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Identification of Structural Elements Towards Disasters: A Case Study of Osing Architecture

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ABSTRACT

Indonesia is an archipelagic country consisting of various tribes and cultures, one of which is the Osing Tribe in Banyuwangi, located at the eastern tip of Java Island, near Bali Island. The culture of the Osing tribe is manifested in the traditional Osing house architecture, especially in Kemiren Village, which is built from a combination of Osing's unique technology and art. From its position, the Banyuwangi area is located at the boundary of tectonic plates, which results in the potential for natural disasters such as volcanic eruptions, earthquakes, landslides, and tsunamis. This research aims to study the structural design of the traditional Osing tribe house in responding to these disasters threat. The identification of the structural elements is then analyzed to determine how the building will transmit the axial and lateral load, as well as withstand disasters. The result is that the Osing tribe house has applied the local wisdom, manifested in the house's tectonic design. The details of the building could respond and distribute the loads caused by disaster. Responding to the load from the volcanic ash, the Osing house's roof needs reinforcement to sustain its rigidity.

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1. INTRODUCTION

Traditional houses play an important role in preserving the cultural identity and history of a community. This traditional house is not just a physical building for shelter, but a manifestation of values, traditions, and knowledge passed down through generations. The traditions passed down through generations are usually carried out orally, which carries the risk of bias and even being forgotten over time. Therefore, the documentation of values, traditions, and knowledge becomes an important activity to undertake.

Study regarding traditional houses and architecture has been done intensively within the context of Indonesia, as Indonesia is a country that has many tribes and local wisdoms. Previous studies have highlighted the sustainability considerations found in Batak Toba culture [1], as well as studied the design typologies for traditional houses connected with certain cultural architectural styles [2], and even how different religious buildings are affecting each other in the past [3]. More technical studies regarding the thermal [4], [5] and ventilation [6] performance of vernacular houses also have been done to investigate and rethink whether the adapted local wisdom could be implemented in a more modern setting. Nevertheless, the study regarding the identification of structural components and performance of vernacular houses in response to the disaster risk is still rarely found.

One of the tribes that still preserves its cultural identity and history through traditional houses is the Osing tribe. The Osing tribe has the traditional village of Osing Kemiren located in the Glagah district. Currently, Osing Kemiren village has been designated as a tourist village in Banyuwangi [7] with an area of 117.032 hectares and a population of 2,569 people. The name of the traditional village Osing Kemiren comes from the name kemiri, which means many candlenut trees. This traditional village is also part of the Ijen Geopark and Cultural Site.

Figure 1. Kemiren Village from East and West (source: author)

The settlement of the Osing tribe stretches from East to West [8]. In Figure 1, it can be seen that the settlement pattern of the Osing tribe is linear. The shape of the traditional Osing house is influenced by three main factors: social factors, environmental factors, and belief factors [9].

The structural system of Osing house has a unique feature, namely the installation of the main structure using a joint system, which means without using nails. In addition, the construction system and structure of the Osing house contain meanings and beliefs where the construction and joints of the Osing house symbolize domestic life and can be seen in the wooden joints that have a vertical arrangement so that they do not meet at a single point [10].

On the other hand, based on its geographical position, Banyuwangi is located on land ranging from lowlands to highlands, above the boundary of the Indo-Australian and Eurasian tectonic plates. The village of Kemiren itself, as a tourist village in Banyuwangi, is located in the Glagah sub-district. Based on Banyuwangi Regency Regional Regulation No. 08 of 2012, concerning the Banyuwangi Regency Spatial Plan for 2012 - 2032, Glagah Village is included in areas with threats of land movement vulnerability and volcanic eruptions [11]. On the national disaster map of East Java by the National Disaster Management Agency, the Banyuwangi area generally has a high threat of earthquakes and tsunamis. There is also a threat of volcanic activity, due to the location of the city.

Previous research focusing on the Osing House are focusing mainly on the sustainability aspects of the structure [12], including the tropicality of the design [13] and the orientation of the masses [14], yet there are still a very few studies detected regarding the design response to the disaster threat.

Based on the above description, the idea emerged to analyze the structural behavior applied by the Osing tribe in building their traditional houses and study the design responses made to withstand the loads that the structural elements of the Osing traditional house must bear, which are caused by the disaster.

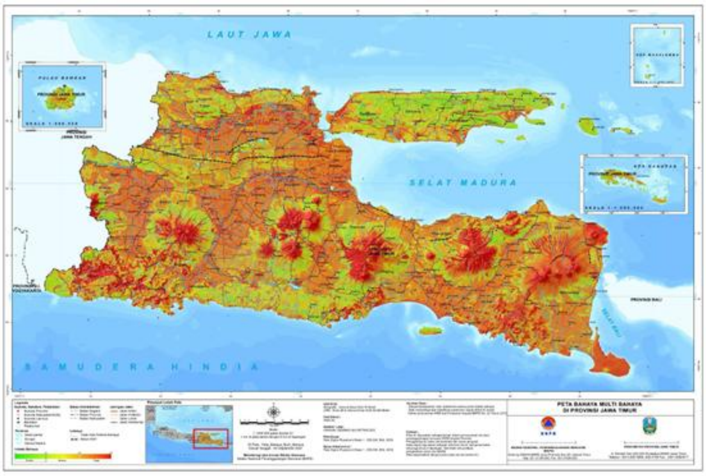


Figure 2. Map of Multi Disaster-Prone Areas in East Java (source: "BAHAYA_MULTI_BAHAYA_JATIM.jpg," accessed Apr. 16, 2025. Available: https://files.bpbd.jatimprov.go.id/)

2. METHOD

This research adopts a qualitative approach by initiating a series of field activities aimed at understanding the structure and characteristics of the Osing traditional houses in Kemiren Village, Banyuwangi. The initial step involves a direct visit to the location for observation and interviews with village elders, who serve as key informants. This interview aims to explore information regarding the history, philosophy, and construction techniques of the Osing traditional house, as well as local knowledge related to potential natural disaster risks. In addition, the sketching of the structural elements of the Osing traditional house is carried out to visually document the construction details relevant to disaster resilience aspects.

Data collection on natural disaster risks in the Banyuwangi region, specifically in Kemiren Village, was conducted through documentation studies and spatial analysis. Existing disaster mapping, both from government sources and scientific research, is integrated to gain an understanding of potential threats such as earthquakes, landslides, and volcanic eruptions. Considering the village configuration that still preserves the existence of traditional Osing houses, disaster risk mapping is focused on the local scale of Kemiren Village, specifically on its typical residential buildings of the Tikel Balung type.

Next, this research applies a comparative method by comparing disaster standards that are applicable nationally and internationally with the actual conditions of the Osing traditional houses in Kemiren Village. This comparison aims to identify gaps and potential vulnerabilities in the traditional house structure against disaster threats. The analysis of structural elements was conducted in-depth to understand how each component of the building contributes to overall resilience. Based on this analysis, the research then identifies building elements that have the potential to be developed or modified to enhance the resilience of the Osing traditional houses against natural disasters.

3. RESULTS AND DISCUSSION

3.1. Osing House

Based on the Literature Study, the traditional Osing house is built using local materials and construction details, namely stone, wood, bamboo, and tiles. The structural system used in this traditional house is a frame system with wood as the main material. The anatomy of the elements that make up the Osing Traditional House is as follows:

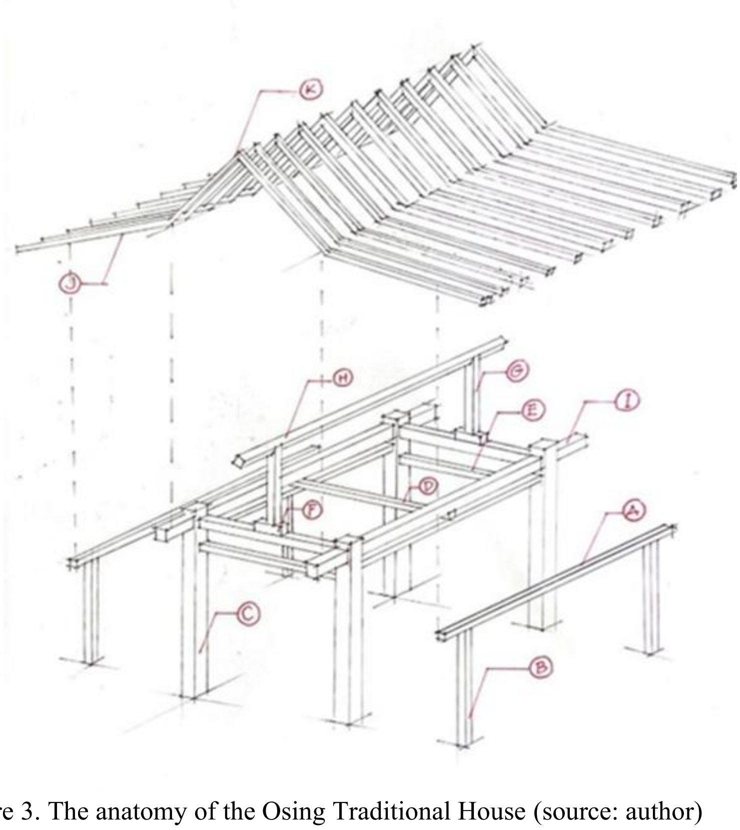


Figure 3. The anatomy of the Osing Traditional House (source: author)

Table 1. Osing House Structural Anatomy (source: author)

Code	Element name	Structural Function
a	Glandar	Beam which connects soko tepas (b)
b	Soko Tepas	Additional perimeter columns that supports side and front roof
c	Soko	Main columns that support the whole building. Soko columns are found in each of the Osing house typology. The configuration of one set of soko columns consist of four soko columns that represent parents of two families that are going to be one family
d	Lambang	Beams that are located above the Jait beams
e	Jait	Main beams that connect four soko columns. The shorter beams are called Jait Cendek, and the longer beams are called Jait Dowo
f	Doplak	A log that is placed between the lambang beams and ander, to strengthen the ander position
g	Ander	Vertical wooden bar that connects lambang and jait beam with suwunan (top roof beam)
h	Suwunan	Roof's top beam that parallel with the pelari cantilever beam
i	Pelari	Wooden cantilever beam that is located above the jait dowo beam. Pelari beam supports the roof by making a landing for dur atas beam
j	Dur Bawah	Sloped roof joists that span between lambang (D) and glandar (A)
k	Dur Atas	Sloped roof joists that span between suwunan (H) and pelari (I)
l	Reng	Wooden beam that leans on dur joists, supporting the placement of terracotta roof
m	Rab	Roof area, that is divided into upper rab and side rab

In addition, the Osing tribe's houses have a distinctive feature at the junction of the column with the ground, called Ubeg. Ubeg is a solid wood where the column rests before being connected to a stone base, which aims to lock and prevent the column from touching the ground, as seen in figure 3, which would cause moisture to rise into the column. In this case, the sopak stone is only placed on the ground and drilled to the size of the ubeg, which restricts the movement of the ubeg itself.

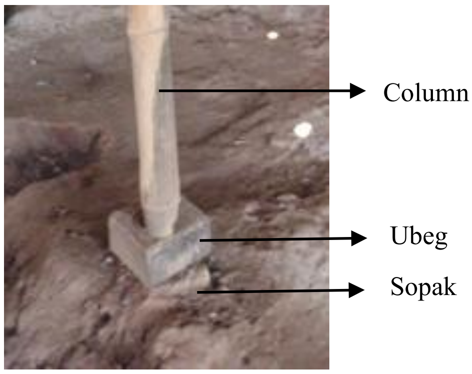
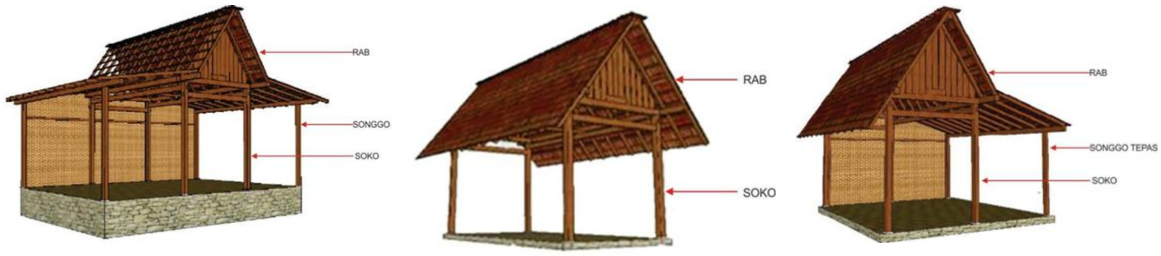


Figure 3. The connection between ubeg and sopak stone (source: author)

Furthermore, in its original state, there are three types of Osing traditional houses, distinguished by their roof shapes, that can be seen in figure 4 [11]:

1. Tikel House
   The tikel house shape is the most perfect form of the traditional Osing house. This house has a roof in the shape of a kampung srotong with 4 (four) Rab, 4 (four) Soko, and 2 (two) Soko Tepas.
2. Cerocogan House
   The shape of the Cerocogan house is a type of house with a traditional village roof consisting of 2 (two) Rab with 4 (four) Soko without Soko Tepas. For a complete house, the Cerocogan shape is often used as a Pawon or kitchen.
3. Baresan House
   The Baresan house shape is a type of house that consists of 2 (two) Rab with 4 (four) Soko and 2 (two) Soko Tepas. This type of house is similar to the Tikel house but appears less perfect. The Baresan house is often used as a kitchen if its Bale is in the form of a Cerocogan.



(a) Tikel House (b) Cerocogan House (c) Baresan House

Figure 4. Variety of Osing House (source: PERBUP Kab. Banyuwangi No. 11 Tahun 2019)

The majority of the typical traditional homes in Kemiren village are Tikel homes, which were built using original methods. However, they have undergone small spatial adjustments based on the demands of the users, such as the inclusion of more partitions and the enlargement of the kitchen's roofed area (pawon).

3.2. Disaster threat in Banyuwangi

Disaster-responsive design will take disaster risks into account in building design, so that the building remains safe for its users and does not collapse until the required time. Especially in the Banyuwangi area, the disasters that must be considered are:

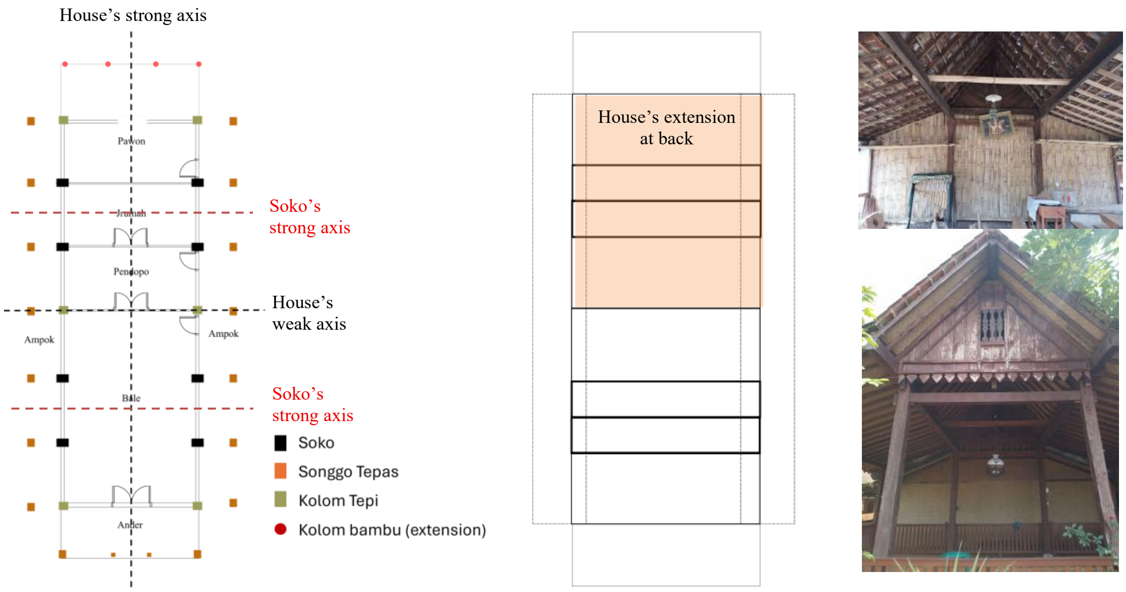
1. Landslide Vulnerability
   The disaster of land vulnerability movement occurs due to land movement caused by landslides, subsidence, and liquefaction [16]. Soil that has become saturated with water, along with the steepness of the slope, will increase the risk of landslides in mountainous areas, including the village of Kemiren. When a building is struck by landslide material, the building will experience additional load beyond what was previously calculated, resulting in structural failure. Conversely, if the ground where the building is located subsides, the building will lose its footing and fail. Liquefaction itself is the transformation of solid material into a liquid-like state. In this case, floods accompanied by earthquakes can cause disaster hazards due to liquefaction, where water-saturated soil experiences shaking.
2. Earthquake
   Earthquakes are waves experienced by the layers of the Earth due to the sudden release of energy from within, creating seismic waves. Banyuwangi, located in the subduction zone of the Indo-Australian and Eurasian plates, has a high risk of earthquakes. Furthermore, data shows that several major earthquakes have occurred in the past, in addition to the potential for megathrust earthquakes in the Indian Ocean [17].
   The SNI-1726-2019 Standard on Earthquake Resistance Planning Procedures for Building and Non-Building Structures maps earthquake zones across Indonesia and provides standards used to calculate earthquake loads, considering soil type, vibration period, and building importance factor. In this case, the Osing Traditional House falls into risk category II out of four categories, as it is a residential building. But the losses that may occur from an earthquake disaster in Kemiren Village are not limited to the destruction of buildings; they also entail the loss of a village legacy that is culturally sustainable, particularly the Osing construction method.
3. Volcanic Disaster
   Desa Kemiren is located on the slopes of Mount Ijen; however, Desa Kemiren is also situated 31.4 kilometers to the east of the active volcano, Mount Raung. In the last five years, volcanic activity has been recorded on Mount Raung, including eruptions in 2021 and 2022, and a watch status in 2023. When Mount Raung erupted, volcanic ash rain also hit the city of Banyuwangi, including Kemiren Village. In addition to being hazardous to health and obstructing visibility, volcanic ash can also become an excessive burden on the roofs of traditional houses, which can lead to collapse if it reaches a certain volume.

3.3. Osing House Analysis

The traditional Osing house has a symmetrical layout, both in its elongated and spread-out sides, in its basic form. Symmetrical and unbranched forms have advantages in facing earthquake disasters, where building plans with irregular shapes, such as buildings with branched masses, can experience torsional effects when exposed to seismic waves, as mentioned in the previous research [18]. This is caused by the distribution of the center of mass and the center of rigidity not being at the same point that caused eccentricity. Furthermore, the junction area between the main body and the arm often becomes a weak point due to changes in stiffness.

However, the elongated shape of the Tikel house will create a strong axis and a weak axis, where the house will be strong in withstanding seismic waves that come parallel to the long axis of the house, and will be relatively weaker in facing seismic waves that come parallel to the short axis of the Tikel house. To address this, we can classify the priority of the structural elements in this Osing traditional house.

Most of the houses in Kemiren Village are Tikel Balung houses configured repeatedly backward, or Tikel Balung houses combined with the Cerocogan house shape. From the axonometry, it can be seen that the main structure of the Tikel Balung and Cerocogan houses is located on four Soko columns situated in the center of the house. The houses are spread with varying widths, ranging from 4.6 meters to 6.31 meters [14], and are still inhabited to this day. In this case, we can see that the short span of the soko is placed on the opposite side of the weak side of the house, namely parallel to the weak axis of the house's mass. This creates a balance, where the wide span of the house, which becomes the long distance of the soko, where the jait dowo is stretched, can also be utilized to increase the stiffness of the weak axis of the traditional house's mass, because it has a longer span than the span of the jait cendek. In this case, the span of the long jait will function as a portal span, while the span of the short jait will function as the building's truss.



(a) Typical House Plan (b) Roof Plan (c) Symmetrical Form

Figure 5. The symmetrical form of Typical Tikel Balung House in Kemiren Village (source: author)

The main columns of this Osing house are eight Soko columns that span and support the ridge beam of the roof. From the sections of the house, the configuration of the soko columns - jait cendek and jait dowo, we will find a framework system of wooden construction. This cross-section shows wooden joints meeting at right angles. The joint in the wooden frame should require a 'sekur' beam to make its configuration stiffer, but this is not found in the Tikel Balung house in Kemiren Village. To stabilize the configuration of the four Soko, the residents have traditionally used small wooden pieces that give pressure on the Soko and Jait joints, thereby reducing the likelihood of movement at those joints. The weight of Jait beams gives the axial load to the small wooden fastener, makes the joint rigid, yet still have room to move along, whenever there is a lateral load, for example, seismic waves. The fastener will be hammered to stiffen the joint, as it will push the jait beam upwards. This can be seen in Figure 6, where the jait beam is cut diagonally at its edge to provide space for the fastening wood. This small fastening wood could be seen in each of the joints of the soko columns.

Strengthening joints is also one of the points in anticipating structural movement during a disaster, which causes the building to be subjected to additional axial or lateral forces.

Besides the mass and layout configuration, as well as the balance in the main frame configuration of the building that will bear most of the moments caused by ground movement, one important principle in responding to the danger of an earthquake disaster is to decouple the ground vibration frequency from the building vibration due to seismic waves. In today's world, this vibration damping technique is often referred to as a base isolator, which is designed using shapes and materials that allow movement at the base of the building.

When we look at the foundation of the Tikel Balung house on the ground, we will not find a solid pedestal like in traditional Javanese houses. The support in the Tikel Balung house consists of wood or bamboo as the soko tepas column, which meets with a piece of wood called Ubeg. This ubeg rests on a sopak stone, a stone with a hole that has the same cross-section as the ubeg wood, so that the ubeg wood can rest on the sopak stone while still allowing movement but remaining stable. This sopak stone is then arranged and slightly embedded in the ground as the foundation base of the house [10]. The configuration of ubeg - sopak and soko tepas allows movement when the building is subjected to soil movement or earthquakes. The position of the sopak stone, which is not rigidly embedded in the ground, also causes the sopak stone to detach during vibrations, thereby simply and naturally interrupting the earthquake vibration waves from the ground and the building, while still enabling the structure to move along with the seismic wave. This mechanism resembles the principle of base isolation that could be found in more modern buildings. This finding align with the previous research that found the use of sand and palm leaves for the same base isolation means to protect the central column of Japanese architecture from the seismic wave [19].

Figure 6. The fastening of Soko - Jait joint (source: author)

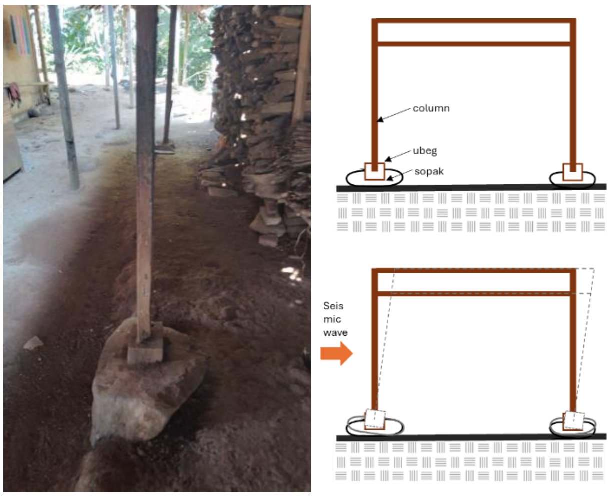


Figure 7. Ubeg - Sobak Joint resembles base isolation (source: author)

To respond to the volcanic ash disaster, the most influential design element is the roof, which protects people from volcanic ash rain, while also serving as a place for volcanic ash to accumulate and settle. The roof of the Tikel Balung House itself has two slopes, namely a steep roof (45 - 60 degrees) in the central area (represented by the green line in image 8), and a gentler roof (15 - 30 degrees) on the sides of the amper, ampik, and pawon. As a roof surface, the steep roof has support in the form of purlin beams and wooden infill boards acting as gables, which can also reinforce the position of the steep roof itself. However, in the flat roof segment, the presence of wooden fasteners or elements that serve as a gable cannot be found. Therefore, the vulnerability level of the flat roof area is higher than that of the steep roof area.

Continuous ash rain can also cause ash accumulation in the area of flat roofs. Therefore, a design intervention is needed, in the form of adding tie beams to secure the roof to the main columns of the house, in order to create a more stable triangular configuration that can withstand the load of volcanic ash.

Figure 8. The two segments of the Tikel Balung Roof (source: author)

4. CONCLUSION

The study emphasizes how Osing traditional homes in Kemiren Village are structurally resilient to a range of natural disaster hazards, such as earthquakes, landslides, and volcanic eruptions. These homes, which were built with a nail-free timber frame structure, have distinctive joinery techniques that increase their seismic resistance. A natural base isolation effect is introduced by using ubeg and sopak stone foundations, which permit movement during ground shaking while preserving structure integrity of the upper structure.

Furthermore, the Osing house's symmetrical design helps to mitigate the torsional effects of earthquakes. To increase lateral stability, structural modifications are necessary because the Tikel Balung house's elongated shape produces both a strong and a weak axis. Small attaching pieces reinforce wooden fastening joints, which act as extra stabilizers to lessen movement at crucial connection points between column and beams, as well as improve the overall structural integrity.

An important consideration when dealing with volcanic threats is the roof structure. Conversely, the flat side roofs are more susceptible to ash buildup and possible collapse, while the high central roof efficiently sheds volcanic ash, as it has a steeper roof angle. To reduce these risks, strengthening actions can be used, such as installing tie beams to provide a more rigid triangle roof shape.

This study emphasizes how crucial it is to incorporate local knowledge into disaster-resistant architecture design. Through the documentation and analysis of Osing construction methods, important lessons can be applied to modern architectural practices, guaranteeing cultural preservation and boosting resilience to disasters.

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