonesia. This incident also caused casualties to areas in Peninsular Malaysia, Thailand, India, Sri Lanka, and the East coast of Africa. The Aceh Earthquake and Tsunami was the most devastating natural disaster with the largest number of casualties in Indonesian history. Now, Aceh has risen and built several places to remember this incident and provide lessons to the community.

Aceh is one of the areas most affected by earthquakes. Efforts to reduce the impact of disaster risk have been carried out by the community in ancient times. One of them is by building wooden houses that are not easily collapsed. One of the buildings that have survived is the type of stilts house. Where the roofing material is made of thatch leaves (but currently many are using zinc as roof coverings - see Figure 3) and several poles support the existence of the house. In addition, there are stairs to enter the house which are placed under the front.

The process of making this house-shaped on stilts entirely uses woods. In terms of construction, the placement of house poles led to the division of Aceh house space generally consisting of three pillar rooms, 16 or five pillar rooms 24. The wood used to make the house uses seumantok wood, the best type of wood in Aceh. This is one reason Aceh houses could last for hundreds of years. on the other hand, the construction is intertwined, the pillars of ordinary houses are made of sturdy wood, while the floors and pillars of Acehnese houses are also of wood. To tighten the wood, the Acehnese ancestors did not use nails, iron, or concrete. But the wood is hollow, chiseled, and then given a hook. This interlocking technique has its purpose. One of them is to reduce vibration. By using a construction like this, Aceh's house is resistant to shaking and does not collapse easily due to earthquakes.

Earthquake disaster mitigation efforts have been applied for a long time in Aceh. However, along with the times, there are changes in lifestyle and needs so that most residents have moved and adapted to modern times by building permanent houses (stone houses). However, not a few of them were aware of the natural conditions in Aceh which was prone and surrounded by an earthquake that had the potential for a tsunami, so they continued to build and maintain wooden houses or stilts houses.
Rumoh Aceh is one of traditional Acehnese houses which has several constituent elements. Each of the elements that make up the Rumoh Aceh also has a distinctive name and philosophical meaning that is no less interesting. Here are some elements of traditional Acehnese houses and their philosophical meanings:

1. *Tameh*: a pole used as a support for the body of the house. This element is motivated by a typical Acehnese proverb, “Kreuh beu beutoi kreuh, beulagee kreuh kayee jeut keu tameh rumoh; Leumoh beu beutoi leumoh, beulagee taloe seunikat bubông rumoh” (If it is hard, it must be as hard as the wood supporting the house; if it is flexible, it must be as flexible as the ropes for the roof of the house). The Acehnese philosophy of life in this regard is to be firm, but still soft-hearted.

2. *Tameh raja*: the king’s pillar, the main pillar on the right side of the entrance. Called the king’s pillar because of its size which is larger than some of the ordinary constituent pillars used.

3. *Tameh putroe*: the princess pole, which is the main pillar on the left side of the entrance. The princess pole is a pair of the king’s pole. Called the pillar of the princess because of its position side by side with the pillar of the king.

4. *Gaki tameh*: pillar legs, i.e. baseboards, usually of river stone. This pedestal serves to support the wooden posts so they don't sink into the ground.

5. *Rok*: ordinary locking beam. Its nature is to strengthen the relationship between the ends of each beam.
6. **Thoi**: locking beam that is perpendicular to the **Rok**.
7. **Peulangan**: where the inner wall (interior) rests.
8. **Kindang**: the place where the outer (exterior) wall rests.
9. **Aleue**: floor, made of small slatted boards.
10. **Rante aleue**: floor fasteners usually made of rattan or rope.
11. **Lhue**: truss beam for floor support.
12. **Neudhuek lhue**: the place where lhue rests.
13. **Binteh**: wall.
14. **Binteh cato**: chess wall, a form of wall braid.
15. **Boh pisang**: a small board on top of a kindang.
16. **Tingkap**: window. The windows of Aceh houses are made small. The main window is on the side of the house.
17. **Pinto**: door.
18. **Rungka**: roof truss.
19. **Tuleueng rueng**: wuwung beam, where the rafters rest on the top end. These beams are made of light wood so as not to burden the roof.
20. **Gaseue gantong**: the legs of the horses.
21. **Puteng tameh**: the end of the chiseled pole, as a beam connector.
22. **Taloe pawai**: roof ties tied to the end of the **Bui teungeut**.
23. **Bui teungeut**: pieces of wood to hold the **neudhuek gaseue**.
24. **Tulak angen**: reject the wind, the cavity where the wind passes on the side wall of a triangular house

**Figure 6.** Floor plan of Rumoh Aceh
The open pillars of Aceh's houses have an important role in flood and tsunami disaster mitigation. This is because water can escape without any obstacles, thus Rumoh Aceh is safe from the threat of disaster. Several locations after the earthquake and tsunami disaster have also shown the robustness of traditional Aceh house buildings that have survived the threat of this disaster. Based on previous research studies, to prove Aceh's houses are earthquake resistant, laboratory tests were carried out through small miniatures and calculations of the SAP 2000 program. Widosari (2010) in his scientific journal "Maintaining Local Wisdom Rumoh Aceh in the Dynamics of Community Life After the Earthquake and Tsunami", reviews the toughness of the Aceh house. Based on these trials, the results obtained were that the Aceh house was proven to be able to withstand earthquakes because the main structure was strong and elastic. The key to this robustness and elasticity lies in the relationship between the main structures which interlock, only with pins, without nails, and form a rigid three-dimensional. Elasticity causes the building structure not to break easily, but only tossed from side to side and then back upright or liquefied (lifted) then able to back to its original place. When an earthquake occurs, even if the building moves, it is only about a few centimeters and is intact. A solid stone foundation that is only planted a little by five centimeters also flexes the movement of the entire building according to the movement of the ground.

So it can be concluded that three main structural components are central to the robustness of the building including the foundation (leg component) as the largest center of the building's load, then the poles and beams between the poles (body components) as load carriers from above and from the side, and the roof frame (component head) as a load support element at the top of the building and from the top side. There are at least two things that make Aceh's house strong and safe from disasters. First the poles, ornaments/carvings, and roofs. When the tsunami hit Aceh, the flood could pass through traditional Acehnese buildings under the house, where the poles stand, the body of the house through carvings of house ornaments, and the top of the house, namely the roof of the house facing the sea. Meanwhile, fibers and pegs also have an important role. Each of the parts that make up traditional Acehnese houses is connected by continuous connections and reinforced with fibers and pegs without nails. This makes the house flexible (flexible and not rigid) that it can follow the direction of the earthquake movement. Each part supports the other to defend its construction against earthquake shocks.

Besides, even the traditional Acehnese houses do not use iron nails or any materials that can make the house heavy. The ends of each beam are joined with dowels and then reinforced with each other by chiseling and holes. In addition, the number of pillars supporting Rumoh Aceh is also large. So that these components can make the house stronger. Even to withstand earthquakes, the poles used are selected from solid wood. Not only that, the position of the pole is also arranged not too tightly. This is very useful to provide space for water currents to pass under the house more freely. So that this traditional Acehnese house is very safe and planned to anticipate flooding.

3.2. The existence of stilts house in Palu

Palu is the capital city of Central Sulawesi Province, Indonesia. Palu is a city located in Central Sulawesi, bordering Donggala Regency on the west and north, Sigi Regency in the south, and Parigi Moutong Regency in the east (Wikipedia, 2020). The people of Palu had already lived with earthquakes. Therefore the local culture has also reflected efforts to anticipate when a disaster occurs, including in designing buildings. The building model that is considered to be able to withstand a disaster is a stilts house. This stage model has various functions. One of them is to prevent wild animals from entering the house. For public buildings, the stage under the house can be used as a rest area. People also often use it as an animal enclosure.
The design of the stilts house in Palu has the advantage of being able to withstand floods and tsunami. However, the waves come are not as body highest of the building or above two meters from the ground floor. The house is also able to withstand a tsunami if the incoming water does not carry a large amount of debris. The house will be destroyed when large debris carried by the wave hits the legs of the building. After the tsunami hit Palu in 2018, most of the traditional houses of Central Sulawesi were still standing, even though the buildings on the left and right were damaged, and flattened to the ground.

One of the stilts houses that has survived and is still standing strong until now after being hit by the earthquake and tsunami in Palu is Banua Mbaso. This house was founded about 115 years ago, measuring 32 x 11.5 m, and was built by King Palu Jodjokodi around 1892, and is the residence of the King and his family and functioned as the center of the royal government at that time. This house on stilts is a combination of Bugis (South Sulawesi) and South Kalimantan-style architecture, which has 36 pillars of the main house and gandaria (terrace) including 8 kitchen poles.

The proportion of height between the three parts is as follows:
- The height of the foot is 2.4 m, lower than the middle at 2.88 m.
- The upper part is bigger in proportion, that is, the height from the attic to the top of the roof ridge is about 3.59 m.

In structural system of Banua Mbaso, there are:
1. The connection between the main floor beam and the main pillar of Banua Mbaso, the functions of the pole position not shifting.
2. The connection between the *pelangga*, *evanga*, and the Banua Mbaso pole. These beams are floor beams that are fixed longitudinally or crossed with the main beam (*evanga*/*pareva*) making them stronger, the support beams are notched at the part where they meet the main beam.

3. *Sobo* / *tau-tau* and floor. In the Banua Mbaso house, the floor is made of ironwood with a width of between 12-15 cm and a thickness of 3 cm, the length dimensions follow the pole intersection and support beams, except for Gandaria, Pakuntu, and Avu floors.

4. Connection of attic main beam and main pillar of Banua Mbaso. The roof beam is mounted in a transverse position, its position is adjusted to the hole in the vumbu. *Ulu avu* extends from the front of the Banua Mbaso roof to the back of the main house.

5. Roof. The joints in the truss generally use a grooved tongue with reinforcement with round pins or pins.
Apart from tsunami waves, traditional houses are also safe against earthquakes of a certain scale. The materials used are generally natural ingredients. Materials affect the structural strength of a building against shocks. In traditional buildings, generally using wood which has better flexural strength than concrete material. Wood is known for its flexural power, while concrete is very rigid. The material used is also selected or the highest quality wood. In addition, bonding the beams between the logs uses pins and ties, more flexible when hit by shocks. Almost all types of houses on stilts use stone as a reinforcing structure for the foundation.

4. Conclusion
This research is not a new research anymore, but this research provides reinforcement to previous studies which stated that stilt houses are a type of house that can withstand natural disasters, such as earthquakes and even tsunamis. This is also evidenced by houses on stilts in Aceh and Palu after being hit by the earthquake and tsunami. The structure of the stilts house has been proven to be a type of building that withstands natural disasters such as earthquakes and even tsunami. The existence of under the floor creates a space to release vibration energy from the ground only a small part propagates to the physical house. Stilts house is built directly attached to the ground without a stage will receive energy directly from the earthquake so it is riskier than a stilts house. Earthquake vibration energy will directly propagate through the foundation of the building roof. Stilts house tradition has been owned by Indonesian people for a long time and is one form of how the community can withstand disasters. Houses made of wood, rattan, or bamboo are more flexible with vibrations thus minimizing damage and loss of life. This was seen in the two research locations in Aceh and Palu during the earthquake and tsunami, which made stilts house able to withstand tens of times when hit by an earthquake in a short period. The key lies in the strength of the building structure, the existence of a stilts house still exists even though it has been hit by a large-scale natural disaster.

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