A review of vertical evacuation on tsunami mitigation case

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Abstract. Banda Aceh City was hit by a tsunami at the end of 2004. The experience of this great disaster directly or indirectly has led to many problems that are a must in finding the right solution. It is very important to do in order to minimize the disaster victims of the tsunami in the future. During the rehabilitation and reconstruction period after the 2004 earthquake and tsunami, between 2005 until now, various mitigation efforts have been carried out. One of the tsunami mitigation efforts is to build tsunami evacuation buildings. The city of Banda Aceh is one of the cities in Indonesia that has vertical tsunami evacuation facilities such as escape building. Although it still does not meet the expected availability standards, it can be called the right initial step for Banda Aceh City in the face of the tsunami disaster in the future. However, its existence will be in vain if the community does not use it to its full potential in their daily activities. This study evaluates the effectiveness of the escape building for vertical evacuation based on some supporting literature reviews.

1. Background
The December 26th, 2004 tsunami caused by the 9.1 SR earthquakes on the ocean floor of the Indian Ocean (west of Aceh) hit Aceh. The tsunami caused hundreds of thousands of people dead and missing, destroying thousands of homes, schools, office buildings and everything in front of the tsunami. In numbers, it caused the loss of 60,065 lives and damaged 21,412 houses in the city [1], [2]. After the disaster occurs, various mitigation efforts are carried out, from the emergency response to the rehabilitation and reconstruction period with all capabilities. These efforts involve many parties, both from within and outside the country. The experience is felt directly or indirectly, has spawned many problems that become challenges to find the right formula. This is done to minimize the tsunami disaster victims in the future.

During the rehabilitation and reconstruction period after the 2004 earthquake and tsunami, a period between 2005 and now, various mitigation efforts have been carried out. One of the tsunami mitigation efforts is to build tsunami evacuation buildings. The reason is that of the relatively flat topography of Banda Aceh which is on average only 80 cm in height from sea level [3]. Rescue buildings have been built at several points located in post-2004 tsunami-prone zones in Banda Aceh. Many rescue buildings were built at points prone because the zone has been re-populated either by residents who used to live there or even newcomers ([4], [5]).

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2. Literature References

Tsunami comes from Japanese. "Tsu" means harbor, "nami" means wave so that it is generally interpreted as a great tide of the sea in port or other words coastal / waterfront area [6]. According to Ministerial Regulation No EMR. 15 the Year 2011, Tsunami is a wave caused by geological processes under the sea in the form of earthquakes, volcanic eruptions, landslides, and the fall of the meteor towards the sea. Tsunamis occur due to earthquakes at shallow depths, as most of the energy released into the ocean water pools above them. The submarine earthquake strikes a large mass of seawater in a powerful beat. The backwaters are crashing at speeds of up to 800 km / h, as they approach the shore the waves slow down but push upward, slam into the land, and destroy whatever is behind the shore.

![Image of tsunami incidence due to fracture]

**Figure 1.** Illustration of tsunami incidence due to fracture.

The earthquake that caused tsunami including:
- Earthquakes centered at sea and shallow (0 - 30 km)
- Earthquakes with a power of at least 6.5 on the Richter scale
- Earthquakes with rising fault patterns or falling faults

Mitigation is a series of efforts to reduce disaster risks, both through physical development and awareness and increased capacity to deal with disaster threats. According to McDonald [7], mitigation includes all activities to prevent emergencies, reduce the likelihood of an emergency, or reduce the deleterious effects of an emergency that cannot be avoided. In the event of a disaster, the most important concern is how to overcome the impact. The more urgent to look for survivors and guide them safely, provide temporary relief and shelter, stabilize the situation, and clear the debris.

In the context of disaster risk reduction, the paradigm shift from disaster management to disaster risk reduction has become one of the government's obligations. The Government is obliged to protect the life and livelihood of the people, including the protection of disasters in the context of realizing common prosperity. To mitigate the potential impacts of a disaster, it is necessary to establish risk identification that is an interaction of threats, vulnerabilities, and capacities. These three components form the basis of the risk assessment generated as an estimate of the impact of the disaster.

The steps that need to be done in the preparation of disaster risk identification in a region include:
- a. Identification of Threats
- b. Identification of Vulnerability
- c. Identification of Capacity
- d. Identification of Risks
Vertical evacuation structures should be easy to reach and evenly distributed throughout the tsunami inundation zone. Site location will be depending on how much time it takes for people to reach its structure. Vertical evacuation structures not only must able to withstand tsunami waves and debris (built-in trash) but must also withstand previous earthquakes and remain functional. The structure should not look damaged after an earthquake, for example, major cracks in walls or other signs of damage as people will refuse to enter the building [9].

- Types of Vertical Evacuation, according to FEMA 646a [10], are:
  - Natural or artificial highlands
  - Parking Lots Building
  - Community Facilities Building
  - Commercial Building
  - School Building
  - Existing buildings.

- Vertical Evacuation Structure Needs Analysis according to FEMA 646a [11], is as follows:
  - Topographic area;
  - Age and type of construction of existing buildings;
  - Number of residents and visitors in an area;
  - Population diversity due to seasons and other upheavals;
  - Number of vulnerabilities and population size;
  - The readiness of population and visitors, and
  - Emergency management and event response readiness.

- The FEMA P646 guidelines stated that tsunami rescue buildings should have the following design features [12]:
  - A strong system with the spare capacity to withstand extreme power;
3. Methods
The method used in this study is by reviewing the existing literature. In addition to the review, this study will also use observational methods in order to compare some of the existing Tsunami Evacuation Building in Banda Aceh with the Tsunami Evacuation Building in Japan. The factors that will be compared and observed is whether the building has been used optimally and its potential in saving human lives when disaster strikes.

4. Discussion
Japan is a country that has experience of the tsunami which often occurred in almost all areas. The latest tsunami occurred on March 11, 2011. The tsunami was caused by the 9.0 magnitude earthquake in the Pacific Ocean Tohoku, Japan. The tsunami killed more than 10,000 people and destroyed towns which also caused an explosion at the Fukushima nuclear power plant. Japan with its technology has many models of mitigation to face the tsunami in the country. One model is a rescue building built with various models and functions.

The Rescue Building at Shirahama Beach Resort in Japan is designed to keep people safe when a tsunami strikes. Concrete Building in Kaifu, Japan, used as a vertical evacuation. Buildings like this are easy to reach, easy to navigate, and also protect the destructive power of the tsunami [13]. In Kise, Japan, rescue building also functioned as a library at the bottom. Buildings like these can be used as community centers and can generate income that can be used for its operations cost.

Figure 3. Tsunami Evacuation Building in Shirahama Beach Resort, Japan

Figure 4. Tsunami Evacuation Building in Kaifu, Japan.
Meanwhile, Banda Aceh is one of the cities where Tsunami occurred back in 2004, after direct observation, not used the Tsunami Evacuation Building to its maximum potential. These tsunami evacuations building also not functioned on a daily basis, this causes the facilities and infrastructure either disfunction or damaged, even if most of these buildings have been designed in accordance to Indonesian national standard and the possibility of site effects. The site effect is controlled by many factors [14]. Incorporating this site effect into building design is crucial for seismic-resistant building ([15], [16]).

Tsunami evacuation buildings in Banda Aceh have fulfilled the criteria of spatial comfort. The spatial comforts are such as good air circulation, sufficient daylight and good outlook [17] of strong structure ([18], [19]). However, from the picture above, it can be seen that the building the building is empty, and some of the rooms look neglected. This building does not function as public facilities for the community. Unlike the Tsunami Evacuation Building in Japan where the ground floor is also functioned as a library. Another evacuation building located in Banda Aceh is Evacuation buildings in Gampong Deah Glumpang. This evacuation building is also aid from Japan. The condition of the building is not functioned in everyday activities. It is unfortunate that this grand building is not used to its full potential.
This condition can be improved by opening these buildings to the public. In the mitigation process, the opening of the evacuation building to the community can also increase the trust of the surrounding community towards this evacuation building. The desired goal in this method by opening the building to the public is for people to have a certain level of trust and a sense of familiarity towards the building, so that during the disaster, especially when tsunami happen in Banda Aceh, people will immediately evacuate themselves directly to this evacuation building without thinking twice.

Another evacuation building is in Gampong Pie, Meuraxa Subdistrict, Banda Aceh, unlike other evacuation buildings that have special functions as evacuation buildings, it is only functioned as an office and study center. The rescue building belonged to Syiah Kuala University and became one of the university's study centers, the Tsunami and Disaster Mitigation Research Center (TDMRC).

TDMRC can resist earthquake up to 10 Richter scale. Based on the direction of the upcoming wave, the position of this building has taken into account. But unfortunately, the floor below (1st floor) is very massive with partition placement is predicted to inhibit the lunge of tsunami waves in the future. The 2nd floor of this rescue building only has a height of about 5 m from the ground. The 2nd floor can not be used as a safe place for human evacuation if a tsunami hit with level as on December 26, 2014. The 3rd floor of this building has a height of about 10.2 m from the ground surface. Thus this floor can be used as a place of evacuation if disaster tsunami arrived. Likewise, the 4th floor is open which can accommodate refugees who evacuate themselves to the building.
The existence of the Aceh Tsunami Museum (MTA) is relatively good in responding to the need for vertical evacuation during the earthquake with the threat of a tsunami. On 11 April 2012 after the M8.5 earthquake occurred, surrounding residents and students and teachers from SMP Negeri 1 Banda Aceh located not far from the Aceh Tsunami Museum to evacuate themselves to the museum. When the panic happens on the main evacuation path on Iskandar Muda road, it is difficult to avoid the occurrence of bottle-neck. The museum became an effective alternative for self-evacuation.

Furthermore, the accessibility of Museum Tsunami Aceh has been equipped with lifts, stairs, and ramps. The museum has 2 units of stairs located in the south and north of the building. The ramp is available starting from the east side of the building which is connected to the central area of the museum by passing over the pool located in the center of this museum, to the 2nd floor at 8 m and continuing to the 3rd floor at the height of 12 m.

5. Conclusion
These buildings should be used optimally; one effort that can be done is to use the building as public facilities. The simplest example is to use the lower part of the building as a library, this example is chosen because the library can attract people, especially children, so it can also increase people’s trust towards the building during a tsunami occurs or other disasters. Although Banda Aceh already has 5 evacuation buildings, there are still many things that need to be addressed, for example in addition to the opening of the building to the general public, is the management of building's maintenance and the improvement itself. When associated with public trust, buildings that are well maintained, and look solid from the outside will create a high level of trust in the evacuation process when disaster comes.

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