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Typology of House in Earthquake Disaster Area: A Case Study of Bobanehena Village, West Halmahera

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Abstract– Bobanehena village is geographically located in the coastal area of subduction route, causing the village to be vulnerable to frequent earthquakes. The 5 SR earthquake struck the village in 2015 caused heavy damages to people's houses. The houses that are susceptible to damage by earthquakes, resulting in many casualties. This research aim is to identify the types of house in Bobanehena village, West Halmahera Regency. Typological data of houses can be used as database for vulnerability assessment in Bobanehena village. The method used was field study, structured interviews, and documentation using field observation to determine the physical condition of houses which are responsive to earthquakes. The results of the research indicate that the residence in Bobanehena village, West Halmahera Regency is in the form of the spatial distribution of earthquakes-prone housing, which forms a longitudinal pattern and expanded to the coastal area. The characteristic of settlement distribution is unorganized and clustered, so it appears to be in a random pattern. The typology of earthquake-prone residences in Bobanehena village can be classified into three types, namely Stengah Leger house, Fala Kanci traditional house, and modern house. In addition, from those three types, Stengah Leger and Fala Kanci are responsive to the earthquake load, for it uses wooden frame construction.

Keywords: Building typology, earthquake resistant building, settlement, earthquake.

Introduction

Earthquake is any sudden shaking of the ground due to the sudden release of energy caused by the straining rock masses in the earth's crust (Pawirodikromo, 2012). The sea regions of Maluku, Ternate, Tidore, parts of North Halmahera and West Halmahera Regencies, Kasiruta Island and Obi Island have the potential for higher magnitude earthquakes (Lumintang, *et al*, 2015). West Halmahera is located on the ring of fire where it is meeting points between three earth plates, so that there are two types of earthquakes that could strike these areas, namely tectonic and volcanic earthquakes.

It is recorded that there are up to 1.001 tectonic earthquakes in West Halmahera from the beginning of November to December 2015 with a magnitude of less than 5 SR (BMKG of West Halmahera, 2015). Earthquakes that occur are swarm type earthquakes that are very rare because they rarely occur in other areas. The swarm event is mostly distributed at a depth of 5 to 12 km in the southeast of Mount Jailolo which occurs because of stress changes around the magma region of the volcano (Nugraha *et al.*, 2017). The area with building damaged severely due to the earthquakes was Bobanehena Village. The data on building damage due to earthquakes in December 2015 showed that 113 houses in Bobanehena Village were severely damaged (BPBD of West Halmahera, 2015), most of which were modern house types with concrete materials, while the traditional houses only got minor damages since they used wood-frame construction. Wooden frame buildings are more resistant to earthquakes in general because of their light mass which results in small inertial forces due to earthquakes with a large force/mass ratio (Directorate General of Human Settlements, 2006).

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Building typology is required in a study investigating the possible associations of building elements to attain a classification of architectural organisms by types (Vidler, 1976). Type is something that before the shape; the type is a principle that remains unchanged although changes in shape (Rossi,1982; Jo, 2003). Typology analysis can be done by examining, classifying, recognizing and describing residential buildings in various historical eras and in various similar contexts or different contexts (Remali *et al.,* 2016). The function of building typology is to compose building elements so that they can be identified to be classified according to certain architectural purposes. The objective of this study is to types of a residential building in earthquake-prone areas that could be used as a database for vulnerability assessment of building against disaster

Research Method

This is a qualitative research conducted by digging information directly at the earthquake-prone settlements. The number of samples was 3 houses selected with the random sampling method. The data collection techniques were field survey and interviews with the homeowners. The empirical data of house building collected including floor plans, views, and photos of the house, especially building a structure and spatial planning patterns inside the house.

Result and Discussion

Research Location

The location of the research was the residential areas in Bobanehena Village, Jailolo District, West Halmahera Regency. The area of Bobanehena village is 10 km² which is divided into 9 Neighborhood (RT) and 3 Hamlets (RW). In 2018 the total population is 1,989 people of 991 women and 998 men with a total of 482 family heads (Bobanehena Village Profile, 2018). The majority of the people is farmer, breeder, and fisherman due to the influence of geographical conditions in that region. A total of 369 units of the house are spread in each RT, with 282 units of permanent house and 87 semi-permanent house. Some houses are not occupied because they have a fairly severe crack on the wall and column elements.

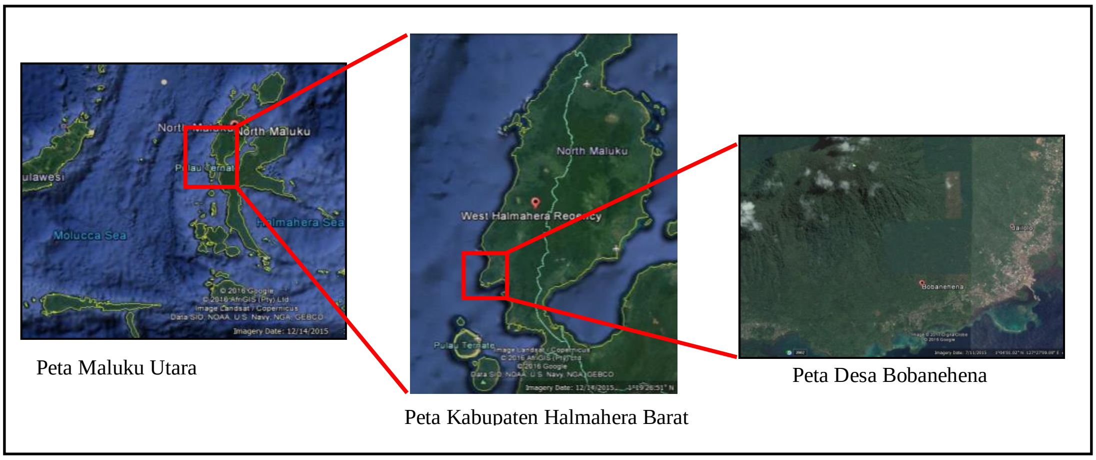

Figure 1. Research Location

West Halmahera is close to the subduction path so it has two types of earthquakes, namely tectonic earthquakes and volcanic earthquakes. The tectonic earthquakes are caused by plate movements and collisions including Mayu ridge zone (Maluku sea plate), Sangihe earthquake zone and Halmahera-Irian earthquake zone. The active fault sources for earthquakes includes Sorong fault while the complex source of earthquakes includes Obi fragment earthquake zone and Banggai-Sula fragment earthquake zone. The tectonic earthquakes are dangerous if they cause a fault, allowing a tsunami to occur. The volcanic earthquakes occur when Gamkonora and Ibu volcanic eruptions are in a small-scale and generally less dangerous (BMKG of North Maluku, 2001). Such conditions cause Jailolo region to experience frequent earthquakes.

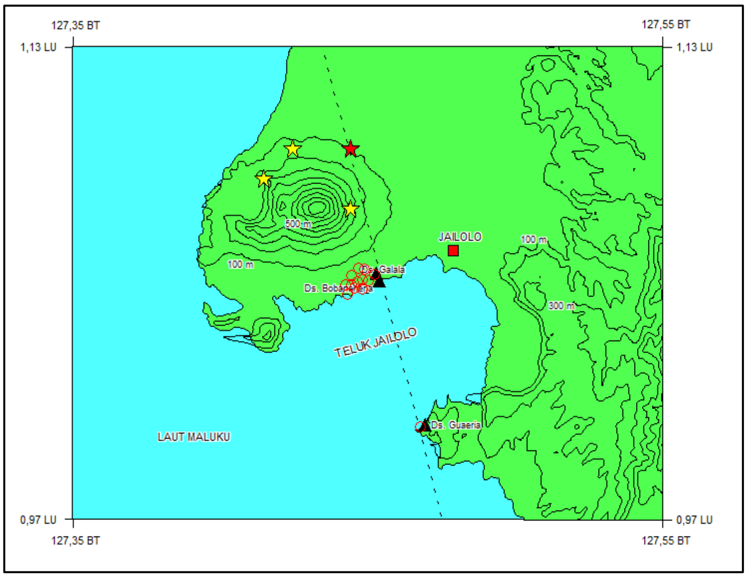

Figure 2. Jailolo Earthquake Map on November 20th, 2015.

(Source: Volcanology Centre and Geological Disaster Mitigation, Ministry of ESDM)

Settlement Distribution Pattern

The settlement distribution pattern of Bobanehena Village extends to the road and develops towards the coast. The characteristics of the settlement distribution pattern are in the form of clusters and unorganized so that the pattern appears to be in a random shape. Geographically, the western area of the settlement of Bobanehena Village is Jailolo mountain peak and the eastern is the coastal area. The population density in this settlement is 90 people/km (BPS of West Halmahera, 2018).

Types of residential houses in Bobanehena Village are classified based on the types of buildings that are responsive to earthquake loads. There are three house typologies from a total of 369 housing units. Those three types are a modern house, traditional house, and semi-permanent house (*stengah leger*). They are distinguished based on the material used, building structure, and resistance to earthquake loads.

When 5 SR earthquakes stroke in 2015, 317 housing units were damaged and 52 housing units survived the disaster. From the data of 317 damaged housing units, it was then classified into 131 units were severely damaged, 97 units were moderately damaged and 89 units were minor damaged. Most of the houses that were severe to moderate damage used concrete materials for construction, while the houses with minor damage used wooden construction materials. On the other hand, the 52 units that survived the damage were generally traditional houses such as the *Fala Kanci* which also used the wood materials for its mainframe construction.

Figure 3. Settlement Pattern in Bobanehena Village, Weth Halmahera

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During the post-earthquake reconstruction, the government gave aid in the form of wooden material, so that currently many houses there use the wooden materials. However, drawing from their local wisdom of Bobanehena, the villagers created a new type of house built from wood and combined with concrete materials. The locals call it a *stengah leger* house.

Building Typology

The shape of the residential buildings in Bobanehena village can be identified through building facade, floor plan, space configuration, structural system, and construction. The classifications of responsive earthquake house are characterized as a floor plan that facilitates emergency evacuation, no cracks on the walls, columns, beams or foundations, joints of structures between columns, beams, and foundations.

Building Facade

The building facade is one of the visual elements that are firstly observed and foremost in architectural work (Sastra, 2013). The visual impression may give a clue to identify the building typology. The facade components consist of gates and entrances, ground floor zones, windows and entrances to buildings, guardrails, roofs and building endings, as well as signs and building ornamentation (Krier, 1983). The facade usually implies the microcosmos (culture) when the building is constructed, describing the criteria for order and arrangement, and expressing signs and ornamentation and decoration (Krier, 1988; Arif, 2014). The building facade in the residential houses in Bobanehena village presents a distinctive form by prioritizing the functionality of the structure as shelter/living space. The facade of traditional houses such as *Fala Kanci* has its own characteristics, where the building is an old house characterized as a traditional house in North Maluku. In contrast, for other types of house, facade displays the shape of the modern house despite expressing its original materials.

	A semi-permanent house using a combination of concrete and wooden materials. The main frame construction is wood, while the construction of the lower wall uses bricks and the upper half of the walls uses a wooden board. The locals call it *Stengah Leger* house. It has a simple facade and natural material exposure.
	Traditional house has a typical and aesthetic building facade. There are four columns supporting the front porch built in bench between columns. The center of the facade has a door and there are unique windows on the left and right. The window and door frames are made of wood mounted vertically and function as supporting structure for beam and roof. Another uniqueness is the ventilation above the windows and door.
	Modern house using iron-reinforced concrete. The building façade exposes the concrete material without finishing. Modern house is usually characterized by a door in the middle and windows on the left and right sides. The left window functions as a window to the bedroom, while the right functions as the living room window. The roof shape is gabled with zinc material.

Figure 4. The Type of House in Bobanehena Village, Weth Halmahera

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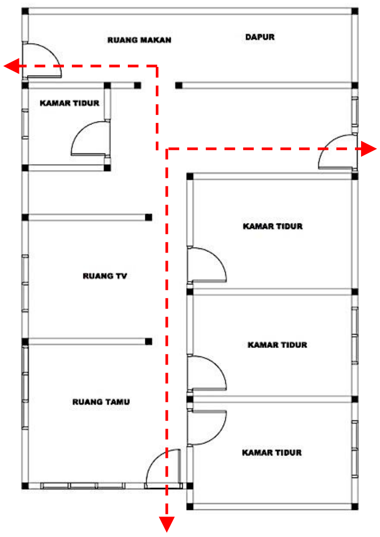
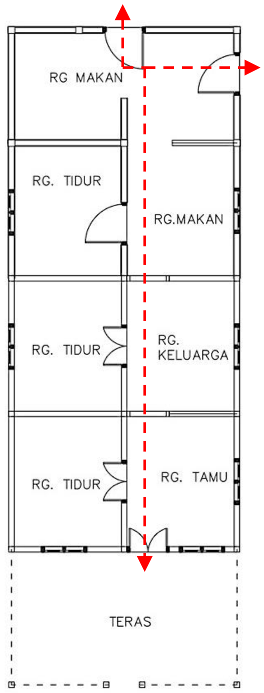
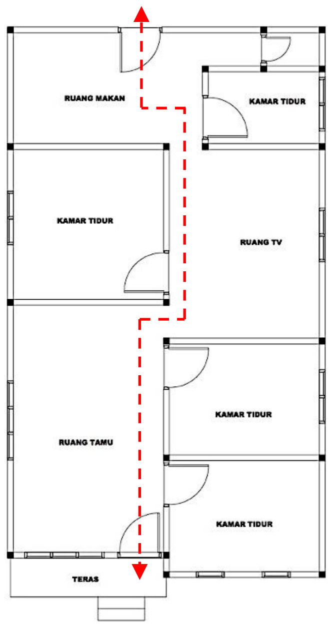
Building Plan Shape

The building plan shape of houses located in the earthquake-prone areas should be designed not only as a circulation network in the building but also as an evacuation route for disasters. The linear, grid and radial circulation patterns are good as evacuation routes because those patterns facilitate the building occupants to quickly reach the gathering point or exit from the building. The residential in the Bobanehena village are generally one-story house with a simple space pattern so that the circulation can facilitate the movements of the occupants inside the house. However, among the several houses observed, only the type of *Stengah Leger* house and traditional house are very responsive to disaster evacuation route by the space patterns.

<table>
<tr><th>Stengah Leger House</th><th>Traditional House</th><th>Modern House</th></tr>
<tr><td>
</td><td>
</td><td>
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<tr><td>The floor plan of Stengah Leger house forms a linear pattern with two exits located in opposites facilitating the evacuation routes.</td><td>The floor plan of traditional house forms a linear circulation pattern so it facilitates the evacuation routes.</td><td>The floor plan of modern house forms a linear circulation pattern yet it has some turn points so this type is quite difficult for evacuation routes.</td></tr>
</table>

Figure 5. The Floor Plan of the House Type

Building Structure

The housing construction can be identified from the structural system and building materials used. The construction identified including the foundation, floor, column and beam, wall and roof constructions. In the three types of residential building in this village, each type has a different structural system and construction. The structural system of the houses are mostly using the rigid frame structural system with concrete and wooden materials or a combination of the two materials. The traditional houses particularly has a typical structural system and construction, where there are many structural elements used that are very responsive to the earthquake loads.

a. Foundation Construction

Stengah Leger House	Traditional House	Modern House
		
It uses mountain stone or river stone for the foundation with a mixture of cement and sand.	It uses a material composition of river stone or coral reef. Such foundation construction is found in *Fala Kanci* traditional house.	It tends to choose a lane foundation because it is generally a one-story building.

Figure 6. The Foundation Construction of House Type

b. Floor Construction

Stengah Leger House	Traditional House	Modern House
		
It uses unfinished concrete materials.	At the beginning of the construction of this house, the floor construction is only in the form of ground. However, it now changes into unfinished concrete materials.	It uses unfinished concrete materials and some are using ceramic/tiles.

Figure 7. The Floor Construction of House Type

c. Column and Beam Construction

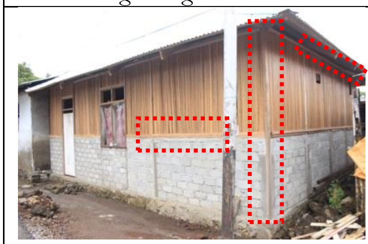
Stengah Leger House	*Fala Kanci* Traditional House	Modern House
		
The main construction of columns and beams uses wooden frames. There are 2 kinds of beams; the first serves as the support for wall using wooden material while the second beam serves as the support for roof construction.	The construction of columns and beams uses wooden frame which has its own characteristics because the bearer beam is mounted horizontally on the center of the wall. The joints between the beams and columns are wooden pegs.	The construction of columns and beams use iron-reinforced concrete. The earthquake forms many cracks in the joints of columns and beams, as well as sloofs and columns.

Figure 8. The Column and Beam Construction of House Type

d. Wall Construction

Stengah Leger House	*Fala Kanci* Traditional House	Modern House
		
It has a unique wall construction because it combines two materials, which is concrete and wood. Concrete is at the bottom and wood at the top.	*Fala Kanci* traditional house has its own uniqueness and distinctiveness, where the wall is made of combination materials of *ancak* bamboo and *kalero* (burnt coral reefs).	The wall is plastered with concrete material causing the walls of this modern house cracks a lot when an earthquake happens.

Figure 9. The Wall Construction of House Type

e. Roof Construction

Stengah Leger House	Traditional House	Modern House
		
The roof frame construction uses wooden material with wooden joints following the gable shape.	It uses gabled shape, with a lower slope than that of houses in general. The main structure of roof frame is wooden material and zinc for the roof.	It uses concrete on façades list with a combination of trestle frame structure with wooden material.

Figure 10. The Roof Construction of House Type

From the three types of house in Bobanehena village, each of them has its own characteristics. *Stengah Leger* house which is a new type of house designed by the Bobanehena villagers, is now developed by the residents. Recalling the earthquakes in 2015, many residents has shifted to use wooden materials for supporting the main structure of their houses. The wooden frame structure is very responsive to the earthquake loads, so *Stengah Leger* type is fairly well to be applied on houses in Bobanehena village. The traditional house is also earthquake resistant. It is because when the earthquake strikes, *Fala Kanci* traditional house is slightly damaged, both on building structures and non-structures. The type of *Stengah Leger* and *Fala Kanci* traditional house are recommended for building houses in Bobanehena village which have earthquake vulnerability.

Conclusion

The spatial distribution of earthquake-prone settlements in Bobanehena village, West Halmahera Regency forms a linear pattern along to the road and expanding towards the coast. The characteristics of the settlement distribution pattern are clustered and unorganized, therefore it appears to be random. The house typology in the earthquake-prone areas of Bobanehena village can be classified into three types, namely *Stengah Leger* house, *Fala Kanci* traditional house and modern house. *Stengah Leger* house is a new type of house created by the residents utilizing the available materials which is a combination of wooden and concrete materials built as one of the houses that can survive the earthquakes. *Fala Kanci* is a traditional in this village that has a construction system responding well to the earthquake loads. Modern house is the dominant type of house in this village despite its vulnerability to earthquake loads. As the consequences, many houses were damaged during the earthquakes. *Stengah Leger* and *Fala Kanci* traditional house can be used as model/pilot houses for the earthquake-prone areas with current architectural style modifications.

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