Soil deformation analysis by using plaxis 2D that cause by vibration of pilling hammer

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Abstract. Highway road construction in Section 5 in the Pekanbaru-Dumai 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. One of the analysis to predict the soil deformation around the pipeline is by using Software Plaxis 2D. from Plaxis 2D soil deformation of the soil can be predicted and made a suggestion to reduce the soil deformation.

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].

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 [1].

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 [2].

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 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. To protect the environment around construction site and alleviate damage to engineering structures and surrounding buildings, it is realistically significant to study propagation law of ground vibration caused by soil compaction and reduce influences of vibration wave on surrounding environment [3].

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. To predict the soil deformation that occurred is by using Plaxis 2D

From the description above, the purpose of the study includes:

- To predict the soil deformation that occurred by vibration of pilling hammer
- To suggest the solution to reduced vibration by making the ditch along the pilling.

2. Methodology

2.1. Ground Vibration

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 [4].

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 [4].

The basic rule is that vibration velocity is measured on building structures etc. by geophone and acceleration on computer installations etc. 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 [4].

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 [4].

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.

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 4 stages:

- **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 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.

- **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.

- **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 3, namely:
  1. V vibration is in vertical direction
  2. L vibration is in longitudinal direction
  3. T 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.
Soil deformation analysis by Plaxis 2D
To predict the soil deformation, in this research use Plaxis 2D and make two different option to reduce the soil deformation, with ditch and without ditch shown in figure 6.

Figure 4. The Instalation of the vibration meter sensor

Figure 5. The planning of ditch construction to reduce the soil deformation

3. Result And Discussion
3.1. 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. According to[5], [6], [7], [8] and [9] Fine-grained soils are cohesive soils. 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 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 [10].
3.2. Vibration Test Result
From the vibration test the following results are obtained:

| 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     |
| test 4           | 14.202          | 3.8665       | 15.2374    | 0.1653   | 0.0384       | 0.1759     |

From this result 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 0.0869 mm, 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 happens 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 becomes high the deformation of soil also high.

3.3. Plaxis 2D analysis Result
There are two options that have been done to predict the soil deformation.

- Without ditch around the pile.
  When made analysis without the ditch the soil deformation occurred still high, it is 0.183 m, shown in figure 7. In this case seen if there isn’t ditch around the pile, the high soil deformation occurred in the pile and also near the pipeline gas. With this result we can predict if piling hammer work the soil deformation will affect the pipeline gas, because the velocity of vibration that cause by piling hammer go through the pipeline gas from the soil.

- With ditch
  To reduce the impact of vibration due to piling hammer of the amplitude that occurs in the gas pipeline, an analysis is carried out by making a deeper ditch from the gas pipeline and the position of the ditch closer to the gas pipeline. Like seen in figure 8 from the analysis using 2D Plaxis.

![Figure 6. Plaxis 2D result of soil deformation without ditch](image)
It can be seen from the PLAXIS 2D displacement / amplitude analysis that occurs will lead to the ditch compared to the gas pipeline, the impact of vibrations moving to the weakest side of the system is the existence of trenches filled with water. The amplitude / displacement on the pipe is as follows shown in figure 9.

From the results of the PLAXIS 2D analysis by making the trench deeper and closer than the gas pipeline will produce a small amplitude / displacement of 0.01053 mm and a pressure of 0.00593 MPa.

4 Conclusions
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. Soil deformation that occurs will lead to the ditch compared to the gas pipeline, the impact of vibrations moving to the weakest side of the system is the existence of trenches filled with water.
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