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Impact of Vibration of Piling Hammer on Soil Deformation: Study Case in Highway Construction Section 5 Pekanbaru-Dumai

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Abstract: In the Pekanbaru-Dumai highway road construction in Section 5 will be built a bridge. The construction of the bridge is in the area of PT TGI gas pipeline. The construction of this bridge uses a pile foundation whose pile is carried out using a beating method using a hammer. The diameter of this pile is 60 cm with a hammer weight of 5 tons and a height of fall of 2.5 meters. This work method will produce vibrations that affect the condition of the gas pipe. One of the aspects that are affected by vibration is the deformation of the soil around the gas pipe. This soil deformation will affect the position of the gas pipe which, if it forms a fairly large slope, may cause gas pipelines to crack. The method used to determine the effect of vibration from the design of the gas pipeline is to use a vibration meter tool. vibration meter is a sensor device that is placed on the stake and on the ground above the gas pipe so that how much vibration and deformation of the soil can be seen. As a result from the test using vibration meter, it was found that the greater the wave velocity due to the design, the greater the deformation that occurs on the soil.

1 INTRODUCTION

Pile foundations are the part of a structure used to carry and transfer the structure load of the building to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Wood, steel and concrete are the main types of materials used for piles. Piles made from these materials are driven, drilled or jacked into the ground and connected to Pile caps [1] (Muhammad, 2008).

In past, theoretical and experimental studies were undertaken by various investigators to evaluate the vertical load and lateral load carrying capacity of single and group piles embedded in different soil stratum. On pile foundations, structures like Buildings, towers, Bridges, Piers harbour and offshore structure are invariably constructed (Muhammad, 2008).

In the erection process a vibration will occur with the potential damage to infrastructure and disturb the comfort of humans around him. Of course the greater the vibration caused, the greater the potential damage caused. This is compounded with the increasingly narrow land in urban areas and in certain areas, so the potential damage that might be caused by the piling is higher because of it the distance to the object is getting closer. For this reason, an analysis will be conducted related to propagation vibrations on the ground as well as factors on the ground that affect it so that vibrations are possible will occur due to predictable pile erection (Fitriyah et al., 2019; HH, 2014).

Rayleigh waves (ground roll) are waves that are known as surface waves that are generated by a momentary pressure at the ground surface that occurs as a result impact and interference between compressive waves and shear waves constructively. The movement of particles on the face of the Rayleigh wave consists of P waves and S waves in the horizontal plane. Another characteristic of the Rayleigh wave is that its amplitude decreases exponentially with the depth it goes through, whereas on the surface the amplitude hardly affects its attenuation, it has a low frequency with a not-so- sharp spectrum (Santoso, 2017; H., ; Muhammad, 2014).

The vibration wave generated in vibrating compaction will quickly propagate from near to far on the surface of ground. The incurred environmental vibration not only generates vibration damage to engineering structures, but also brings unfavorable influences

[1] API 1002 2013 " Steel Pipeline Crossing Railroad and Highway"

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on production and the lives of residents around the construction site. If enough safety protection measures fail to be taken, the vibrating compaction construction may lead to cracking of subgrade retaining wall, culvert and bridge abutment, disturb normal life of surrounding residents, affect safe production of the neighboring industrial and mining enterprises, and damage normal use and safety of surrounding buildings (Chen et al., 2019; Maizir, 2015; Muhammad, 2008).

The structural work of the Pekanbaru-Dumai highway road is designed crossing with the PT TGI pipeline position, the highway road works are constructed with pile foundations. The vibration caused by the erection felt quite large, so PT TGI was worried that there would be an impact on their gas pipeline due to the work of the pile. Therefore testing was carried out to determine how big of the impact of the vibration on the PT TGI gas pipeline.

2 LITERATURE REVIEW

2.1 Vibration Test

Ground vibration is seismic movement on the ground caused by rock blasting, pole erection, traffic, excavation, vibration due to compaction etc., which is a form of energy transport through the soil, can damage adjacent structures when vibrations reach a certain level. Some types of energy released from blasting propagate in all directions from explosive holes as seismic waves with different frequencies. Energy from seismic waves is dampened by distance and waves with the highest frequency being muffled faster. This means that the propagation of the dominant frequency from an explosion is a high frequency in a short distance and a lower frequency at a greater distance [2].

Ground vibration measurements are usually carried out at one or several points on the ground. For total analysis, the practice is to measure in three directions: vertical, longitudinal and transverse. Usually the vertical component is dominant at shorter distances. Therefore it is usually sufficient to measure in the vertical direction. For vibration analysis of measured values, vibration phenomena can be recorded as a function of history over time. Then displacement, particle velocity and acceleration can be recorded. The basic rule is that vibration velocity is measured on building structures etc. by geophone and acceleration on computer installations etc (Syahidi, 2017; Sukiman and Yakin, 2017). with an accelerometer. If vibration velocity is measured, acceleration can be calculated and vice versa. The most interesting parameter to pay attention to is the damage structure criteria that need to be protected from vibration (HA., ; Santoso, 2017; Sukiman and Yakin, 2017).

2.2 Effect of Ground Vibration on Geological Factors

Soil and rock are porous material with a relatively rigid base mass. The pores are filled with water or air. Soil is a mass consisting of mineral grains that have friction and cohesiveness between materials. In cemented mineral granular sedimentary rocks together with magma rocks and metamorphous mineral rocks it has crystallized in rock masses which usually contain water gaps and joints. In practice it may be difficult to assess accurate propagation velocity of seismic waves in different soils and rocks seen in Figure 1.

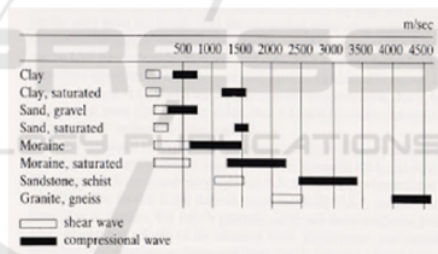

Figure 1: Propagation velocity of seismic waves in different soils and rocks [3]

Each geological environment has the characteristics of each ground vibration that influences the propagation of vibration waves. The characteristics of ground vibration depend on the following properties:

- Elastic soil constants (elastic and shearing moduli) which determine the wave propagation speed
- The type and depth of the soil that determines the dominant range of frequencies and types of waves
- Soil moisture and groundwater level
- Topography and morphology, which can focus on seismic waves
- Damping characteristics from the soil

[2]Ground Vibration Dalam Kegiatan Blasting Batuan. Viewed in 04 April 2019. http://studi- kelayakan-tambang.blogspot.com/2017/03/ground- vibration-dalam-kegiatan.html

2.3 Potential Damage Caused By Vibration

When planning a project, where driven piles or sheet piles are to be used, the design engineer must identify potentially vulnerable structures and installations in the vicinity of the project site and propose limiting values of ground vibrations. As part of this task, the risks must be assessed of vibration damage to structures and vibration-susceptible installations or environmental aspects affecting occupants of buildings. As the prediction of building damage can be complex, theoretical methods have low reliability. However, it is possible to assess the potential damage to buildings based on statistical observations. This approach is used in codes and standards but is limited to the specific conditions in the region where the observations were made. Therefore, local building standards should be applied with caution in other regions, where pile driving methods, geological conditions, and building standards may be different.

The damage potential of pile-driving vibrations depends on the displacement and the frequency of the vibration. Neither of these two characteristics alone will damage a structure. Concerning displacement, it is common knowledge that a structure can be uniformly jacked through several feet without causing damage. Likewise, with regard to frequency, normal sound, in pa ssing through a wall, can vibrate the wall at high frequencies (several thousand cycles per second) without causing damage. It is a combination of displacement (amount of motion) and frequency which causes damage. The particle velocity of earthborne vibration is the best measure of damage potential because it combines displacement and frequency in the most significant manner. The relation between Velocity and Frequency seen in figure 2.

Several investigators have found that particle velocities in excess of 4. 0 in. I sec are required to cause plaster cracks in dwellings. Figure 3 shows a comparison of the results of several of the investigations. With appropriate conservatism, the investigators agree that a vibration level of 2. 0 in. /sec (particle velocity) is safe with regard to plaster cracks in residential-type structures

The effect of ground motion on an engineered structure can be computed by commonly used methods in the earthquake engineering field. The structure is considered a lumped mass-spring dashpot system, and its response to a series of impacts can be calculated. Based on observation and experience, it can be stated that ground motion particle velocities below 4. 0 in. /sec are well within the safe range for engineer structures.

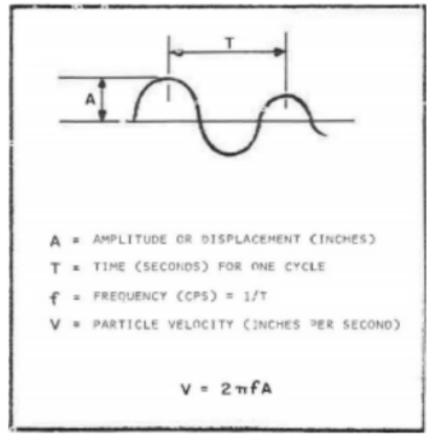

Figure 2: Propagation velocity of seismic waves in different soils and rocks [4]

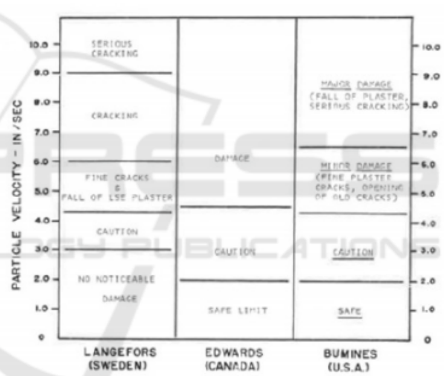

Figure 3: A comparison of the results of several of the investigations about the effect of particle velocity to structural damaged

3 RESEARCH METHOD

This research was conducted with the aim of knowing how much the vibrational impact on soil deformation at the PT TGI gas pipeline location. The research locations are STA 78 + 448 Titian Antui Village, Madau District, Bengkalis Regency - Riau and Pipeline: Grissik - Duri Section.

This research was conducted in 3 stages:

1. Initial Investigation

   the initial investigation was carried out to look back on the problems that occurred in the field based on information from the informants. From

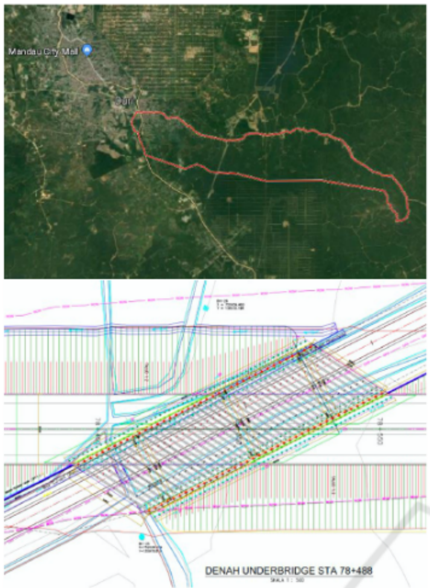

Figure 4: Research Location on STA 78 + 448 Titian Antui Village, Madau District, Bengkalis Regency - Riau

the initials of this investigation, the data is obtained in the form of data and current conditions with visualization of photos and other supporting data.

2. Soil Investigation

   soil investigation is a model of general investigation that must be done in looking at the problems that occur in a structure above the ground. From this soil investigation, soil data was obtained related to the physical and mechanical properties of the soil.

3. Vibration Test With Vibration Meter

   This vibration test equipment consists of three sensors that read vibrations produced by piles of 3 directions as seen in figure 4, namely:

   (a) 1V vibration is in vertical direction

   (b) 2L vibration is in longitudinal direction

   (c) 3T vibration is in transversal direction

This sensor is installed on the stake and on the gas pipe. with the aim when the pile works vibration that occurs due to erection will be read on the sensor that works and is read on a computer device as shown in the figure 5.

Figure 5: The Direction of The Sensor

Figure 6: The Instalation of The Vibration Meter Sensor

4 RESULT AND DISCUSSION

4.1 Soil Investigations Result

From the results of soil investigation, it was found that the type of soil at the position of the gas pipe was soft clay with high plasticity.Fine-grained soils are cohesive soils (Sukiman and Yakin, 2017). One of the problems in the geotechnical field is cohesive soil which is usually soft soil. Soft soil can expand or shrink due to the entry or discharge of water. Giving a load on soft soil, will cause an increase in the voltage acting on the soil. Additional stress that works on soft soil will initially be bear by pore water due to the

Table 1: Result of Vibration Test

Lokasi Pengujian	Velocity (mm/s)			Displacement/Amplitude (mm)		
	Vertical	Longitudinal	Tranversal	Vertical	Longitudinal	Tranversal
test 1	4.9017	0.9328	2.6744	0.0869	0.0135	0.0422
test 2	2.7704	1.3061	1.6897	0.0374	0.018	0.0229
test 3	12.7969	3.6527	12.5259	0.1535	0.02	0.1518
test4	14.202	3.8665	15.2374	0.1653	0.0384	0.1759

incompressible nature of water. This will cause excess pore water to arise. This excess pore water will be dissipated by the release of soil pore water through the soil pores, while the additional stress is

Initially the pore is gradually transferred to solid soil particles. This will result in a reduction in the volume of the land, resulting in increasing of the deformation of the soil.

4.2 Vibration Test Result

From the vibration test the results are obtained as shown in Table 1. From the results we can conclude if the velocity of the vibration from piling is high the deformation of the soil also high, like in the test 1 in vertical wave the velocity is 4,9017 mm/s and deformation is 0,0869mm, in the test 2 the velocity is lower than test 1 2.7704 mm/s and the deformation also lower than test 1 0.0374 mm. this situation happen because the velocity of vibration can produce energy and also force, so the force from the velocity can affect the soil like a load. If the velocity become high the deformation of soil also high.

5 CONCLUSIONS

From this research we can conclude : Cohesive soil (clay) has a high deformation because of the mechanical aspect of this soil that have pore, initially the pore is gradually transferred to solid soil particles. This will result in a reduction in the volume of the land, resulting in increasing of the deformation of the soil. The higher wave velocity due to the design, the higher deformation that occurs on the soil.

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