Disaster-friendly sundanese traditional building construction

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Abstract. Indonesia is one country that is highly prone to earthquakes because it is located at the juncture of four tectonic plates, namely the Asian continental shelf, the continental shelf of Australia, the Indian Ocean plate and the Pacific plate. In the southern and eastern parts of Indonesia there is a volcanic belt that extends from the island of Sumatra, Java and Nusa south eastern Sulawest, the sides in the form of old volcanic mountains and the lowlands are mostly dominated by swamps. The condition of potential and proneness to disasters such as volcanic eruptions, earthquakes, tsunamis, floods, and landslides. Indonesian society have a local knowledge for facing disasters. Local communities in particular areas have local knowledge for facing disasters. Such knowledge is commonly kept by members of the communities and applied to their environments, including houses. This research aims to describe disaster-friendly Sundanese traditional building construction. It employs the evaluation method, by comparing Sundanese traditional house construction to the standards of disaster-friendly construction. The results indicate that the Sundanese traditional building constructions have been qualified as disaster-friendly buildings.

1. Introduction
The phenomenon of an earthquake is one of the natural disasters that we can not predict around the world, including in Indonesia. Naturally these natural phenomena can not be avoided. This is because the plates that are in the earth's crust move actively. Effect of movements and collisions between the plates is what produces the tremor. One form of disasters that often occurs in Indonesia is earthquakes.

Problems faced by the countries in the world that is prone to earthquakes is how to make friendly home construction models earthquake to be safe and comfortable for humans which is connected with the local wisdom communities in Indonesia, especially Sundanese communities. Some examples of earthquakes in Indonesia, especially in West Java which many took many lives and property were earthquakes with a strength of 6.8 magnitude that a potential tsunami. Most of the fatalities were caused by falling debris died houses or buildings that do not withstand earthquake vibrations. This was due to a house or building was not designed to withstand earthquake loads. The concept of earthquake resistant buildings is essentially an effort to make the building into a coherent whole, which can not be separated by the earthquake. The application of this concept is one of them make a good and strong bond between building elements, the selection of appropriate construction materials, and the implementation of good and appropriate standards. In addition, local knowledge in the form of Sundanese traditional architecture should be one of the main reference in designing the model homes that are friendly to earthquakes.
In a static state, a building only bears the gravity, which refers to its own weight and live load (if any). When the ground shakes, the building receives the vibration which is transmitted to the top part through the foundation. If the building is rigid/stiff, it will follow the movement of the ground. The surface acceleration of a local earthquake directly affects building construction; this results in the maximum horizontal force on the building. The size of the force is equal to the mass of the building multiplied by the acceleration of the ground (Canadian Wood Council, 2003).

To minimize the impacts of earthquakes, the Indonesian Government has established SNI-176-2002, which is the planning standard of earthquake resistance for building structures. Some limitations of earthquake resistant building construction planning are:

- Building plans should be simple, symmetrical and not too long, 6 meters;
- Roof construction should use a material that is lightweight and simple;
- The foundation land should be dry, dense, and has uniform hardness (distributed hardness), and the basic foundation should be deeper than 45cm;
- The foundations need to be tied to one another by means of foundation beams.

The community awareness of the importance of Pengurangan Resiko Bencana (PRB) or Disaster Risk Reduction is getting better; this is indicated by many emergency simulations which are conducted in affected areas. The supporting facilities provided by the Government through the National Disaster Management Agency (BNPB), such as emergency shelters and early warning systems, are adequate. However, the community awareness is not accompanied by the understanding of how to create building structures and constructions that can reduce the risks of disasters, which can be learned from local architectures. Local knowledge (wisdom) is the knowledge developed in a society, which is obtained through a process of trials and errors to the physical environment, such as against earthquakes, floods, and many others. Such knowledge is mostly kept by local communities; it is commonly applied to their environments, such as buildings (houses).

2. Method
This research aims to analyse the Sundanese traditional building construction in withstanding earthquakes. It was conducted by using the descriptive-evaluative method. The research process was conducted by doing inventory analysis of building construction elements and comparing them with the construction standards of simple earthquake-resistant buildings from SNI-176-2002 Standard Planning Earthquake Resistance for Building Structure Building Institute in Indonesia.

3. Results and Discussion
The most typical Sundanese traditional building is imah panggung, which is a house with a pit under the floor, approximately 40-60cm. Panggung derived from the word pang and gung, which mean being put on the highest place (Nuryanto, 2006). Panggung is the most important form for Sundanese people, with long suhunan and jure. Long suhunan is the roof with the shape of a long ridge from front to back (like a saddle), while jure is a roof with a ridge forms a shorter or a so called triangular roof shield. The panggung shape dominating building/construction system in Tatar Sunda (another nickname for West Java Province in Indonesia) has engineering/technical and symbolic functions. Technically, imah panggung has three functions: not interfering water absorption field, the pit functioning as a conditioning space with air flow crossing for warmth and coolness, and the pit for storing firewood supply (Adimihardja, 2008).

The symbolic function of imah panggung is based on the belief of Sundanese people that the world is divided into three elements: handap (under world), ambu luhur (top world), and tengah (middle world). Tengah is the centre of the universe and man put himself at this centre. Thus, human habitation should be located in the middle, not at ambu handap (underworld/the earth) or ambu luhur (the world top/sky). Houses must be supported by poles which serve to divide the whole house with the lower and upper world. Furthermore, the poles should not be located directly on the ground; it should be given pedestals that separate the poles/house from the land. The pedestals are rocks called umpak (Adimihardja, 2008).
The structure and construction of the Sundanese imah panggung are light and simple, because most of the materials used are from the local environment and self-made (Figure 1). This can be seen from the foundation of the houses, which are stones taken from rivers, hills, or mountains. The walls are made of woven bamboos or wooden planks; the floor is made of talupuh or palupuh, which are shredded bamboos or woods. The roof frame is made of bamboos and woods, with hateup kiray and injuk as the roof cover. While the construction seems light and simple, it is strong and sturdy. It is proven by the durability/endurance of the construction during and after earthquakes. This condition can be seen in Kampung Baduy, Naga, Kasepuhan Ciptagelar, and Dukuh. The houses are sturdy; none of which collapsed.

![Figure 1. Structure and construction of Sundanese traditional imah panggung (Nuryanto, 2015)](image)

In terms of building materials, traditional Sundanese buildings have met one of the requirements of earthquake resistant buildings, which is made of lightweight materials, such as bamboos and woods. The advantages of wood as a building material have been revealed by Brostow et al. (2010); wood consists of two parts: the center which can resist compression, and the outer part which can resist tension (Figure 2). Wood, having low water content, has a better ability to resist compression. Furthermore, wood cells can continue the compression/pressure. Wood is a material which can support the development of green architecture.

Another material which is commonly used for Sundanese traditional buildings is bamboo. According to Sharma et al. (2015), bamboo has many advantages as a construction material; it is renewable and has wood-like mechanical properties. Bamboo fiber has many variations; it can be used for interior and exterior building materials. Tomas (2014) asserts that bamboo is a very flexible material and widely available; therefore, it should be used as an engineering material for houses and other buildings.
In general, the strength system of Sundanese traditional imah panggung uses bonding, pupurus connection, and paseuk (pegs). On the frames of the floor, walls, and foundations, beams are installed and connected, both vertically and horizontally using the pupurus (pen and holes); the connection uses ropes or rattan and wooden pegs. No nails, nuts, and bolts are used because they are prohibited by the custom and contrary to the rules of their ancestors (taboo). According to Felix (1999), connection pegs have an efficiency level of 60%, which is better than bolt connections that have an efficiency level of 30%, or nail connections that have an efficiency level of 50%. Structures and construction have close links; if one of them does not exist, the building cannot be constructed. "Euweuh rarangka can teu ngarangka, euweuh ngarangka wangunan can TEU ngadeg" – this means that there is no frame of the house that can be constructed. The arrangement of structure and construction of houses of the Sundanese community are based on the panggung form; they are divided into two types: handap and luhur. Handap is a structure located under the floor of the house, consisting of lelemahan (ground) and umpak/tatapakan (foundation). On the other hand, luhur is a structure located on the floor, such as pangadeg/adek (wall), lalangit/palapon (ceiling), and rarangka (frame). The structure is a separable part of the construction, because its functions support the strength of the building.

Umpak is constructed above the ground level, which is the foundation made of stone with a defined construction technique (Figure 3). Three types of Umpak are known: buleud, lisung, and balok. Buleud is a type of umpak which is round; lisung is trapezoidal and balok resembles a cube. Generally, people use the round umpak. According to local residents, umpak can be mounted in two ways: dina luhur taneuh, which is above the ground, and dina jero taneuh, which is partially buried in the ground. Commonly, they mount the umpak by burying it in the ground. Based in the analysis of the requirement for earthquake resistant buildings, the foundation used in Sundanese traditional buildings has met the requirement. They use foundations which have been bound to one another.
Luhur structure is differentiated into three parts: pangadeg, lalangit, and rarangka. Pangadeg structure is a frame collated based on two components: wall and floor. The wall structure is arranged based on three components: tihang, pangadeg/tihang adeq, pananggeuy and tihang nu ngabagi. It is made of bamboo woven with a braid system, and the board wall with sirih stacking system (see Figure 4). The pananggeuy and tihang nu ngabagi construction uses pupurus connection technique, and oblique hooked lip reinforced with nails, pegs, and ropes; it is also applied to sunduk awi.

On the floor structure, Sundanese community has three types of flooring: talupuh, papan (board) and bilik (chamber). Talupuh or palupuh is floor made of bamboo which has been stoned to a certain size as needed. The bamboo used is usually the Gombong type or Wulung type, which has a diameter of ± 15-20 cm and thickness of ± 12-15 mm. When it is cleaved and stoned, the width can reach ± 30 cm. The Sundanese community believes that the tapuluh floor has some advantages, such as easy to make and fit, inexpensive, as well as more beautiful look.

The lalangit and rarangka are suhunan structures, which are roof truss arranged based on two components: frames and ceilings (see Figure 5). The frames consist of two parts: nu mikul and nu dipikul. Nu mikul is the main frame, while nu dipikul is the supporting frame. The whole suhunan structure uses wooden and bamboo frames formed triangle frames. For the nu mikul structure, makelar
adeg (10x15cm) is placed perpendicular on top of the pamikul. Pamikul (8x15cm) is mounted horizontally, connecting the makelar adeg. On the right and left of the makelar adeg, jure suhunan is mounted with a slope of ± 30-45. Jure suhunan (8x15cm) connects the pamikul block, which lies beneath the makelar adeg at its upper end. On top of the makelar adeg, some members of the Sundanese community mounted a chock (5x10cm) horizontally. To strengthen the jure suhunan position, a chock (8x12cm) is mounted on the left and right of the makelar adeg.

![Diagram of friendly home construction earthquakes](image)

**Figure 5.** Friendly home construction earthquakes (Nuryanto, 2006).

In the structure of nu dipikul, there is gordeng or gording (6x12cm), which is placed on the jure suhunan horizontally based on the span of the frames. Some part of the roof does not use gordeng. Above the gordeng, people install layeus or rafters (5x7cm) vertically in the direction of the jure suhunan. The layeus connects the pamikul with the chock. Above the layeus, ereng or sloping (2x3cm) is placed parallel to the jure suhunan beam, starting from the bottom to the top. In general, bamboo layeus and sloping were used. To strengthen the position of jure suhunan, side brackets (5x5cm) were also mounted underneath with a certain slope. Some people do not use gapit, lesplang, pangereut, panglari, nunjang, wind ties and locking beams, due to material efficiency. Once the frame is complete, the roof cover can be fitted. The installation of hateup roof cover is easier than injuk, because the construction is not too complicated. In hateup construction, ereng is not needed because the roof cover has been adjusted according to the layeus distance ± 45-50 cm. Generally, the wood
connection techniques used are hooked-straight lip, hooked-oblique, and pen-holes, reinforced with rope and rattan. The connection and bonding techniques require thoughts and attention, because mistakes will cause serious damages.

On the suhunan structure or the roof of imah panggung, Sundanese traditional community, such as in Baduy Kajeroan, Kasepuhan Ciptagelar, Kampung Naga, and Dukuh Pantang, uses roof tiles (made of clay). Because it is prohibited by their ancestors, they call it teu wasa or teu wani. In their cosmology, using roof tiles (made of clay) means burying themselves alive, because only dead people deserve to be in tombs. "Jelema hirup keneh kunao kudu di ruang", meaning that living people should not be in the grave. Furthermore, using roof made of clay from the ground also means committing adultery with ‘mother’, as in their belief the land represents the earth which has the meaning of ka indung. “Manusa hirup tina saripatina taneuh” means that humans live from the essence/core of land. Taneuh or soil also has the meaning of death. Those who dare to use the roof will be kabendon (received anger) by the ancestors, such as pain, bad luck, and hard life. This also applies to other materials, such as asbestos, zinc roof, and other materials made of clay/land core. The materials are prohibited to use as it is contrary to the ancestors’ rules. The roof structure of Sundanese traditional buildings uses a lightweight material, which is in line with the requirements of earthquake resistant building construction. For example, a traditional house on Cikondang - located at RT 03, RW 03, Cikondang, Lamajang Vilage, Pangalengan, Bandung Regency – still stands although the area has been affected by an earthquake measuring at 7.3 magnitude occurring Wednesday, September 2, 2009. The local knowledge is reflected by the house, answering the question whether local buildings can withstand an earthquake (Pikiran Rakyat, September 7, 2009).

Unlike hundreds of houses which were cracked up or collapsed, the 12 x 8m house stands strong. Almost nothing has changed. The roof is made of fiber and the wall is made of woven bamboo. There was no damage, except factors related to the age of the building and lack of maintenance of the building, which can be seen from the windows of the house and the door, as well as the 9 sereseg on each window. The advantage of this house is it is earthquake-resistant. It is due to the belief that it is taboo to make houses from stones, because it is prone to earthquakes. The use of roof which is made of clay is also taboo, as it is believed by the Sundanese community that living people should not live under the land (represented by the clay).

Figure 6. The various typologies of vernacular houses in the southern part of West Java (Triyadi & Harapan, 2008)
The results of research conducted by Triyadi and Harapan (2008) showed that the vernacular buildings in the southern part of West Java (Figure 6) are examples of houses that have withstood earthquakes striking the area. The buildings are able to survive, while many other buildings (non-vernacular) collapsed. This is evidence showing the application of indigenous knowledge of Sundanese (East Java) community to buildings. Such knowledge is one of potentials which should be explored through research/fieldworks, so that data on the indigenous knowledge can be used by communities, especially local communities.

4. Conclusions
The strength of Sundanese traditional imah panggung uses bonding, pupurus connection, and paseuk (pegs). On the frame of the floor, walls and foundation, the beams installed use pupurus (pens and holes); they are also tied with fiber ropes or rattan and wooden pegs. No nails, nuts and bolts are used, because they are prohibited by customs and contrary to the rules of their ancestors (taboo).

In Sundanese traditional imah panggung, iron nails or modern construction/buildings parts are rarely found. For connecting the poles, bamboo paseuk or rope made of palm/coconut fibre are used. For the roof, the houses use fibers, palm leaves or thatch leaves. It is very rare that Sundanese traditional houses use roofs made from clay. Another interesting aspect is the materials used in the houses. It is impossible that booths with thin walls and wooden floors are used by a community which has barbaric civilization. Houses for Sundanese communities are not for protection from enemies, but from nature, such as rains, wind, sunshine, and animals.

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