Urban resilience based on local seismic culture in earthquake prone region

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Abstract. Bima Regency, located on Sumbawa Island, is an earthquake-prone region. The condition is the impact of its position on Sumbawa Island, which is flanked by two earthquake fault lines. Urban resilience is related to the region's ability to maintain its form, function, and system in the event of a natural disaster. This paper discusses how local seismic culture in Bima can create urban resilience, so it becomes a sustainable disaster-responsive district. This study aims to identify the existence of local seismic culture to increase regional resilience in the context of disaster mitigation. A case study was done by collecting data through field observations and secondary data from the Statistics of Bima Regency. Local seismic culture already exists and is practiced by the local people of Bima to build their dwellings to be adaptive and responsive when an earthquake strikes. It becomes an internal strength in developing the region's resilience. The local seismic culture can be a model for disaster mitigation preceding other regions in Indonesia prone to earthquakes.

1. Introduction
Geographically, Indonesia is at the confluence of several tectonic plates and in a situation called the ring of fire because it has the most active volcanoes in the world. So, this condition resulted in frequent earthquakes. Bima Regency, located on Sumbawa Island, is an earthquake-prone region. Sumbawa Island is flanked by two active fault lines, the Indonesian Ocean's tectonic plates and the Eurasian plates in the south, and the Flores back arc thrust in the north [1]. So, this condition causes frequent earthquakes in Bima Regency. Sixteen times of earthquakes occurred from 2015 to 2017, with a magnitude of 5 - 6.2 [1]. Therefore, efforts to increase the region's resilience can be pursued by exploring their local seismic culture.

The condition of an area prone to natural disasters requires its people to have awareness in reducing risks to survive in the environment where they live. Local seismic culture is the knowledge of local people about the earthquake's effect on buildings and how they consistently apply it to strengthen buildings [2,3]. Local people then pass on this knowledge to the next generation, and they make improvements. They repaired or replaced the construction techniques that failed with other techniques. This process goes from generation to generation so that it is rooted in the culture of building their dwellings so that it becomes their local seismic culture [4,5]. Local seismic culture is related to local wisdom that is local ideas of suitable value and followed by local communities in responding to various problems to meet their needs, which have been implemented for generations [6]. Local wisdom is also called indigenous knowledge. In terms of the living culture, indigenous knowledge is the mindset and
behavior of people who create forms and technology to build houses, which are carried out by trial and error to become a safety system in their houses [7]. Local knowledge related to building houses can also be used for disaster mitigation because it is very contextual with local environmental conditions. In disaster-prone areas, the community and the government have efforts to reduce the risk of natural disasters in their region, called disaster mitigation. The community might make an ongoing effort of disaster mitigation activities through physical development, awareness of community understanding, and increased community preparedness in dealing with disasters [8,9]. The purpose of disaster mitigation is to reduce disasters' negative impact and increase the region's capacity. Urban resilience arises from the ability of local communities to respond to conditions when natural disaster threats occur. Urban resilience is a planning concept related to urban areas' ability to maintain the form, function, system when disruptions occur, and adapt to changes to anticipate future threats [10]. The local community can adapt to unusual environmental conditions. Local seismic culture as part of local wisdom already exists and is practiced by the local people of Bima in building their dwellings so that they are adaptive and responsive when an earthquake disaster occurs. This character must be continuously maintained to set a precedent for other regions in Indonesia that are prone to earthquakes. Thus, how local seismic culture in Bima can potentially create urban resilience in disaster mitigation, so it becomes a sustainable disaster-responsive district.

The purpose of earthquake disaster mitigation is to reduce earthquakes' negative impact by reducing the region's vulnerability and increasing the region's capacity to anticipate the next earthquake. Both objectives can be achieved if the local seismic culture still grows and develops in the community. The area's capacity increases if the community has technical competency and methods to build earthquake-resistant houses. This capability provides opportunities for the community to prepare, prevent, cope, and recover after a disaster. Local communities in Bima are adaptive and responsive when an earthquake strikes because local seismic culture still exists until now. For this reason, local seismic culture in Bima is fascinating to become a case study in the context of disaster mitigation for the resilience of its territory. This paper aims to identify the existence of local seismic culture to increase regional resilience in the context of earthquake disaster mitigation in the Bima Regency.

2. Methods
This study consists of three stages, as shown in Figure 1. The first stage is a literature study on local wisdom in disaster mitigation for regional resilience and about local seismic culture for disaster mitigation. The results of this literature study form the basic framework for reviewing case studies. The second stage is a case study of a local seismic culture that lives and develops in Bima Regency. We collected primary data through field observations and secondary data from BPS-Statistics of Bima Regency. We investigate the secondary data using distribution analysis. Data on the existence of wooden houses on stilts, how they are strengthened and maintained, and the sustainability of these wooden houses in Bima Regency was identified through field observation, and then descriptive analysis was done. The sustainability of this stilt house with wood material can increase regional resilience in Bima Regency. The third stage is a future outlook for local seismic culture as part of urban resilience planning in Bima earthquake-prone regency.

![Figure 1. Methods framework.](image-url)
3. Local seismic culture as local wisdom of people in Bima regency
The characteristics of local seismic culture in buildings are local resources, namely materials and local carpentry skills, building reinforcement and maintenance, and aspects of the sustainability of the building's functions [2, 4]. Local architecture in Bima is closely related to local seismic culture because of the houses on stilts with wooden materials built by local artisans and a part of people's local wisdom in Bima. This section discusses local seismic culture in Bima architecture in all three of these characteristics.

3.1. The existence of timber stilt houses
Wooden stilt houses are found in every village in Bima Regency. The typology of wooden houses in Bima is divided into four types according to the number of poles. They are houses on stilts with six poles (figure 2A), nine poles (figure 2B), twelve poles (figure 2C), and sixteen poles (figure 2D).

![Figure 2. Typology of timber stilt houses in Bima regency.](image)

In 2018, the total number of residential buildings in Bima Regency was 123,384 buildings, in which the highest number are in Sub-District Sape (14774 buildings) and the least in Lambitu Sub-District (1530 buildings), as shown in figure 3A. Figure 3B shows the percentage of residential buildings using brick, wood, and bamboo material in each sub-district. Houses using wood material still dominate in almost all sub-districts except in Monta, Madapangga, Woha, and Sanggar. This fact is very supportive because of houses with wood materials dominating in 78% of 18 sub-districts in Bima. Lambitu Sub-District has the highest 97% percentage, and then the second-highest rank is Wera District 92.2% (figure 5). With an average of 63.6%, houses with wood materials still dominate the types of houses in Bima Regency. The house form is a stilt house like the example in figure 2. The wooden stilt house is a vernacular house of the Bima community, which is still proven to exist today. All parts of this house, both structural and non-structural, use materials from local wood.

![Figure 3. Number of residential buildings and types comparison by material per sub-district [11].](image)
Building structures constructed with wooden materials have an outstanding response during an earthquake [12]. Correspondingly, traditional wooden frame constructions have better durability than masonry wall construction [13]. There was evidence from the past earthquake events; buildings with wooden construction proved to be able to survive than houses used brick walls. So, the existence of wooden houses on stilts in Bima is proof that this house has the adaptability of Bima's condition, which is prone to earthquake disasters. Its sustainability is proof that local seismic culture still lives in residential buildings for local communities.

3.2. Strengthens and maintenance of a building
Buildings in earthquake-prone areas need treatment and reinforcement to anticipate the occurrence of the next earthquake. Local people in Bima have a culture of working together to repair their houses. Figure 4A-4D shows the repair of Mr. Ismail's house in Mbawa Village, Donggo Sub-District, in August 2018. They repaired some parts of the house, namely the position of the structure posts, which were initially tilted, then re-ignited by lifting the house together (figure 4C), adding diagonal bars to the roof structure, and replacing the roof cover (figure 4D). Sloping poles occur because of buildings that are swayed by the earthquake. So, the position is tilted, but there is no damage to the material. However, it proves that wood material has a large deformation capacity with minimal damage under earthquake load [14]. The people also replaced a diagonal bar element on the pillar that held the stilt structure (Figure 4B). Social activities in maintaining buildings and strengthening the wooden stilt house structure have become part of the local seismic culture [2]. These social community activities can be part of disaster mitigation efforts through physical development and increasing community preparedness in dealing with disasters [8,9].

![Figure 4](image)

Figure 4. Repairing and strengthening of a stilt house on Mbawa Village, Donggo Sub-District 2018.

The local building expert in Bima led the building repairs assisted by the surrounding community. This opportunity is also part of an effort to transfer knowledge to the next generation. Thus, they can master carpentry skills related to earthquake-resistant construction techniques. The transfer of skill and knowledge is part of the sustainability of local seismic culture that supports the region's resilience for community preparedness in the face of the next earthquake [4,5].

3.3. The timber houses sustainability
Until now, people in Bima Regency are still building wooden houses on stilts. These facts are a sign that sustainability is still maintained, both in terms of material and craftsmanship. Figure 5A-5D shows the preparation for constructing a wooden house on stilts in Kole Village, Ambalawi Sub-District. Figure 5C shows a foundation made of concrete. This concrete replaces the flat stone foundation that is usually used in wooden houses on stilts in Bima. Figures 5A, 5B, and 5D show the wooden trunks that will be assembled into a wooden stilt house.
In Figure 6A-6D, we can see the construction of wooden houses on stilts with 16 poles completed in Kole Village, Ambalawi Sub-District. It uses teak wood for structural and non-structural building material. Figure 6B shows a very smooth wooden wall. A wall with a wooden frame and filled with wood panels has an excellent response to the earthquake in terms of energy dissipation capacity. For example, the walls of traditional Chinese houses with wooden frame structures with wood panels have better energy dissipation capacity than frames without wood panels [15]. So, the presence of wooden walls in the Bima stilt house is also an essential part of supporting the house's resilience in response to earthquakes.

The sustainability of local seismic culture can support the region's resilience in the event of a disaster. This culture is part of the efforts of local people to survive when disasters occur. Thus, it should be an inseparable part of the disaster mitigation program, a regional government program to improve its resilience. The challenge now is the availability of building materials that are a good quality timber at affordable prices. Besides, some people consider that wooden houses on stilts are old traditional houses.
For this reason, keeping the sustainability of local seismic culture requires the involvement of local governments.

5. Conclusion
This paper has discussed the existence of local seismic culture (LSC) in Bima Regency and how local seismic culture in Bima can increase regional resilience in the context of earthquake disaster mitigation. The first existence of local seismic culture was timber stilt houses, which still dominated Bima's type of houses. The second is community social activities to maintain and strengthen residential buildings to be better prepared to face the next earthquake. The third is the sustainability of wooden stilt houses in Bima. These facts become evidence that the LSC is part of the local Bima culture, which is part of the local wisdom. It is the community's response to environmental conditions prone to earthquake disasters and part of disaster mitigation efforts that have lived for generations. The LSC that lives in Bima's local community becomes an internal strength that has become a hereditary culture. Thus, this potential is significant for regional planning in the Bima Regency in developing the region's resilience. This study is the initial stage in developing the LSC approach model in planning urban resilience development in Bima Regency. Thus, complete data is needed relating to the needs of wood materials for building materials and human resources readiness to transfer knowledge and skills.

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