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Analysis Of Liquifaction Potential Using The Method Microzonation in Coastal Zone at North Aceh District

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ABSTRACT

Liquefaction is a natural phenomenon that occurs when previously sandy soil turns into mush as a result of an earthquake and has the potential to become a natural disaster if not anticipated early. the coastal zone of Dewantara District is included in the earthquake-prone area (referring to the results of previous studies, the value of the seismic vulnerability index is between 0.41 to 18.3 Kg, with the potential for damage caused to be medium and high risk) because most of the area is an area that has alluvial plains a wide beach and located on a tectonic route so that it is estimated that there is a potential follow-up threat after an earthquake occurs, in the form of liquefaction. Determination of the distribution of liquefaction potential due to earthquakes is determined based on data obtained from microtremor measurements. The specific objective of this study is to provide information regarding the potential and vulnerability of liquefaction to Policy Makers/Local Governments in evaluating plotting areas and/or preparing regional spatial plans based on disaster risk reduction/mitigation aspects. Based on the results of the processed data analysis, several important conclusions can be identified in this study. The character of soil vulnerability is related to the value of dominant frequency (f0), soil amplification (A0), and seismic vulnerability index (seismic vulnerability index). This relationship can be used to formulate whether an area has the potential to experience lateral ground motion (liquefaction) which potentially can affect the coastal area of Dewantara District. Based on microseismic data analysis (standard deviation), several disaster-prone zone points were obtained in the north and east of the measurement point. In detail, this is shown by the map of the distribution of SVI values in the Coastal Area which is in the range of 20-100, especially in the north it is at a value above 75, which allows for a higher chance of liquefaction on the condition that there are major earthquakes accompanied by with rock pores filled with fluid.

Keywords: *Liquefaction, Microzonation, Seismic, Mapping, North Aceh*

1. INTRODUCTION

The coastal zone of Dewantara District is included in a disaster-prone area with a moderate level of risk with disaster threats in the form of earthquakes, tsunamis, volcanoes, floods, landslides, drought, extreme weather, extreme waves and abrasion as well as forest and land fires[1]. These natural conditions have several very detrimental potentials, one of which is an earthquake. Referring to the results of previous research (Deassy Siska, 2018-2020. Mapping Seismic Vulnerability to Support Spatial Plans in the City of Lhokseumawe. Higher Education Cooperation Research Ministry of Research, Technology & Higher Education) The City of Lhokseumawe has a seismic vulnerability index value between 0.41 to 18 .3 kg, with medium and high risk potential damage [2]. Based on these results, it is estimated that there is a potential follow-up threat after the earthquake occurs, in the form of liquefaction in the Lhokseumawe City Region to enter the coastal zone of Dewantara District and its surroundings.

In the context of Regional Development, development and urban management based on disaster mitigation, these two maps are needed, especially the Microzonation Map (detailed risk map) as a basic reference and/or as a recommendation for calculating and mapping potential damage to civilian buildings and other infrastructure, as a warning early warning for mitigation purposes as well as input for seismic and liquefaction engineering. Based on the description of the problems that have been presented, the focus area of this research is disaster with an emphasis on sustainable mitigation in areas with high vulnerability to natural disasters, especially earthquakes and liquefaction. This research is in line with the strategic issues contained in the 8 (eight) strategic research topics in the Malikussaleh University Research Master Plan for 2020-2024, with research topics in the fields of Technology Development, Infrastructure and Transportation Management, namely: Aceh as a disaster-prone area (ring of fire).

Liquefaction is a symptom of dissolving fine-sized sand which is loose and water-saturated due to earthquake shaking where the triggering force exceeds the force possessed by the local lithology in resisting shocks [3]. The specific objective of Mapping Potential Liquefaction Microzonation in the coastal zone of Dewantara District, Aceh Province is to provide information regarding potential and vulnerability of liquefaction to Policy Makers/Local Governments in evaluating plotting areas and/or preparing regional spatial plans based on disaster risk reduction/mitigation aspects. So as to minimize the impact of damage, loss and loss of life as well as the huge post-disaster rehabilitation and reconstruction costs. Microzonation is a technique for dividing a large zone into small zones with certain criteria, one of which will be included in the Microzonation Map of Liquefaction Potential in the coastal zone of Dewantara District is a portrait of moving ground conditions and potential for earthquakes with the accompanying threat in the form of liquefaction, thus it can be identified and determine which areas are considered to have high potential (red zone), medium (yellow zone) and safe zone (green). Previous studies have produced a Seismic Vulnerability Map for the City of Lhokseumawe and this research will produce a Microzonation Map of the Liquefaction Potential of the coastal area in the Dewantara sub-district.

In the context of Regional Development, development and urban management based on disaster mitigation, these two maps are needed, especially the Microzonation Map (detailed risk map) as a basic reference and/or as a recommendation for calculating and mapping potential damage to civilian buildings and other infrastructure, as a warning early warning for mitigation purposes as well as input for seismic and liquefaction engineering. Based on the description of the problems that have been presented, the focus area of this research is disaster with an emphasis on sustainable mitigation in areas with high vulnerability to natural disasters, especially earthquakes and liquefaction. This research is in line with the strategic issues contained in the 8 (eight) strategic research topics in the Malikussaleh University Research Master Plan for 2020-2024, with research topics in the fields of Technology Development, Infrastructure and Transportation Management, namely: Aceh as a disaster-prone area (ring of fire).

2. REVIEW OF LITERATURE

This research started from several previous studies related to microseismic, microtremor and liquefaction as mentioned in Figure 1. In previous studies, mapping of seismic vulnerability was carried out using the HVSR method. The HVSR analysis method was first developed by Nakamura in 1989. The results of the HVSR analysis show a spectrum peak at natural frequencies [4].

The history of North Aceh cannot be separated from the history of the development of the Islamic Empire on the coast of Sumatra, namely Samudera Pasai, located in Samudera Geudong District, which was the first place for the presence of Islam in Southeast Asia. The Islamic kingdoms in Aceh experienced ups and downs, starting from the time of the Kingdom of Srivijaya, Majapahit, the arrival of the Portuguese to Malacca in 1511 so that 10 years later Samudera Pasai was also occupied, until the Dutch colonial period. The Dutch de facto controlled Aceh in 1904, when the Dutch were able to take control of the last stronghold of the Aceh warriors Kuta Glee in Batee Iliek in Samalanga.

In 1999 North Aceh District, which consisted of 26 sub-districts, was split again into 30 sub-districts by adding four new sub-districts based on Government Regulation of the Republic of Indonesia Number 44 of 1999. Along with the division of the new sub-districts, North Aceh had to give up nearly a third of its territory to become a new district, namely Bireuen Regency based on Law number 48 of 1999. Its territory includes the former Assistant Regent's area in Bireuen. Then in October 2001, three districts within the North Aceh region, namely Banda Sakti District, Muara Dua District, and Blang Mangat District, were made into the coastal zone of Dewantara District. Currently North Aceh District with an area of 3,296.86 km2 and a population of 529,571 people oversees 27 sub-districts.

Dewantara District is a sub-district in North Aceh District which is located to the west of North Aceh District, Geographically, Dewantara District is bordered by: North with the Malacca Strait, South with Nisam and Banda Baro Districts, West with Muara Batu District, East with Muara Satu District The government of the coastal zone of Dewantara District, along with a map of Dewantara District as shown in Figure 1.

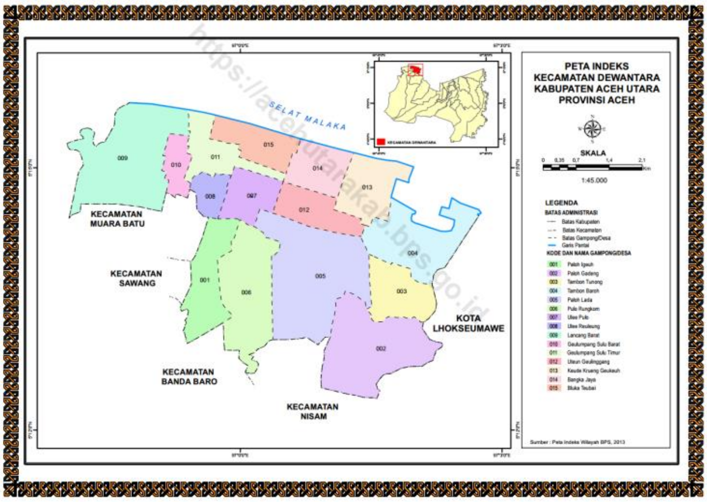

Figure 1. Map of the Dewantara District Area (Source: BPS, 2020) [5].

The higher the value of the seismic vulnerability index (Kg), the higher the level of damage that will be caused by an earthquake. This happens because the higher the level of seismic vulnerability, the lower the stability of the soil structure and the higher the damage caused. The map of the distribution of seismic vulnerability values in Lhokseumawe City is shown in (Figure 2).

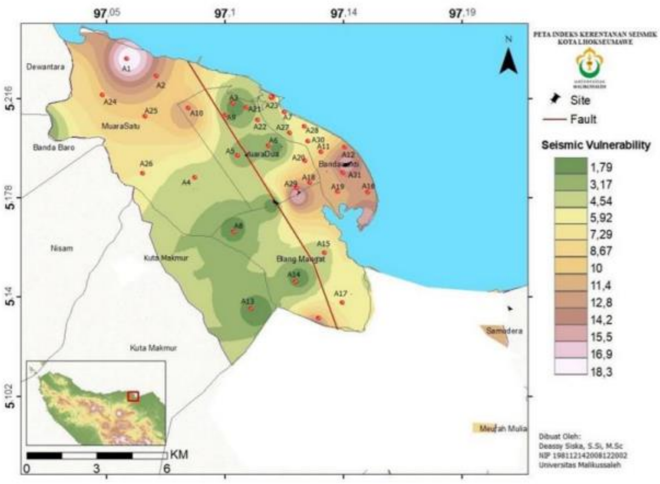

Figure 2. Seismic Vulnerability of Lhokseumawe City [6].

The results of the analysis of seismic vulnerability index values in previous studies showed that Lhokseumawe City and its surroundings had a seismic vulnerability index value of around 0.41 to 18.3 [7]. The Sumatran fault is distributed along the island of Sumatra from Lampung to Andaman Island with a length of more than 1900 km and is divided into several segments [8]. The Andaman-Sumatra-Java forearc zone extends for more than 4000 km which is the result of the meeting between the Indo-Australian Plate and the Eurasian Plate. The speed of these plates meeting varies from 3.9 cm/yr in the Andaman section, 5.0 cm/yr in the South Sumatra section of Nias, and 5.7 cm/yr in the more southern part of Sumatra [9].

Microzonation Microzonation is a technique for dividing a large zone into small zones with different criteria for each zone depending on the purpose of the zoning itself. One of the things contained in the microzonation map is a portrait of the condition of the moving soil and the type of soil on the surface. The effect of soil vulnerability can occur due to waves propagating from the earthquake source (ground motions) through a porous (permeable) layer and is supported by the large amplification value of an earthquake source. Potential vulnerability of the soil can be investigated by analyzing vertical (SV) and horizontal (SH) waves from a micro seismic or tremor phenomenon from natural waves generated by the earth. the presence of liquefaction potential soil vulnerability will be influenced by the value of seismic vulnerability (SVI), earthquake frequency, amplification and ground acceleration (peak ground acceleration[10].

The major issues in the challenges of infrastructure development in Indonesia include geographical issues. Indonesia occupies a very active tectonic zone and is surrounded by four major plates, namely the Eurasian Plate, the Indo-Australian Plate, the Philippine Sea Plate and the Pacific Plate. This causes Indonesia to have the potential to experience many earthquakes and have an impact on life disturbances and damage to infrastructure. This geographical issue is included in the scope of seismic vulnerability [11]. Seismic susceptibility is an index that shows the level of susceptibility of the surface layer to deformation during an earthquake [4]. Seismic susceptibility microzonation map can be used as a reference for urban development and planning [12]. The seismic susceptibility is directly proportional to the amplification value and inversely proportional to the dominant frequency value, as shown in equation 2.1.

$$A = \frac{V_p}{V_s} \qquad 2.1$$

The higher the value of the seismic vulnerability index (Kg), the higher the level of damage that will be caused by an earthquake. Analysis of liquefaction potential also requires a variable which is interpreted in an equation that defines the capacity of the soil as liquefaction resistance (CRR). The following graph shows the relationship between CRR and the corrected QC1 value (Figure 3).

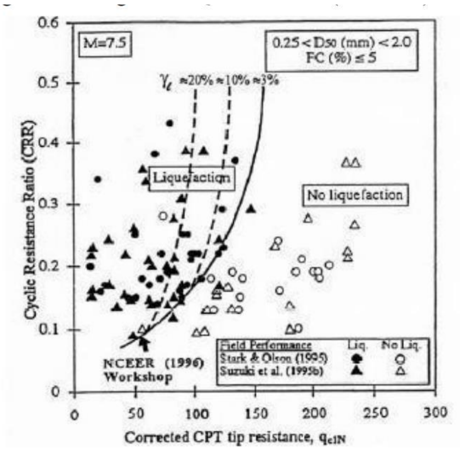

Figure 3. Graph of the relationship between Qc and CRR to liquefaction potential

The second parameter is the cyclic stress ratio which is a variable used to define seismic phenomena that occur in the soil layers. The calculation of CSR value is formulated by Seed and Idriss (1971) as follows:

$$CSR = 0{,}65\ x\left(\frac{a_{max}\ \sigma_0}{g x \sigma_{01}}\right) x r_d \quad \text{(Pers. 2.2)}$$

The rd value is the stress reduction at a depth which is used to estimate the magnitude of the CSR reduction coefficient [13]. Liquefaction is the process of changing the condition of a water-saturated sandy soil to become liquid due to increased pore water pressure whose value becomes equal to the total pressure due to dynamic loading, so that the effective stress of the soil becomes zero [14]. Liquefaction is also a phenomenon of loss of soil layer strength due to vibration according to [15].

3. RESEARCH METHOD

Microtremor is a tool that can measure weak ground motion with a movement amplitude of 0.1-1 µm from a period range of 1/10 from 1s to 10s [16]. Research on microtremor to map the potential for liquefaction, for example from [17]. The measurement was carried out in the Yuan-Lin area, Central Taiwan, where this liquefaction event was clearly observed in the Chi-Chi earthquake. The results show that in the liquefaction zone the natural frequency ranges from 0.8-0.9 Hz with a higher amplification factor in the area around the zone that has the potential to experience liquefaction. The seismic susceptibility index (Kg) also has an effect and higher Kg values are obtained in the liquefaction zone [4].

The microseismic acquisition method was carried out in an area of 7 x 6 km2 with 56 measurement points separated by 1 km at each point with a normal gridding distribution (Figure 6). Measurements were made at each point for 70 minutes with a sampling rate of 100 Hz. Each measurement point is designed or selected based on the presence of free-field to avoid the influence of noise caused by trees. The resulting raw data will be processed in Geopsy software to extract the broadband signal components Vp and Vs into frequency and amplification values.

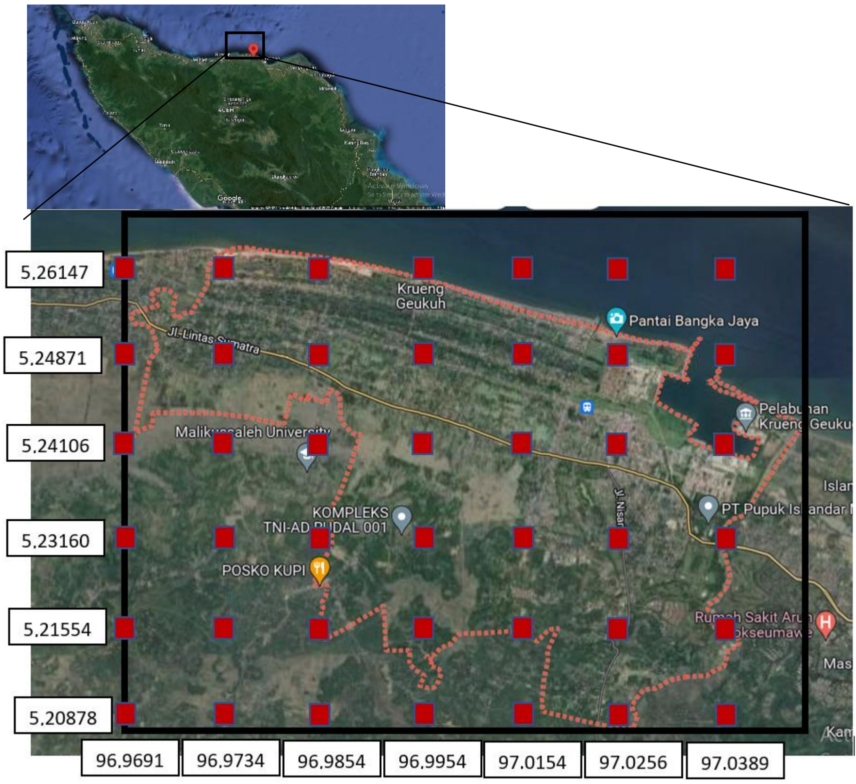

Figure 4. Survey design for the research area in Dewantara District, North Aceh District. The red dots are the measurement points which total 42 points with a space of 1 km at each measurement point.

Data processing to obtain the HVSR value at each point is carried out in the following way: the data is filtered between 1 and 25 Hz by a band-pass 4 Butterworth filter, after that the mean and linear trends are removed, then each component of the recorded signal is limited (windowing) in a 10 second time series and for each time window, FFT (Fast Fourier Transform) is calculated and smoothed.

The research method used in this research is the microtremor data method which is performed using the Open HVSR software. The Fourier spectra are calculated for the selected segments using the Fast Fourier Transform (FFT) algorithm which is an algorithm used to represent signals in the time domain and frequency domain. The time domain (period) is defined as the time it takes a signal or wave to reach a full wave. The frequency domain is defined as the number of waves that occur in 1 second. In this process, the value of the spectral velocity (Vs) is calculated. After seismic vulnerability mapping, a linear relationship between seismic vulnerability (Kg) and liquefaction is carried out. The final result is a liquefaction map of the coastal area in Dewantara sub-district with a research flow chart.

Liquefaction events can cause subsidence, collapse, tilting of buildings, ground cracking, landslides, and damage to public facilities. For example, during the Nigata 1964 earthquake, Kobe 1995, Turkey 2002, Taiwan 1999, India 2001, Maumere December 1, 1992, Aceh and Nias December 26, 2004, Bengkulu, 2000, Jogjakarta, May 27, 2006 followed by the phenomenon of liquefaction events. Knowledge of liquefaction vulnerability is very important for carrying out mitigation efforts that are adjusted to the degree of vulnerability of an area to liquefaction hazards [17]. The HVSR method can identify the level of vulnerability of an area to strong ground motions. If an area has a large seismic vulnerability index, the level of earthquake risk will also be high. Noor, M. R. S.'s research mapped the value of the seismic vulnerability index for the alluvial fan area in Yuan Lin which shows that high Kg values will have the potential to experience liquefaction [18].

4. RESULTS AND DISCUSSION

4.1 Distribution of Dominant Frequency Values (f0)

The dominant frequency distribution based on the results of data processing and HVSR analysis can be seen in Figure 8 below. Based on the distribution map, the dominant frequency values are relatively uniform and range from 1-18 Hz. Meanwhile, the dominant frequency of Nakamura's earthquakes in theory ranges from 5-15 Hz [11]. Nakamura revealed that f0 has a relationship with the depth of the bedrock or bedrock with the smaller the value of f0, the greater the depth of the bedrock. Areas marked by the yellow to red ovals are susceptible to earthquake damage. This is due to the same earthquake frequency range as this prone area, so there is a possibility that resonance may occur during an earthquake.

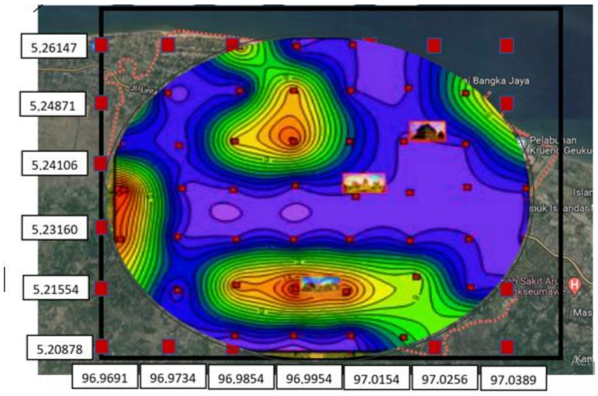

Figure 5. Map of the distribution of f0 values (dominant frequency)

Figure 5. Map of the distribution of f0 values (dominant frequency), showing the presence of dominant frequencies related to the thickness of the bed rock or bedrock, based on 42 measurement points. It can be seen that the dominant frequency in the study area is in the range of 1 – 18 Hz, which is included in the earthquake prone frequency according to Nakamura [10].

4.2 Distribution of Amplification Factor Values

The amplification factor (Am) or peak ratio of the HVSR spectrum at the study site can be seen in Figure 9, which produces values from 1 to 7.

Areas marked with red ovals are high amplification, which means that they may have been damaged by the earthquake due to high amplification deviations.

High amplification factors (Am> 4) were found in almost all research areas. The distribution of high amplification factors throughout the measurement area shows that topography is not the only factor that controls the amplification factor, but is more dominated by the presence of more dominant rock physical properties. Based on the results of this study, there are several local relationships between amplification (Am) and dominant frequency (f0) as a relative indicator of the potential for ground motion. Reference [12] explains that the amplitude/amplification factor depends on the impedance contrast in the rock. Thus, the potential for liquefaction and soil vulnerability will be seen at the greater the amplification value. The amplification value classification is based on [12], showing an experimental relationship in the current study, where the current study is included in the high amplification value because it is above 4

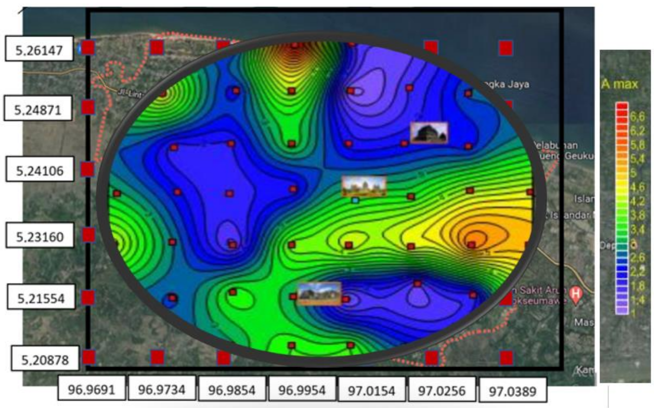

Figure-6. Map of the distribution of Am values (amplification)

Figure-6. Map of the distribution of Am values (amplification), showing the presence of peak HVSR ratio values at the study site, based on the distribution of 42 measurement points. The value of Am in this study ranged from 4 to 7, which was distributed dominantly in the eastern region of the study.

5. CONCLUSION

Based on the results of the processed data analysis, several important conclusions can be identified in this study. The character of soil vulnerability is related to the value of dominant frequency (f0), soil amplification (A0), and seismic vulnerability index (seismic vulnerability index). This relationship can be used to formulate whether an area has the potential to experience lateral ground motion (liquefaction) which potentially can affect the coastal area of Dewantara District. Based on microseismic data analysis (standard deviation), several disaster-prone zone points were obtained in the north and east of the measurement point. In detail, this is shown by the map of the distribution of SVI values in the Coastal Area which is in the range of 20-100, especially in the north it is at a value above 75, which allows for a higher chance of liquefaction on the condition that there are major earthquakes accompanied by with rock pores filled with fluid.

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