Evaluation of Compatibility of Simple Residential Structures with Earthquake-Resistant Residential Technical Guidelines

Muhammad Syarif[1], Andrial Imran[2], Maria Menung Migo[3], Sri Astika[4]

[1,2,3] Civil Engineering Department Politekinik Negeri Nunukan
Jl. Limau Sedadap, Nunukan Selatan, Nunukan, Kaltara- Indonesia 74482
[4] Business Administration Department, Politekinik Negeri Nunukan
Jl. Limau Sedadap, Nunukan Selatan, Nunukan, Kaltara- Indonesia 74482
muhammadsyarif837@gmail.com[1], andrialimran@pnn.ac.id[2],
mariamenungmigo@pnn.ac.id[3], sriastika99@gmail.com[4]

Abstract. In Indonesia, earthquakes generally cause human casualties, property victims, and shelter. The earthquake did not cause direct human casualties but was caused by the ruins of buildings during the earthquake, hitting people around them. What can be done is disaster mitigation, one of which is by promoting the use of earthquake-resistant building construction, which refers to the Indonesian National Standard for Earthquake-Resistant Buildings, SNI 1726:2019. The purpose of this study is to examine the application of the Indonesian National Standard (SNI) for earthquake-resistant buildings in residential housing in the Nunukan area. Quantitative, qualitative, and participatory methods were used in solving problems in this study through surveys and questionnaires, in-depth interviews, and socialization with residents. Random sampling determination provided that the respondent was residing in a simple house made of brick or adobe walls with a roof made of wood. The survey and questionnaire were conducted in four villages in Nunukan Regency, namely East Nunukan Village, Central Nunukan Village, and South Nunukan Village, with a total of 160 respondents. The data analysis method uses descriptive statistics in the form of a table of each variable and the relationship between variables and bar charts. The table is used to describe the conditions of the SNI application level. The results showed that only 60 percent of earthquake-resistant building requirements were applied to residents' residences in the Nunukan area.

Keywords: Earthquake-resistant house, Indonesian National Standard (SNI)

1. Introduction

Humans need a house as a place to live to meet their needs, shelter from the weather and wild animals, and survive natural disasters such as earthquakes. With the high frequency of earthquakes in Indonesia, existing buildings, including residential houses, should be built taking into account the possibility of an earthquake. Basically, a building is said to be earthquake-resistant if the structural elements of the building are strong against all the loads it receives, including earthquakes. In addition to being strong, the structure of the building must also be able to deform during an earthquake. That is, when an earthquake occurs, the building must be able to follow the earthquake force it receives and experience a large deflection without breaking any structural elements. The risk of an earthquake occurring is very high in the territory of Indonesia, so the risk of buildings experiencing structural damage is also very high, both due to poor planning and implementation or even because earthquake resistance has

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high, both due to poor planning and implementation or even because earthquake resistance has not been designed at all. In Indonesia, there is an Earthquake Resistance Planning Standard for Building Structures (SNI 1726:2019). This standard is a substitute for the Indonesian National Standard SNI 1726:2012 and is a requirement in planning earthquake-resistant buildings. It is necessary to apply the Indonesian National Standard (SNI) for Buildings for Earthquake Resistance in residential areas in the Nunukan area.

2. Method

This study used qualitative, quantitative, and participatory methods together. The focus of the quantitative method is on the distribution of questionnaires containing pre-arranged questions, while the qualitative method is carried out by asking questions directly and having the correspondents answer directly, as well as making observations in the field. Participatory method by providing counseling about earthquake-resistant houses for builders. This study basically collects two data sources: primary data derived from survey or questionnaire results and in-depth interviews. The survey/questionnaire was conducted in 3 sub-districts in Nunukan Regency, namely South Nunukan sub-district (Jl. Limau, Sedadap, and Sei. Jeppung neighborhoods), East Nunukan sub-district (Cik Ditiro neighborhood and the Port), and Nunukan Tengah sub-district (Jl. TVRI neighborhood). The respondent's condition is to live in a simple house made of brick or adobe walls. All kelurahan use the same list of questions (questionnaires), which are equipped with instructions for filling in the answers. In-depth interviews were conducted to explore the respondent's knowledge if the respondent did not know the intent of the questions in the questionnaire because they were technical in nature. Besides that, the houses that have been built need direct observation from the interviewer. Socialization by providing counseling was carried out in the Nunukan Selatan Village area to provide knowledge to residents about the causes of earthquakes, how to mitigate in the event of an earthquake disaster, and the SNI for earthquake-resistant buildings. Data from the survey results in three sub-districts in the Kab. Nunukan (Kelurahan Nunukan Selatan, Nunukan Tengah, and Nunukan Timur) are classified based on the variables to be studied. The relationship between variables is tabulated, then depicted as a bar chart. The table is used to describe the level of implementation of SNI.This research was conducted based on the facts in the field, which show that cases have not been consistently fulfilled, both from the planning and implementation aspects that have occurred in a number of regions. The design used is to analyze houses without floors. The research that is used is to look at the work model as evidenced through photographs, then engineer the original form. The basic requirements for earthquake resistance are a practical guide in the construction of simple 1-story buildings with residential functions. Fulfillment of the basic requirements for earthquake resistance aims to create a single dwelling house that is safer against the impact of damage caused by an earthquake. The basic requirements for earthquake resistance include:

1. Good quality of building materials;
2. Existence and suitable structural dimensions;
3. All the main structural elements are well connected;
4. Good workmanship and quality

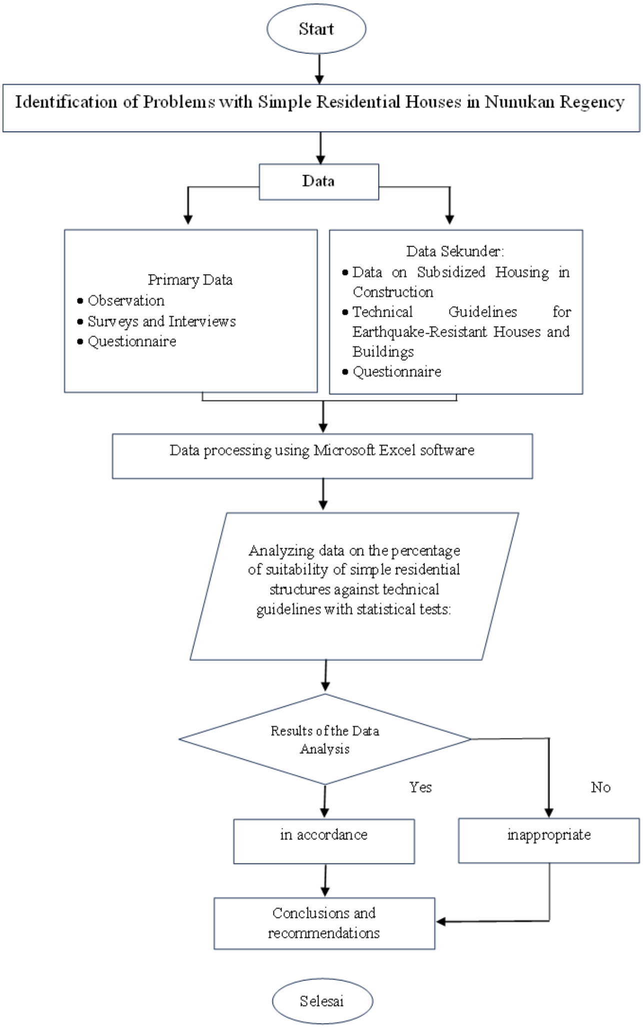

Fig 1. Research methodology flowchart

3. RESULTS AND DISCUSSION

The trajectory of an earthquake with a strong or weak scale and a certain return period is a potential that will occur in Kab. Nunukan. Residential houses that are unable to compensate for the earthquake shocks that occur are one of the reasons for the need to understand earthquake-resistant residential houses based on the Indonesian National Standard (SNI). In addition to endangering the occupants, building construction that ignores the Indonesian National Standard (SNI) regarding earthquake-resistant structures also endangers the surrounding environment because it has the potential to be crushed by the ruins of the building. Indicators for assessing people's understanding of the SNI for earthquake resistant buildings in the Nunukan area include a series of questions related to community knowledge about the existence of an SNI for earthquake resistant buildings, the application of SNI to earthquake resistant buildings in the homes of respondents who fall into the category of simple houses including: buildings located on the ground stable, the plan of the house is designed symmetrically, the sloof structure is anchored to the foundation, using kiln-dried wood, using a lightweight roof, walls made of masonry/adobe bricks are anchored every 30 cm vertical distance and anchored to columns, practical columns are installed on each wall with an area of 12 m2, the column as a binder for the ring/ring and rigid beam structure, the building frame is all tightly and rigidly bound, on the truss frame, precisely at the point of the wooden connection knot, bolts and fastening plates are provided, using mortar 1 Pc: 4 Sand, done by experts. Based on the survey that was conducted, it was revealed that all respondents living in the East Nunukan, Central Nunukan, and South Nunukan sub-districts stated that they did not know there was an SNI for earthquake-resistant buildings, while only 5 percent of respondents who lived in the South Nunukan and East Nunukan sub-districts knew of an SNI for earthquake-resistant buildings. This is probably due to the government's lack of socialization regarding this SNI. This is also an opportunity for the Nunukan State Polytechnic to take part in the socialization of this SNI, for example, through community service programs.

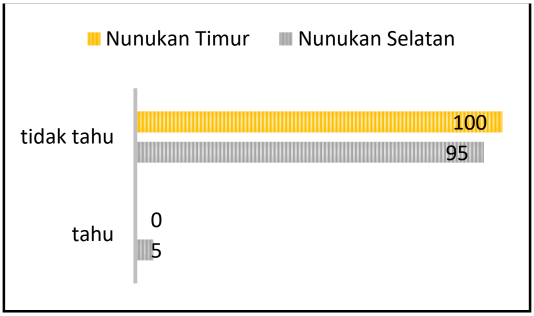

Fig 2. Knowledge of SNI for earthquake-resistant buildings

Buildings erected on stable land are a requirement for building simple houses. Stable soil will be able to withstand the pressure or load of the building both vertically and horizontally without having an impact on shear failure or large deformations that trigger structural failure. The results of observations in the field showed that residents in the South Nunukan and Central Nunukan Sub-Districts had placed their residential buildings on stable land.

Fig 3. Construction of residents' houses on stable land

The second requirement for an earthquake-resistant building is a symmetrical building structure. The symmetrical structure is more resistant to earthquake seismic loads in addition to avoiding the occurrence of torsional moments (twisting) due to the eccentricity of the load, which will trigger the collapse of the structure. Most of the respondents had designed a plan for their residence in a symmetrical shape. This can be seen in Figure 4. Only 15 percent of respondents who did not design residential buildings in a symmetrical shape lived in Nunukan Timur Village, as did 3.5 percent of respondents who lived in South Nunukan and Central Nunukan Villages.

Fig 4. The house construction stage has been designed symmetrically.

The foundation plays a role in receiving the superstructure force to be passed on to the soil beneath it. Thus, the foundation is designed to be strong enough so that the load can be supported and carried on properly to the subgrade so that soil deformation does not occur. The part of the structure above the foundation is the sloof, which functions to spread the column and wall loads to the foundation. The sloof is attached to the columns and also anchored to the foundation to ensure stable construction. This is to anticipate any ground movement, for example, seismic loads from earthquakes that trigger the collapse of structures. The results of the questionnaire also revealed that almost all respondents did not anchor the sloof to the foundation in the three sub-districts, namely Nunukan Selatan, East Nunukan, and South Nunukan. The next earthquake-resistant building requirement is a building using dry wood. Since our ancestors, wood has been an important building material for building houses. According to PKKI 1970-NI.5, the wood material used is dry, not young, intact, and fairly straight, and the degree of humidity is not more than 14%. In earthquake-resistant buildings, the walls are composed of lightweight materials such as planks, plywood, and cubicles that are tied to columns. Meanwhile, if the wall is composed of adobe bricks, choose one that is not brittle or makes a loud sound when both are tapped. Each 30 cm vertical spacing of the wall arrangement is installed as anchors to the column, which are 50 cm long and 6 mm in diameter, so that the wall structure blends with the column so that it is strong against shear due to earthquake seismic loads. According to the survey results, most residents in the three sub-districts did not anchor the masonry walls to practical columns; only a small number of practical columns were anchored, but they did not comply with the SNI for earthquake-resistant buildings, namely vertical distances of 100 cm and 150 cm. One of the houses of the residents of the Nunukan Selatan sub-district has cracks and separation between the sill and the wall. This occurs because the masonry wall is not anchored to the sill so that the wall does not blend with the sill. The ring beam load is the roof load, all of which will be supported by the column structure. From the column, the load is then distributed to the sloof so that the wall does not receive part of the load. Besides that, the role of the column is to frame, in other words, the wall stiffener so that it is stronger to accept wind gusts and earthquake shocks. All residents who live in Nunukan Tengah and Nunukan Timur Subdistricts have used practical columns for each 12 m2 wall area. Most residents who live in the South Nunukan Sub-District have used practical columns for every 12 m2 wall area; only a small number of them do not use practical columns, namely 5 percent of respondents in the East Nunukan Sub-District and 17.5 percent of respondents in the Central Nunukan Sub-District.

Fig 5. Residents' houses use practical columns.

One of the requirements for earthquake-resistant buildings that refer to SNI is the use of mortar with the specification 1pc: 4 sand. The results of the survey revealed that residents living in South Nunukan Village had fulfilled the SNI requirements. Most of the respondents stated that they used 1pc:4sand species at their residence and used 1pc:5sand, 1pc:6sand, 1pc:7sand, 1pc:8sand, as shown in Figure 6.

Fig 6. Use of mortar with 1pc specs: 4 sand

Most of the respondents living in Nunukan Timur and Nunukan Tengah Kelurahan have used experienced builders to build their houses. In fact, all respondents living in the South Nunukan Sub-District stated that they used experienced masons, as shown in Figure 7.

Fig 7. Continuous stone foundation with mangrove stakes

Mangrove wood chipping aims to increase soil shear resistance in another sense: soil improvement (Tjandrawibawa, 2000). With the existence of this crevice, the carrying capacity of the soil has increased. This wooden pile foundation is very suitable for the condition of the former swamp land area. The mangrove wood cones used are 8–10 cm in diameter, 1.5 m long, and 2 m with 1 m of wood spacing. For the carrying capacity of a single mangrove wood, it has a maximum load that can be carried, reaching 170–300 kN (Rifky, 2014). Cerucuk can be used in groups with a distance of 3D (diameter) to 5D (Rusdiansyah, 2015). In the structural elements of the columns that have not been cast, it is found that the condition of the reinforcement reinforcement is inadequate for its installation (using 90-degree hooks), indicating that the building components are not properly connected.

Fig 8. Column iron assembly without a 90-degree hook

In addition, the reinforcement at the connection points of the beams and beam-column connections on this wall does not have additional reinforcement bends that can increase the bond strength of the joints. Reinforcement of beam joints and beam-to-column joints in walls like this must be avoided because it will not create a solid building. Lap splices of column reinforcement are generally also found in the plastic hinge area (column base), so this can result in reduced inelastic deformation capacity of the building structure (Wijaya et al., 2014). In addition, columns with reinforcement that are not connected to beams, as shown in the figure above, tend to detach easily when receiving earthquake loads. As a result, the entire building will collapse and endanger the occupants. A typical reinforcement of foundation beams to column connections for earthquake-resistant houses is proposed. It has no additional bending of reinforcing steel, which can increase the bond strength of the joint. The stirrup reinforcement used does not have additional hooks at both ends. In addition, the distance between the two stirrups is also too far, ranging from 20 cm to 40 cm. The design of earthquake-resistant houses requires that the distance between the two stirrups not exceed 15 cm and the length of the hooks be at least six times the diameter (6D), as shown in Figure 8 (Boen, 2009). Based on field observations, columns and walls are also not connected. Conditions like this are common in Indonesian people's homes. For earthquake-resistant house designs, walls and columns must be connected by placing iron anchors (minimum diameter of 10 mm and length of more than 40 cm) in every 6 layers of bricks (Boen, 2009). The existence of these anchors can increase the strengthening of the connection between the brick wall and the column (Ismail, 2010b). However, the use of additional steel reinforcement installed horizontally through the two columns on both sides of the brick wall would be much better because it could increase the energy dissipation capacity, stiffness, and horizontal displacement capacity of the wall. (Bachroni, 2013).

Fig 9. Building components are not connected properly.

Column casting is done manually by workers, relying only on experience. Workers also do this casting without considering the ratio of the mixture of cement, sand, and gravel, as in the foundation casting process. Casting like this has the potential to produce low-quality concrete, which will affect the strength of the resulting building structure. This will have an impact on the quality of the concrete produced. The concrete used for earthquake-resistant houses has at least a compressive strength of 150 kg/cm2, which can be obtained from a mortar ratio of 1 cement, 2 sand, and 3 gravel (Boen, 2009). Several studies have proven that the use of this mix ratio can produce concrete with a compressive strength value of more than 150 kg/cm2.

Fig 10. Manual mixing of concrete

4. Conclusion

There are several conclusions that can be drawn from the results of studies that have been carried out regarding the understanding of builders and their implementation of the requirements for earthquake-resistant simple buildings in Nunukan district. Construction materials such as sloop beams, practical columns, ringbalk, mortar and concrete materials, as well as mortar and masonry materials, are sufficient, except for the understanding of lintel beams, which is still lacking. Implementation of simple buildings (column reinforcement, beam reinforcement, mortar and concrete materials, and mortar and brick masonry materials) in Nunukan district is in the less category, namely in sloop beam reinforcement, column reinforcement, and lintel/bintel beam reinforcement only, with the implementation of mortar and concrete materials as well as mortar and brick masonry material showing sufficient, and based on the analysis that has been carried out, it can be concluded that the houses built have not followed the design principles for earthquake-resistant houses. The quality of workmanship on building components is still low. The relationship between the structural components of the building also does not follow the requirements and minimum standards for good connection details for earthquake-resistant houses. Public awareness to build houses with reference to the SNI for earthquake-resistant buildings is not that great, as evidenced by the survey that has been conducted. Most of them do not know there is an SNI for earthquake-resistant buildings. Furthermore, the application of SNI to earthquake-resistant buildings for residential communities revealed that only 6 of the 10 building requirements referring to SNI for earthquake-resistant buildings were fulfilled, or only 60 percent of the requirements for earthquake-resistant buildings were applied to residents' homes.

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