Analysis of Ground Shear Strain (GSS) In Mapping, Liquefaction Vulnerability Potential Using HVSR (Horizontal To Vertical Spectral Ratio) Method. Case Study: Sepaku Subdistrict, North Penajam Paser Regency, East Kalimantan

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Abstract. East Kalimantan has been designated as the new Capital Province of Indonesia. The criteria for determining the relocation of the nation's capital have passed various studies in the placement of a new state capital, one of which is by reviewing disaster aspects such as the risk of earthquakes, volcanoes and tsunamis. Based on historical records of earthquakes that have occurred, East Kalimantan is not a completely safe area from potential earthquakes or tsunamis. By using the HVSR method, the authors tried to determine the value of Ground Shear Strain (GSS) in the research area, namely Sepaku District, Penajam Paser Utara Regency. The result show that there were three zones namely Zona A, Zone B and Zone C had GSS values in Sepaku Subdistrict with landslides, soil compaction and liquefaction potential, namely 0.4 - 0.54. The result of HVSR interpretation curve are based on the phenomenon of the resulting ground shear strain value in accordance with the geological conditions in the research area of the Sepaku Subdistrict, Penajam Paser Utara Regency, East Kalimantan in characterizing the soil profile in the study area.

Keyword: Amplification Factor, Dominant Frequency, GSS, HVSR method, Liquefaction.

1. Introduction
Administratively, the research area is located in the province of East Kalimantan in North Penajam Paser Regency, Sepaku Subdistrict. The government has determined the relocation of the candidate for the nation's capital through various studies, such as assessing aspects of disaster, the risk of earthquakes, volcanoes, and tsunamis [1]. The area is located in the Kutai Basin. The Kutai Basin was formed due to basin subsidence from the Early Oligocene to the Early Miocene. The deposited material comes from the southern, western and northern parts of the Kutai Basin. The Adang Fault is located in the southern part of the study area which is thought to have formed during the Eocene period. Almost all of the rocks in this area are deformed, from Pre - Tertiary to Late Tertiary. As a result of this process an anticline and syncline were formed known as the Samarinda Anticlonorium and fault. During the Early Oligocene
to Early Miocene periods, there is a continuous decline. The deposited material comes from the southern, western and northern of the Kutai Basin areas (Fig.1).

![Figure 1. The regional geological map of the study area of Penajam Paser Utara Regency, East Kalimantan was modified from (Hidayat et al, 1994 and Supriatna et al, 1995).](image)

2. Methodology

2.1 Amplification Factor
The value of the amplification factor of the soil is related to the contrast ratio of the impedance of the surface layer to the layer below it [2]. If the impedance contrast ratio of the two layers is high, the gain factor is high, and conversely. The energy from earthquake waves can be trapped in a soft layer near the surface.

2.2 Dominant Frequency
The dominant period (1 / dominant frequency) is the period of vibration that corresponds to the maximum value of the Fourier amplitude spectrum [3]. The dominant frequency value can be obtained through the HVSR curve where the amplitude (H / V) is the maximum value. The characteristic frequency of an area can be estimated through the dominant frequency obtained from the HVSR curve.

2.3 Ground Shear Strain
Ground shear strain is the ability of a soil layer material to stretch and shift during an earthquake. If the area has a high GSS value, potentially have a high risk of ground motion due to the earthquakes, such as soil compaction, ground vibrations, and soil stretching to liquefaction [2][4].

| Table 1. The relationship between strain and soil dynamic properties (Nakamura, 1997). |
|---------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Size of Strain $\gamma$ | 10^{-6} | 10^{-5} | 10^{-4} | 10^{-3} | 10^{-2} | 10^{-1} |
| Phenomena | Wave, Vibration | Crack, Settlement | Landslide, Soil Compaction, Liquefaction |
| Dynamic Properties | Elasticity | Elasto-Plasticity | Collapse |

Repeat-Effect, Speed-Effect of Loading
3. Result and Discussions

The distribution of the amplification factor value in the study area is 1.5 – 8 (Fig. 2). The random distribution of values is proven when the dominant frequency value is low, the amplification value is high and conversely. The greater of the amplification factor value, so that the softer of the sediment in the area, conversely if the amplification factor value is low, the sediment layer will be harder.

![Amplification map of research areas in Sepaku District.](image)

**Figure 2.** Amplification map of research areas in Sepaku District.

The dominant frequency value has a value in 0.5 – 14.5 Hz (Fig.3). The surface sediment thickness of the study area was spread from low to high levels. Low dominant frequency is identified as having soft soil type. The areas that have a low dominant frequency value are very susceptible to multi-reflection or trapping of the earthquake waves in sediments. It causes of the large potential for damage to allow liquefaction [2].
The measured value of ground shear strain in the study area show the level of strain in the constituent materials during an earthquake. The amount of shear strain in a place by multiplying the seismic susceptibility index based on the microtremor with the amount of PGA in bedrock \[2\]. So that the values of the shear strain distribution in the study area is obtained, namely 0.02 - 0.54. The ground shear strain value classification can be determined in Table 1. If the strain $10^{-6}$, the soil conditions can only occur vibrations, but in the strains $10^{-2}$ - $10^{-1}$, the soil layers can occur landslides to liquefaction. Based on the map that has been produced, there are three zones which can be seen in Figure IV divided into Zone A, Zone B and Zone C which are considered to have the potential for landslides, soil compaction to liquefaction based on the relatively high ground shear strain value, namely 0.4 - 0.54 (Fig. 4.). The potential for this relatively high strain value is causing of soft soil types, shallow groundwater depths and weak plane zones. Based on the topography in the field, the geological cross-section analysis using HVSR parameters, Zone A and Zone B have the potential for soil compaction to liquefaction because it located in the lower Kutai Basin area which has a very thick surface sediment thickness. This zone is an indication of a weak plane zone which if the earthquake occurs, it will have high compression and extension forces. Whereas in Zone C, it can be potential for soil compaction to landslides. Because the resistance of slopes in high topography will decrease when the soil movement increases so that it will be accumulated by soil with high water content. This occurs is causing of high strain in the event of an earthquake or high pressure due to the compaction of sediment on the surface which can allow collapsible. The area is part of the mining and agricultural land that still operating with most of the densest forest located in the Tengin Baru area, Sepaku District.

**Figure 3.** Dominant Frequency Map of research areas in Sepaku District.
Figure 4. Microzonation map based on the ground shear strain value of the research area in Sepaku District.

With a small PGA value, the potential for liquefaction in the study area can be caused by other factors. One of the factors is loading (gravity) on the sediment below the surface. It will be occurred if the activity of the sedimentation process from the delta of the study area is very high [5]. The soft soil produced from the delta sedimentation process has a high water content. So that it can flow if there is an earthquake event loading or magnitude in the Sepaku Subdistrict area. [5]. The phenomenon due to gravity in the study area can allow mud diapir due to the compressional system of the surrounding sedimentary rock that is moving through the sedimentation process from the delta [5]. In addition, various passive structures and faults can gradually cause landslides to liquefaction phenomena. So that it needs further study of the aspects of engineering geology and drill data in more detail.

4. Conclusions
Based on the analysis that has been carried out on the research results of this final project, it can be concluded:

- The values of the ground shear strain in the research area ranges from 0.02 to 0.54. The values of the ground shear strain is caused by the seismic susceptibility index and the PGA value of the research area in Sepaku Subdistrict, Penajam Paser Utara Regency.

- Based on the resulting ground shear strain value, the research area of Sepaku Subdistrict, Penajam Paser Utara Regency has the potential to occur the phenomena of landslides, soil compaction to liquefaction. However, the criteria for ascertaining the potential liquefaction still require more detailed data such as drill data in characterizing subsoil facies. However, by having the characterization of thick and soft sediments, the potential for mudflows from the sedimentation activity of the delta can occur.

- There are three areas which are divided into Zone A, Zone B and Zone C are considered has the potential for landslides, soil compaction to liquefaction based on the relatively high ground shear strain values, namely 0.4 - 0.54. It caused of the soil type, groundwater depth and weak field zone factors. Zone A and Zone B has the potential for soil compaction to liquefactions.
While Zone C have the potential for soil compaction to landslide. The area is part of the mining and agricultural land that still operating with most of the densest forest located in the Tengin Baru area, Sepaku District.

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