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Natural Frequency Measurement of Modest Dwelling Houses

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Abstract – Around 1000 to 4000 units of modest dwelling houses are annually built in Aceh Province. A modest dwelling house is a small type of house with limitations in space planning which is very suitable for small families with middle to lower incomes. This lower middle-class community is a group of people who are very vulnerable and will be very severely affected when a disaster occurs. A modest dwelling house is a one-story building with simple construction and structure in its physical form. On the other hand, Aceh is also one area that is very prone to earthquake disasters from along the subduction zone and Sumatran Fault. Therefore, measuring the frequency of a modest dwelling house is crucial to understanding all house elements' conditions. It is essential to estimate the integrity and safety of the house after an earthquake occurs. The method used in this research is using the field experiment method in the form of measuring the natural response of the building to vibration based on microtremor data. This study uses a seismometer. The data is stored in a data logger. The seismometer is placed on the floor of the house. Data collection is carried out when no major activities are around the house. Measurements were carried out for a minimum of 60 minutes. Computer analysis with specific parameters obtained using Geopsy software. The result of this study indicates that the dominant frequency of modest dwelling houses measured is around 2.99 Hz. The analysis results from the field experiment were validated using pushover analysis of the detailed engineering design data. The modeling results show that in the x-axis direction (parallel to the direction of the building), the frequency obtained is 7.14 Hz. Pushover analysis on the model with the y-axis direction (parallel to the side of the building) obtained a frequency of 7.46 Hz. This validation shows a huge difference between the frequency of field measurement results and computer modeling results. Many factors, including decreasing or degrading the concrete construction quality in the field, can cause this gap.

Keywords: modest dwelling house, earthquake, natural frequency, mitigation.

Introduction

Every year, around 1000 to 4000 units of modest dwelling houses are built in Aceh Province (Tribunnews, 2021). A modest dwelling house is a small type of house with an area of less than 70 square meters, which has limitations in space and is very suitable for small families with middle to lower incomes. This lower middle-class community is a vulnerable group to any disasters. Physically, a modest dwelling house is a building that has one floor with simple construction and structure. This type of house is usually built as subsidized housing by the government. The technical reference for constructing this modest dwelling house can be referred to the 2006 Earthquake Resistant Building technical guidelines (Wicaksana & Rosyidah, 2019).

On the other hand, Aceh is one area prone to earthquakes caused by the subduction between the Indian-Australian and Eurasian Plates and is also crossed by the Sumatran Fault zone. According to the Directorate of

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Volcanology and Geological Hazard Mitigation (DVMBG), Indonesia is a country with an active earthquake-prone area, especially the Aceh area, which is justified as the ring of the fire area. The earthquake that shook Aceh Province with its epicenter in the western offshore of Banda Aceh on December 26, 2004, was the fourth largest earthquake since 1990 and is evidence of the high level of seismic vulnerability of Aceh Province. Until the end of 2021, the condition of earthquake vulnerability in Aceh Province is further strengthened by data from the Regional I Earthquake Center station, the Meteorology, Climatology and Geophysics Center (BMKG) Region 1 Medan, North Sumatra (North Sumatra), which recorded 35 earthquakes in the past week or the period of 23-29 July 2021 in the Aceh and North Sumatra regions (BMKG, 2021). This ring of fire area has serious problems that we must mitigate for future disasters, especially if modest dwelling house buildings continue to be constructed annually without inadequate building structures. Seismic load must be considered (Hasan *et al.*, 2021) if we design a modest dwelling house in an earthquake-prone area such as Aceh. In principle, this research is urgent in planning and implementing the construction of modest dwelling housing infrastructure in Aceh, which is justified as an earthquake-prone area.

Materials and Methods

Methods

This research begins with a literature study to get a comprehensive initial understanding of the research object's condition and the study area. Then the field data collection was carried out to estimate the building frequency and for modeling purposes. The final stage includes analysis and synthesis of the obtained results, including validating the results.

Desk study

Secondary data is collected. Permits for the field survey are arranged and managed at this stage. All parameters used in the survey form were reviewed and studied. Several existing or previous data were also collected and further studied.

Field measurement

The process of collecting data and field testing is carried out in stages, from collecting data on the condition of the building structure and measuring microtremor data (Calvi *et al.*, 2006). The building structure was observed visually. Measurement of the microtremor was carried out using a RasberrySHAKE 3D seismometer. The seismometer is placed at the center of the building. The position of the seismometer is adjusted to follow the direction of the building. Then the three legs on the seismometer are adjusted by turning left or right to level the device. If the position of the air bubble is in the middle, it indicates that the seismometer is right on the position of a flat surface area. Then the power cable is connected to the seismometer. When the power cable is connected, the device will automatically start to turn on, indicated by several colors (green, blue, and red) on the seismometer. After waiting for ±60 minutes, immediately transfer the measurement data to the laptop by turning on the internet router. The field microtremor measurement using a seismometer is shown in Figure 1.

Data analysis

All data collected were grouped and analyzed using a computer application. The analysis of this research uses Geopsy software or similar applications. Microtremor data is recorded in the form of a waveform. The measurement data (raw data) obtained is composed of 3 components, namely the vertical component (V), the north-south horizontal component (N), and the west-east horizontal component (E). The recorded data is converted into a miniseed format. After all the data is in a miniseed format, it is processed using Geopsy to convert the waves in the form of time to frequency.

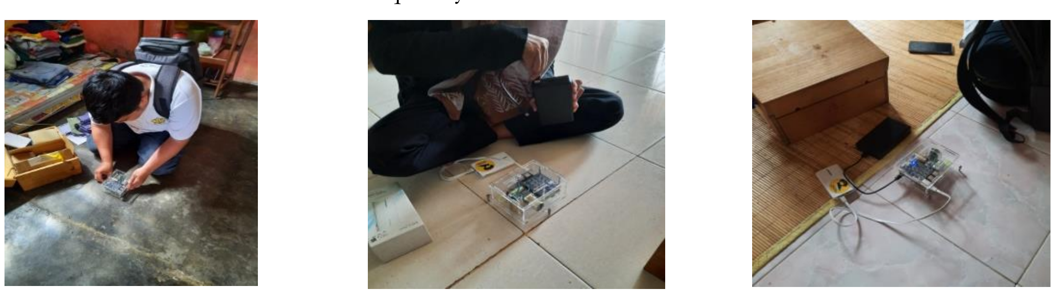

Figure 1. Field measurements using a seismometer

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Results

Field microtremor data of the modest dwelling house buildings were reviewed. An example of records of the raw waveform of the microtremor data on buildings at the study site is shown in Figure 2.

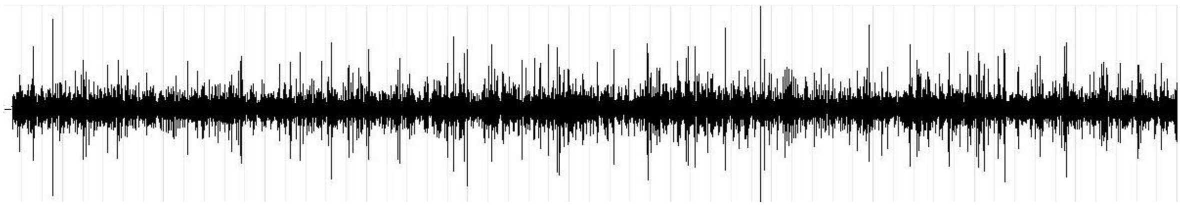
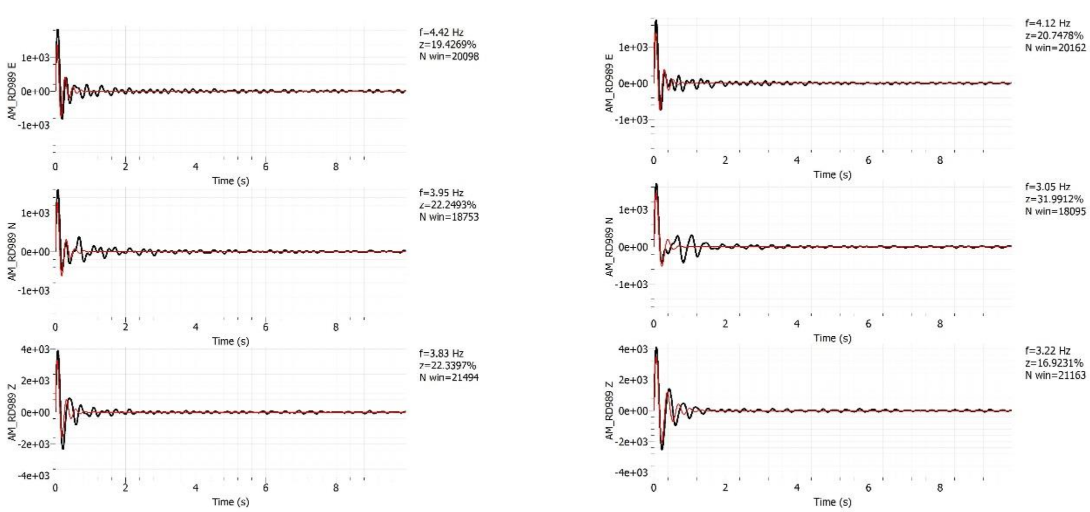


Figure 2. Microtremor data on buildings at the study site

The analysis results of this study are based on data from microtremor measurements in several modest dwelling houses in Meulaboh, Aceh Barat. As aforementioned, microtremor data measurements were carried out on the floor in the center of the building. The raw waveform data must be converted into a miniseed format (*.msd) using the Geopsy software. Vibration data processing to obtain the building's natural frequency value also uses the same application (Geopsy). Before performing a spectrum analysis to obtain the dominant frequency value of the measured building, a damping analysis was carried out to detect the possibility of harmonic vibrations from the recorded data. The results of the damping analysis are shown in Figure 3 and Figure 4. The spectrum analysis of the field measurement data is tabulated in Table 1. Each spectrum curve is presented in Figures 5 to 8. The results of this study indicate that the dominant frequency of the measured modest dwelling house buildings varies from 2.02 Hz to 2.99 Hz. However, the frequency of 2.02 Hz is questionable as some disturbances occurred during the field measurement.

Table 1. Microtremor data analysis tabulation

Location	Predominant frequency	Remarks
TM-01	2.99 Hz	-
TM-02	2.75 Hz	-
TM-04	2.75 Hz	-
TM-05	2.02 Hz	Disturbance during field measurement



(a) (b)

Figure 3. The results of the damping analysis on (a) TM01 and (b) TM02

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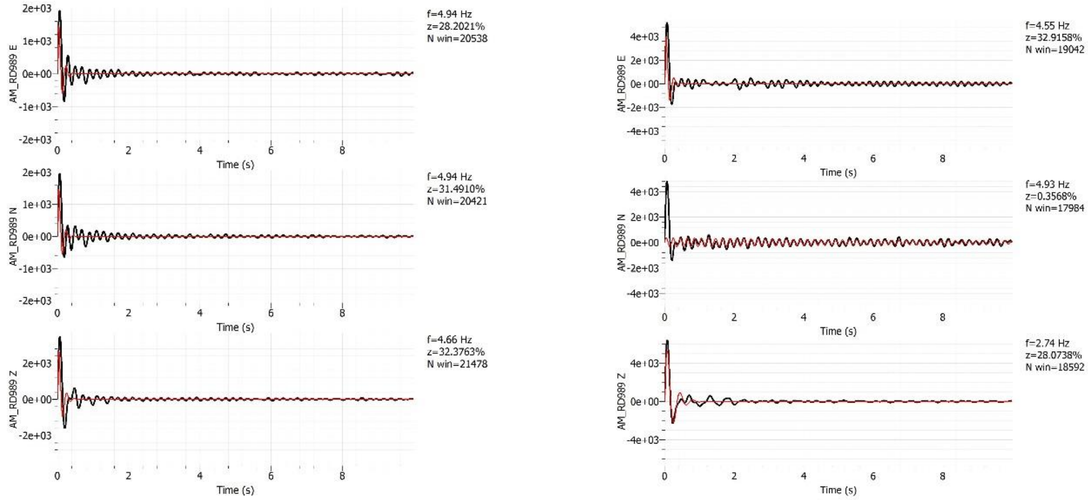

(a) (b)

Figure 4. The results of the damping analysis on (a) TM04 and (b) TM05

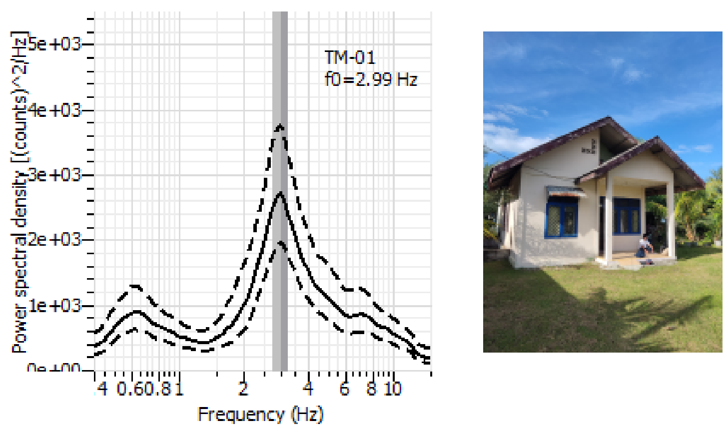

Figure 5. Results of microtremor data analysis on TM01

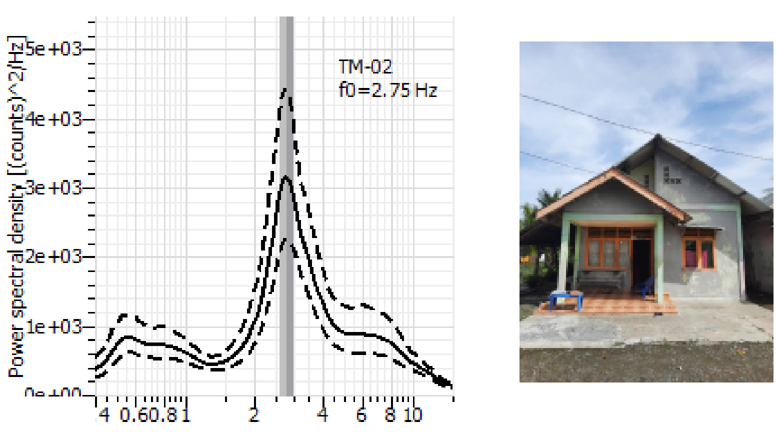

Figure 6. Results of microtremor data analysis on TM02

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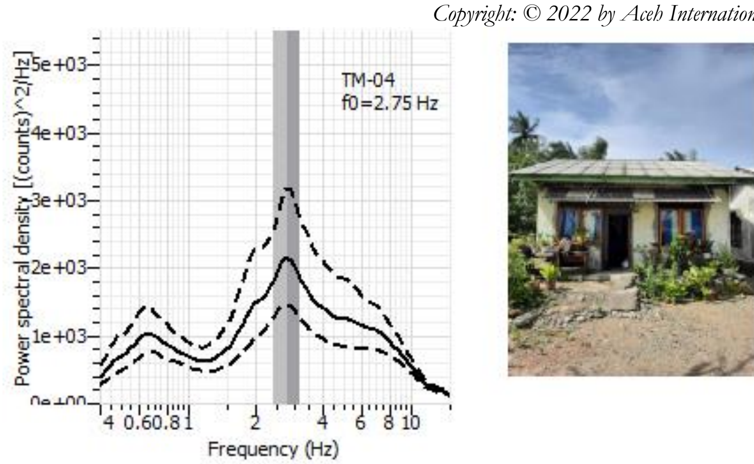

Figure 7. Results of microtremor data analysis on TM04

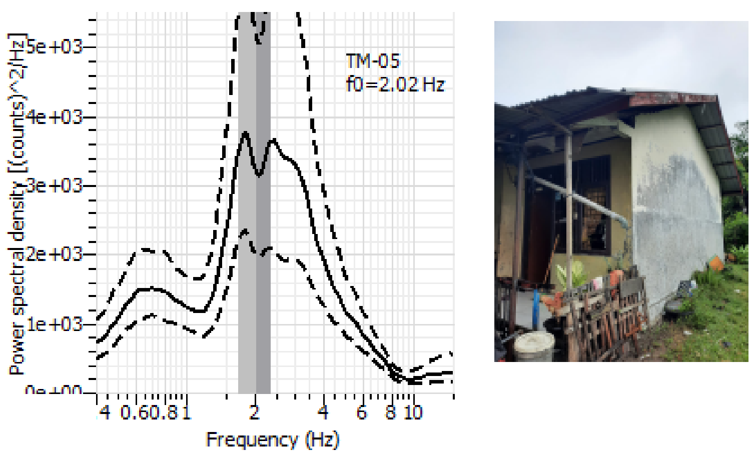

Figure 8. Results of microtremor data analysis on TM05

Discussion

The field microtremor data analysis results were compared with the analysis of a modest dwelling house model built based on the standard provisions of the applicable building rules. Configuring the geometry of the house building is the first process that must be carried out in the modeling using the SAP2000 software. The building's structure is modeled into the closest modeling form at this stage. Material property input is the next step which is inputted into the SAP2000 data program. Then, the data on the cross-sectional size of the model elements and the loads acting on the house was entered. The calculation output is the final result obtained from all the stages described above. The previous process strongly influences the accuracy of the calculation results, errors in the previous process will significantly affect the accuracy of the data generated by this program. Based on visual inspection data in the field, a modest dwelling house model was built, as shown in Figure 9. Detailed data of the built model is presented in Table 2.

The pushover method was employed to deduce the fundamental frequency of the building (Casarotti *et al.*, 2005). Pushover analysis in the x-axis direction (parallel to the direction of the building), the period obtained is 0.14 s or a frequency of 7.14 Hz. Pushover analysis in the y-axis direction (parallel to the side of the building) the period obtained is 0.134 s or a frequency of 7.46 Hz. This validation shows a huge difference between the frequency of field measurement results and computer modeling results. Many factors can cause this discrepancy, including degradation of the concrete construction quality in the field. The decline in the quality of the existing concrete has also been identified by several researchers, such as Ngudiyono et al. (2015) obtained a compressive strength value of 12MPa - 13.4Mpa from the Hammer Test, Lutfi & Subtoni (2017) found the compressive

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strength value in the existing column of 6.6MPa and on the existing beam of 10.23MPa, Hidayati et al. (2021) obtained the compressive strength test value of the existing column of 12.46MPa.

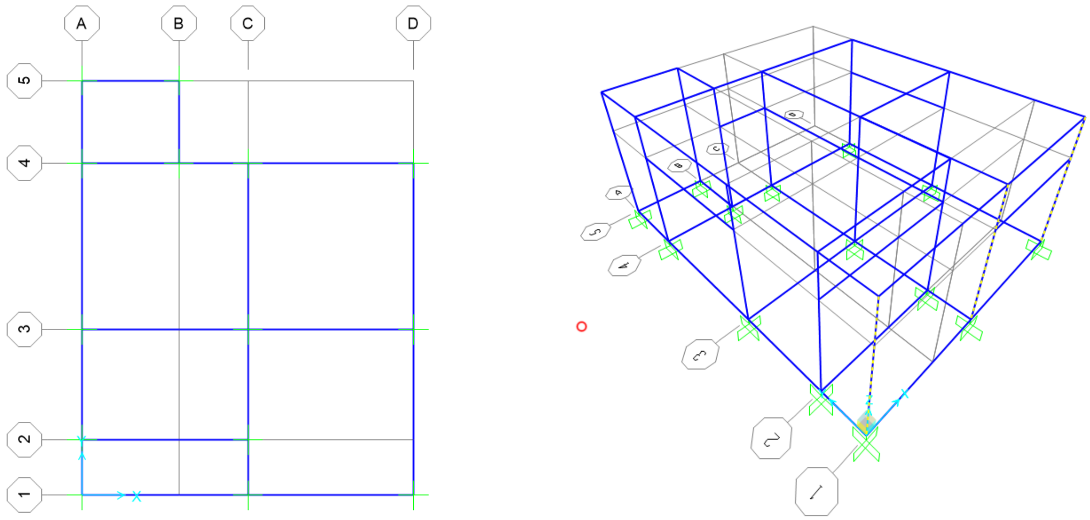

Figure 9. Modest dwelling house building model

Table 2. Detailed data tabulation of simple house-building models

Item	Data	Remarks
Size of the main building	6 x 6 m	-
Main column dimension	180x180 mm	-
Ground beam dimension	180x200 mm	-
Column high	3.2 m	-
Concrete compressive strength	17.5 MPa	-
Rebar quality	300 MPa	-
Ring beam dimension	110x110 mm	-

Shirokov *et al.* (2016) carried out an analysis and modeling to determine the frequency of modular structures, which are generally similar to the modest dwelling house of this study. A good agreement is suggested from the comparison between the results of this study and Shirokov *et al.* (2016).

Conclusion

Every year, up to 4000 units of modest dwelling houses are built in Aceh Province. A simple house is a small type of one-story building with a simple construction and structure in its physical form. On the other hand, Aceh is also one of the areas that are very vulnerable to earthquakes. Therefore, measuring the frequency of modest dwelling houses is essential to know the condition of all house elements when an earthquake occurs. The method used in this research is using the field experiment method in the form of measuring the natural response of the building to vibration based on microtremor data on the floor of the building being reviewed. Computer analysis with specific parameters obtained the dominant frequency of simple house buildings measured around 2.75 - 2.99 Hz. Validation of the results from the field experiment was carried out using planning data and pushover analysis, which showed that the frequency varied from 7.14 Hz to 7.46 Hz. This validation suggests low structural quality in the field.

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