Distinctive Structural Systems of Vernacular Houses: Insights into the Architectural Tectonics of Lamban Balakh in Pekon Hujung, West Lampung, Indonesia

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Abstract

Lamban Balakh, a traditional house in Indonesia shows how rich the cultural heritage and environmental adaptation. Traditional houses designed to adapt to the surrounding natural conditions, including earthquakes, use local materials and construction techniques that have proven effective over time. Despite its ability to withstand earthquake shocks, as demonstrated during the Liwa earthquakes of 1933 and 1994, there is still a limited in-depth understanding of the unique structural system of the *Lamban Balakh* building.

This study aims to explain the unique structural system of *Lamban Balakh* and how it functions as an adaptive strategy to reduce earthquake risk in the Lampung community. The study utilized a mixed-method approach, combining a systematic review with analyses of literature (journals, books, and earlier research) and data collected through on-site surveys, including observations, interviews, and documentation of structural details to find the unique structural features and adaptable construction methods of *Lamban Balakh*.

The results suggest that *Lamban Balakh's* unique system is made up of an elevated stage structure, a flexible thre-part structural separation, a wooden locking joint system, and a bamboo roll system that makes it more flexible during the earthquakes. The building's use of local natural materials, separation of structural elements, stone-pile foundations, and roof shape all make it strong and culturally important. This study finds that *Lamban Balakh* is a great example of local expertise and creative structural adaptation, making it a great example of earthquake-resistant vernacular architecture in Indonesia.

Keywords: Tectonics, Earthquake-resistant Structure, Traditional Architecture, Lamban Balakh, Pekon Hujung.

Introduction

One of the most important things human beings need is a shelter: a place to live. In Indonesia, this is reflected in the variety and cultural richness of traditional houses (Kamarusdiana, 2019). Each ethnic community has its own architectural style that shows what they believe, value, and do. Traditional Indonesian houses are built as 'homes,' but they also show how architecture, culture, and the natural and social settings work together. Their designs, strategies, and construction methods are flexible enough to work in different environments and withstand the natural disasters such as earthquakes. They use local materials and special relationships and support systems (Rapoport, 1969; Ibrahim, 2011).

Traditional house architecture is actively maintained and preserved by communities as an expression of their social and cultural life (Rostiyati, 2013). This preservation is crucial for sustaining traditions and collective identity. Traditional houses change with time and in different places, show how people live together and how they adapt to their surroundings. They also give us information about the many types of houses and how they are arranged in space. These adaptations promote sociocultural compatibility with the surrounding environment and underscore the essential connection between individuals and their eco-systems (Fastor, 1969).

Indonesian traditional architecture typically divides houses into three symbolic sections: the lowest section (foot), the middle section (body), and the upper section (head): each according to local philosophical and belief systems (Gruber & Herbig, 2005; Rostiyati, 2013). The "feet" stand for the animal underworld, the "body" stands for human life, and the "head" stands for the divine or ancestral realm. This three-part split affects both the physical construction and its cultural and spiritual meaning of the houses.

Lampung is a province in Southern Sumatra known for its diverse and rich culture. There are two primary traditional groupings of people there: Saibatin and Pepadun (Setiawati & Murwadi, 2019). The traditional houses of Lampung make this difference evident by showing how each group lives and what they believe. People know that Lampung houses have stilt constructions, have symbolic carvings, large communal rooms, and complex timber joinery. All of these things show that the builders knew a great deal about the resources and challenges of the areas.

In Pekon Hujung, Belalau District, West Lampung—commonly known as Pekon or Lamban—traditional Lampung stilt houses continue to function as residences and hubs for traditional activities (Faisal & Ikaputra, 2022; Lestari & Fadhili, 2020). The Lamban building system is highly earthquake-resistant, as it has survived severe seismic events in Liwa in 1933 and 1994 due to its structural flexibility (Sudarsono et al., 1994; Hidayat & Naryanto, 1997). The spatial layouts, shaped by established customs, values, and viewpoints, highlight the importance of traditional houses as representations of identity, environmental adaptability, and the safeguarding of the cultural heritage of Lampung.

Theoretical Framework

Tectonics is the study of how the Earth's crust changes shape and moves under the surface. These processes are caused by forces inside the Earth, like mantle convection and plate tectonics. Over long periods of time, they create geological features like folds, faults, mountains, sedimentary basins, and ocean valleys. The interactions between tectonic plates control how the lithosphere grows and spreads. This causes things like earthquakes, volcanic eruptions, and collapses on Earth. Tectonics is a geological and geophysical theory that studies how the Earth's structure changes over time. It examines the formation and shaping of mountains, earthquakes, volcanoes, continents, ocean basins, and mineral grains (Lenardic, 2018; Moores et al., 2013; Dewey, 2018; Stern, 2018; Zheng, 2017). Tectonics mainly studies the moving forces that shape the Earth's surface, creating well-known geographical features like mountains and fault lines. This area aims to comprehend the continuous transformation of landscapes. Tectonics connects the natural and built worlds in discussions about architecture. It explains how Earth's natural processes and the buildings we produce work together by showing how they affect both the land and the buildings we make.

The tectonic terrain of Indonesia has a significant impact on many aspects of life, including how buildings are built, how strong they are, how people identify with their culture, and how they express themselves through art. Tectonics affects local architecture, shaping everything from how components are joined to how buildings are designed as a whole. This alteration in architecture reveals a blend of ancient and new styles. For example, South Sumatra and Lampung have high fractal dimensions, which means that their shapes are not very regular. When fractal values are higher, it is more likely that fault systems will stick together, leading to fewer earthquakes (Suharna et al., 2018).

According to Darman & Sidi (2000), the Semangko Fault is situated within the Bukit Barisan volcanic arc and is distinguished by a network of wrench faults. The Mananga and Lampung–Panjang fault lines are very important to the greater Sumatran fault system. It is seen from the big earthquakes that hit Liwa in 1933 and 1994. Andi et al. (1986) and Hidayat & Naryanto (1997) found that the basic regional values in southern Sumatra, especially in Lampung, are much higher than they should be. It means that the bedrock in this area is not very deep. The tectonic framework of the region is influenced by structural trends oriented in North-Southeast, Northeast-Southwest, and East-West directions, primarily shaped by the subduction of the Indo-Australian plate, the Mentawai fault, and the Sumatran shear fault, as depicted on Hamilton's seismological map.

The Semangko Fault extends from Aceh to Semangko Bay in Lampung and comprises \at least 11 segments along the Bukit Barisan range (Subardjo, 2001). This right-slip, strike-slip fault system is typically shallow, usually less than 30 km deep, with earthquake axes trending Northeast-Southwest and characteristic slip vectors directed north-northwest (Naryanto, 1991; 1995). The most common places for earthquakes to happen in Sumatra are offshore, to the West of the island. This shows how strong the tectonic forces are in this area. To figure out how likely an earthquake is, how the terrain will change over time, and how buildings will adapt to the location, you need to know about this tectonic framework.

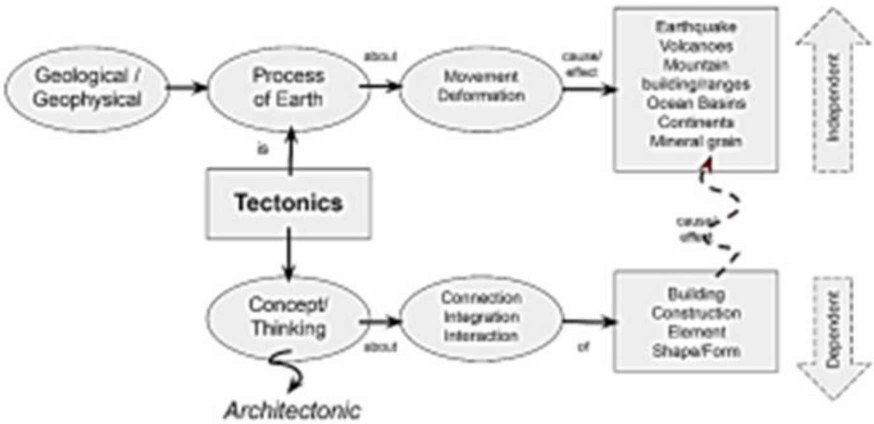

Fig. 1: Theoretical Framework - Meaning of Tectonics
Source: Researcher, 2024

Tectonics in architecture is a way of thinking or a meaning (symbols) about how to connect with the creative/artistic process that makes shapes and uses materials and products like buildings, details, materials, construction techniques, and spatial connections to get the architectural or design results you want (Hensel, 2023; Hematang & Ikaputra, 2022; Theodossopoulos, 2022; Kim, 2009; Frampton, 1995; Weber, 2018; Snooks, 2022). The concept of tectonics in architecture serves as a framework or symbol for engaging with the environment or the creative/artistic process that shapes and utilizes materials and products to achieve desired architectural or design outcomes, including buildings, details, materials, construction techniques, and spatial connections. This view is different from the usual belief that structures are only intended to hold up other structures. The structure of a building is exposed and handled as an important aesthetic feature called an architectonic through tectonics.

It involves adding structural elements to the outside of the structure so that they become part of the building's skin. This serves both structural and aesthetic purposes. This method makes form and function work better together by combining construction methods with artistic expression to make buildings that are not only strong but also beautiful and fit well with their surroundings.

Tectonics is a scientific study of the geological processes that make up the Earth's lithosphere and has a significant application in the world of architecture, where the architectonic concept combines these elements to create buildings and structures that are not only functional but also have a deep aesthetic and symbolic value, namely by combining thoughts and feelings in the process of construction and design of buildings.

From the above explanation, it was found that the definition of tectonics in geology focuses on geological and geophysical processes, including crustal movements and earth formations. The understanding of tectonics in architecture is a form of adapting concepts to integrate the environment and creative processes using construction materials and techniques to achieve design goals.

Literature Review

The complex connections between architecture and its environmental, cultural, and social surroundings is well shown in the study of traditional houses, especially when looked at through the lens of tectonics. When it comes to traditional homes, the idea of tectonics in architecture is about how construction methods and materials can be used to show off and celebrate the building's structural and material logic. In traditional architecture, this generally means that the building fits in well with the terrain around it and has a strong link to local customs and traditions.

Tectonics of the Traditional House

According to Prijotomo (2002), the architecture of the Indonesian archipelago is a unique mix of philosophical, empirical, and scientific knowledge. This makes it different from traditional architectural styles that mostly reflect the culture of the area. This view expands our comprehension of vernacular architecture, depicting it as both a functional answer and a cultural and social expression. Indigenous building practices have changed over the years as ways to adapt to the unique problems and social situations of their communities.

The concept of housing in architecture is often shaped by societal influences (Morgan, 1981; Junianto, 2018), as the design and layout of vernacular structures closely reflect cultural values, behavioral patterns, and viewpoints. Pangarsa et al. (2012) contend that the symbols incorporated into traditional edifices reflect a community's cosmological worldview and its relationships with the natural and spiritual domains. Matondang and Sani (2021) suggest that comprehending these symbols sheds light on the subtle ways people see and feel about their living spaces.

In the case of Bima Regency, where timber stilt houses and granaries have shown great earthquake resistance due to their building methods and practical knowledge (Hariyanto et al., 2022), we learn a lot about vernacular tectonics. This robustness is not solely attributable to material selection; it results from generations of refinement in woodworking techniques that enhance structural performance under seismic stress. The *Sasadu* house is another example of this expertise. Its joints and beam arrangements are carefully made to absorb and dissipate seismic energy. The ceiling beams, which act like a pendulum, keep the house stable with a special clamping system that uses friction to dampen vibration (Prihatmaji, 2023).

The new architectural designs show basic ideas of balance, stability, strength, and rigidity (Sagita & Pradipto, 2020). Traditional buildings get these traits by using materials and forces in a way that makes sense, combining purpose and cultural meaning. In contrast, the comprehensive approach of vernacular history teaches us important lessons. By looking back at historical techniques, modern designers can create architecture that is long-lasting and respects the local biophysical and sociocultural environments. This shows that real, context responsive design is still important for architectural success.

Principles of Earthquake-resistant Structures

The concept of tectonics in architecture is based on the physical and visual effects that come from the connection and integration of structural parts. Architectural tectonics examines uniqueness and studies the interrelation of materials and shapes, as well as the visual articulation of structural composition. The tectonics of a building show how its shape and function are related by showing how parts like walls, roofs, columns, and joints work together to tell a coherent story. This method puts a lot of significance on constructive integrity and material honesty. It sees strength, durability, and beauty as the most important values.

Structure is very important for keeping buildings and the people who live in them safe from threats from both inside and without. To be secure and stable, building frameworks must be able to handle gravity, wind, earthquakes, and other stresses. In this way, traditional Indonesian architecture teaches us a lot. Vernacular buildings in Lombok, Karo, Toba, and Bima are naturally resistant to earthquakes because of historical construction methods and local knowledge.

Research shows that traditional buildings in Lombok are resistant to earthquakes because they use properly thought-out geometry, structural joints, and building materials (Fajar et al., 2020). These architectural concepts show a deep awareness of the area's seismic conditions, as seen by the usage of wood, bamboo, and specific building methods. In the Karo and Toba regions, houses built with non-engineered systems that have symmetrical structures and little horizontal variation are strong because they balance the forces and friction (Tarigan et al., 2022). This symmetry stops too much shear and rotational stress, making local homes stronger and more flexible.

Bima's vernacular houses also have unique structural solutions. For example, stilted foundations, diagonal bracing, and wooden pegs help keep the buildings from bending during earthquakes (Hariyanto et al., 2022). Such creativity arises from profound collective knowledge, empowering societies to adapt to perilous situations. The notion of base isolation—using columns that rest on flat stones—makes buildings much more resistant to earthquakes without needing cemented foundations, as shown by traditional Indonesian builders (Lumantarna & Pudjisuryadi, 2013). Lightweight, flexible designs work well, as shown by examples from Kampung Naga. These designs let buildings move with seismic forces and limit damage (Yani et al., 2015). Mandailing techniques, including column-and-beamstrengthening, give buildings the flexibility they need to reduce the danger of earthquakes (Irma et al., 2019). Meanwhile, buildings like the *Omo Hada* in Nias use base isolation based on friction and new foundation systems to show how stable indigenous design and materials can make a building (Pudjisuryadi et al., 2011; Gruber & Herbig, 2005).

The findings from various regions of Indonesia show that traditional knowledge is still very important for designing buildings that can withstand earthquakes. Such localized knowledge, whether conveyed through symmetry, adaptable joinery, or base isolation, highlights the enduring significance of vernacular architecture—not just as cultural heritage but also as an essential approach for resilient and sustainable construction methods in seismic areas.

Research Method

This study was independently conducted in 2024 in Pekon Hujung, Belalau District, West Lampung Regency, focusing on the structural system of the traditional *Lamban Balakh*. A mixed-methods approach based on a systematic review was employed, incorporating literature review, field observation, interviews, and documentation of the building's physical and technical attributes. The literature review encompassed journals, books, and previous research to elucidate the principal concepts of tradition, tectonics, and the structural system of Lampung vernacular houses. Fieldwork included visiting *Lamban Balakh* in person to record the condition of the buildings, the methods used to build them, the wood joinery systems, the foundation structures, and the staging and bamboo roll systems. Structured interviews were performed with residents, traditional authorities, and local artisans to investigate indigenous knowledge and assembly processes through generations.

Each structure component of the building was systematically recorded from the stone foundations and wooden columns to the locking joints, floor plans, and limasan roof type. As supporting evidence, visual material such comprehensive construction photos, floor plans, and sectional drawings were gathered. The data analysis utilized a comparative, qualitative methodology, contrasting field findings with the structural criteria for earthquake-resistant housing delineated in the literature and other investigations within Indonesia's seismic zones. The results were categorized into material adaptation, joinery systems, and building tactics to emphasize structural distinctiveness and adherence to the principles of traditional tectonic architecture, as exemplified by Lamban Balakh of Pekon Hujung.

Findings and Discussion

Traditional houses in Pekon Hujung, namely *Lamban Balakh*, demonstrate a smart architectural adaptation to natural phenomena. Lampung's traditional houses are generally built using raised structures. The elevated floor of the house not only protects against floods and wild animals but also provides flexibility and resistance to earthquake tremors. This raised structure allows the house to 'move' along with the ground vibrations, reducing the risk of structural damage.

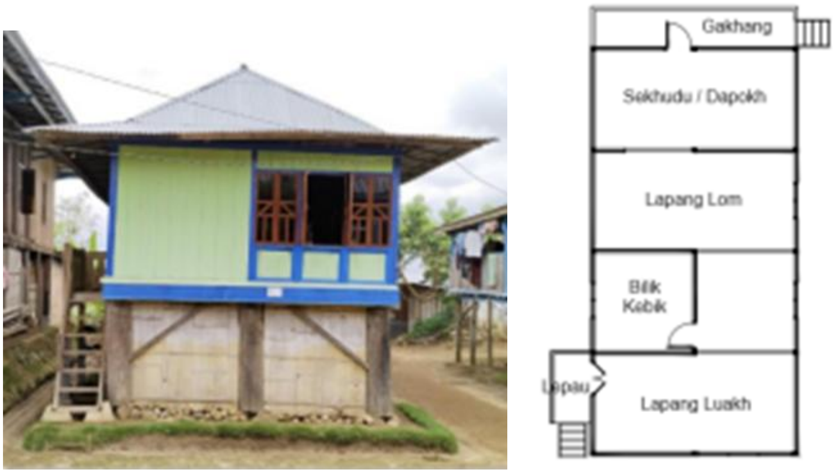

Fig. 2: Fasade and Plan of Lamban Balakh in Pekon Hujung
Source: Researcher, 2024

The layout of Lamban is simple, and the rooms are typically symmetrical and can be changed. It shows that family members have intimate, open, and communal interactions. The simple architecture and symmetrical design assist lessen the effects of earthquakes since symmetry helps keep the structure balanced during an earthquake shock (Siswanto et al., 2013).

The names of the rooms in Lamban Balakh and what they are used for are as follows:

(1) Lepau/Ambin/Serambi/Bekhanda as a place to receive guests and a place used by the residents of the house to relax;
(2) Lapang Luakh, usually as a place of deliberation (musyawarah) and also as a guest bed by installing a barrier screen and mat or mattress;
(3) Lapang Lom, this room is divided into several rooms. Lapang Lom is private area, specifically used by family members and cannot be used by guests or relatives who come from outside the house;
(4) Bilik Kebik is a part of the house that is used as a bed for the personal activities of the residents of the house;
(5) Dapogh or Sekudhu is a woman's room to prepare food and cook; in it, there is a furnace (Sekelak) with wood fuel;
(6) Gaghang Kudan as a place to wash kitchen utensils and other household appliances.

The study examines the distinctive architectural knowledge inherent in the vernacular buildings of Pekon Hujung, which, despite their seemingly simplistic design, exhibit complex construction techniques and environmental adaptability. The study focuses on inherited local knowledge and examines how traditional Lampung builders choose durable native materials such as teak, Merbau, bamboo, and river stones, and use tried-and-true methods such as wooden peg floor locking and geometric joinery. These techniques, passed down over the years, create interlocking joints that are both strong and flexible, allowing the building to move safely during earthquakes. The design, which features very few decorations and a clear separation between structural systems, shows how even small features (such as rolling systems under the floor and geometric end motifs) can enhance strength and cultural identity.

Structural research reveals additional adaptive measures, such as discontinuous columns between the upper and lower floors and the deliberate implementation of steep, *limasan-shaped* roofs to lower the centre of gravity and effectively distribute weight. Typically, houses are built on high pedestals or round river boulders so that during an earthquake, the columns can move above the base without the fear of the structure collapsing (Matondang & Sani, 2021). The fact that many people use load-distributing supports and high-elasticity wood helps spread stress, making these homes less likely to break during an earthquake. The study shows that vernacular architecture in Lampung is a living library of sustainable building knowledge by examining these elements. It shows how technological needs and the natural environment can work together.

Structural Section Separation

From the point of view of spatial growth, the traditional houses in Pekon Hujung Lampung Village grow slowly as more people move in and need more space. The buildings change shape from squares to L-, T-, and I-shaped constructions. It has a wood-based structure and is the best structural system for places that are likely to have earthquakes. (2021) Matondang, A., Sani, A.A. The *Lamban* structure is made up of three parts: the upper, middle, and bottom. Each portion was built separately but is still connected to the earth. This division makes the construction more flexible and able to withstand earthquakes. The lower structure is held up by a foundation made of stone footings that hold up the house's weight and anchor the round building columns. These stone footings are the first line of defense against underground vibrations and help keep things stable during earthquakes.

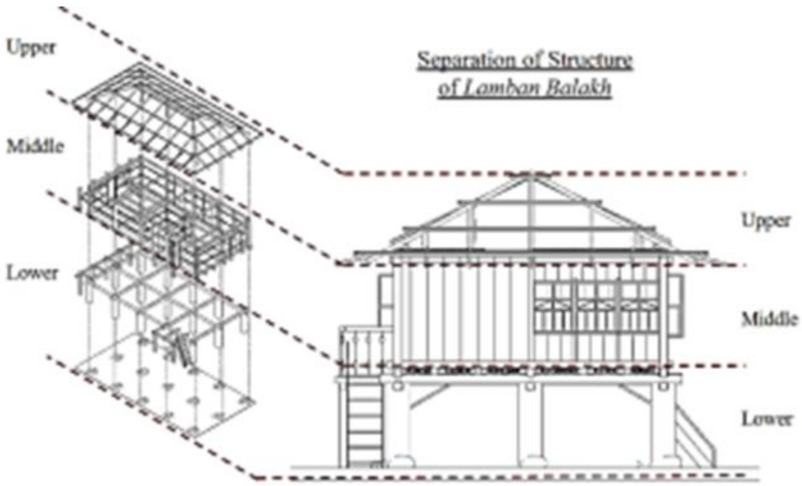

Fig. 3: Separation of structural parts of Lamban Balakh
Source: Researcher, 2024

The middle structure made up of the floor and walls, and the roof is the top structure, are not connected to the structures above them. The bottom and middle constructions used different columns.

Fig. 4: Continuous structure
Source: Researcher, 2024

This building system was put into place slowly, starting at the bottom and working its way up over a long period of time. The separate structural structure makes sure that each section can move on its own during an earthquake, which absorbs and spreads seismic energy, lowering the chance of major damage to the building. The connection between the columns and the beams is made with a reinforced wood perforation system that has a locking mechanism that connects the upper and lower constructions.

Fig. 5: Detailing interlocking system Structure
Source: Researcher, 2024

The lower structure gets the first lock, then the middle structure, and finally the top structure or roof. This locking method is without nails. Thus, each structure can connect to the others without forming a rigid whole. Some illustrations show how the simulation of the installation process for interlocking and stacking structural joints in the *Lamban* buildings.

The Roll System Structure

One way that the *Lamban* can be flexible is by using whole bamboo strategically between the lower column and floor structures. These bamboo sections are not connected together, so they can move freely in two horizontal directions, like a wheel, following the motions of the ground during an earthquake. This flexible framework lets the building bend and swing with the ground's movements instead of fighting against them. Adding a flexible structural system to a structure spreads out the stress caused by seismic forces instead than concentrating it in one place. This general flexibility helps keep buildings from falling down during an earthquake.

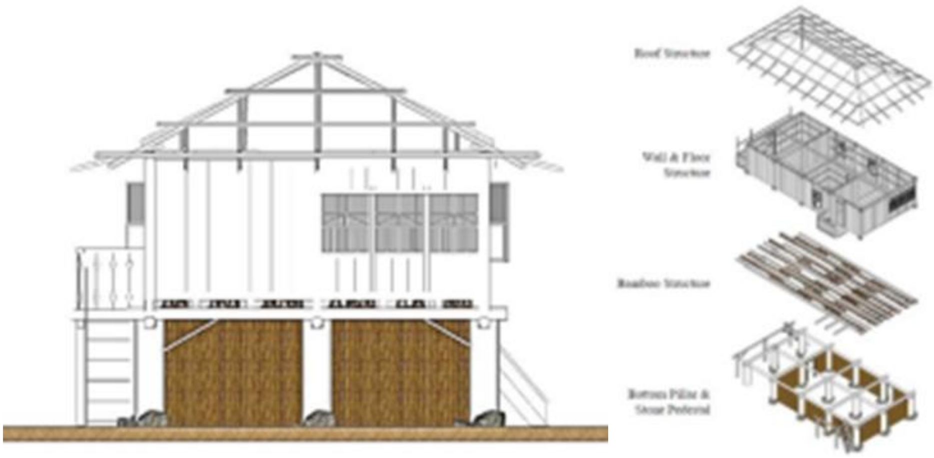

Fig. 6: The placement of bamboo: between the substructure and the floor structure Source: Researcher, 2024

Following illustration shows the placement of bamboo beneath the floor structure, functioning like wheels under the floor of the *Lamban* building, allowing lateral movement during an earthquake.

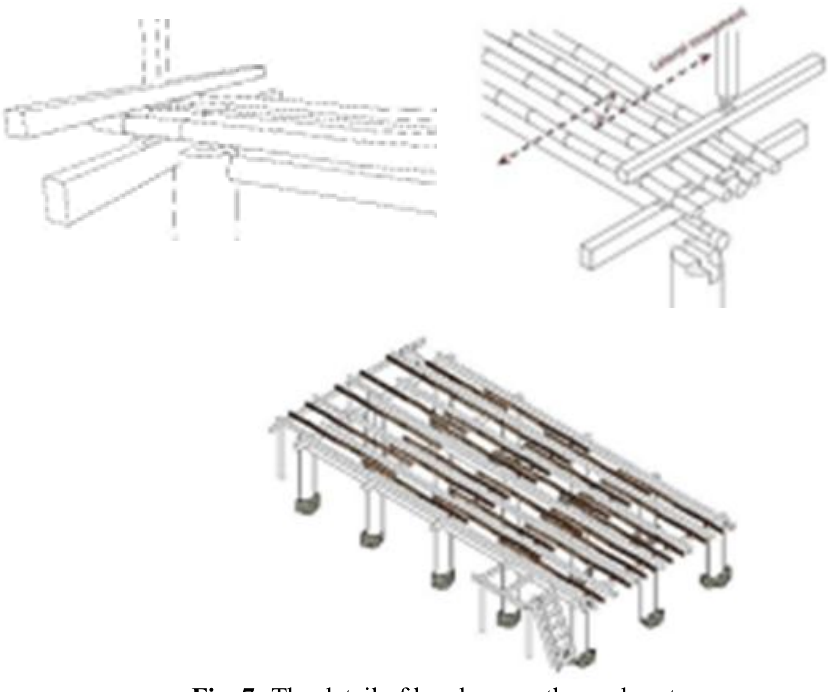

Fig. 7: The detail of bamboos as the rool system
Source: Researcher, 2024

From the discussion of the Lamban Balakh structural system above, several basic things can be drawn that make Lamban Balakh an earthquake-resistant building, along with the uniqueness of its structural system, including:

- Stage Structure: Lamban Balakh is built with a stilt structure that allows the house to 'move' along with the vibration of the ground, thus reducing the risk of structural damage. • Structure Separation System: Lamban Balakh structure consists of three main parts that are separated but interconnected continuously from the base to the roof. The bottom, middle, and top structures can move independently during an earthquake so that they can effectively absorb and distribute seismic energy.
- Stone Pile Foundation: The bottom is supported by a stone foundation that resists nderground vibrations and acts as a flexible stabilizer during an earthquake.
- Wood Locking System: The columns and beams were connected by a wooden locking system that allowed each piece to move independently during an earthquake. The locking system binds to the structure without the formation of a rigid unit.
- Roll with Bamboo System: The use of whole bamboo placed between the bottom column structure and floor adds flexibility, allowing for free movement in both horizontal directions.
- Roof Shape: The limasan shape with a steep slope helps to reduce the heavy load at the top, lowering the center of gravity of the house, and increasing stability.
- Evenly Distributed Load: The use of support posts that are evenly distributed throughout the foundation of the house helps distribute the load efficiently and reduce pressure at one specific point.
- Elastic Local Materials: The use of highly elastic wood such as teak, merbau, and bamboo allows these materials to absorb and dampen earthquake vibrations.

These basic things also follow the rules for traditional earthquake-resistant constructions in Indonesia, which come from old customs and have been passed down through the generations. The system in issue that doesn't employ engineering includes wood or bamboo materials, flexible building methods and structural joints, foundations on the ground, simple house plans and roof designs, and geometric shapes.

Conclusion

Traditional Indonesian houses in Lampung reflect the deep connection between architecture, social, cultural, and environmental factors. These houses are built using local materials and techniques that increase resistance to natural disasters, such as earthquakes. *Lamban Balakh* is especially recognized for its ability to adapt, with a stage construction that keeps it from flooding and remains flexible during earthquakes.

There are three main sections to the structural separation system in *Lamban Balakh*: the bottom, the middle, and the top. Each element is separate but always connected from the foundation to the roof. The bottom is supported by a stone foundation that also works as a flexible stabilizer during earthquakes. A wooden lock holds the columns and beams together. Allows each part to move independently during an earthquake, thereby absorbing and spreading seismic energy. The roll mechanism in *Lamban Balakh* also places the entire bamboo between the lower column framework and the floor, without any ties. This roll system helps the building move and swing with the ground rather than staying steady, prevents tension from piling up in one place, and prevents it from falling during an earthquake.

The *Lamban Balakh* structural system is unique and smart because it was built on a profound understanding of how earthquakes work and on local knowledge passed down through the generations as an example of traditional architecture in Indonesia that can adapt to and withstand earthquakes.

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