INCLINOMETER INSTALLATION FOR MONITORING SOIL MOVEMENT IN SENIPAH PIPELINE, EAST KALIMANTAN

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ABSTRACT

Soil movement occurs and causing the landslide in Indonesia. Inclinometer is tool for monitoring the activity of soil movement that occurs in subsurface. PT. Total E&P Indonesie use inclinometer for monitoring soil movement on Senipah pipeline. In Senipah area, East Kalimantan, that located in Formation of Kampungbaru (Tpkb) is composed of quartz sandstone intercalation with clay and silt. However, the area of inclinometer installation is dominated by sandy CLAY and silty CLAY. The method on using inclinometer installation is drilling activity to create a borehole. Soil investigation was conducted during the installation, there are sampling method, insitu soil test, and laboratory test. The sampling methods are core sample, undisturbed sample, and SPT sample. Standard Penetration Test (SPT), visual classification (soil description), pocket penetrometer test, and torvane test are included in Insitu tests. Laboratory tests are water content, density, motorvane, and triaxial. The main steps for inclinometer installation are setting up the casing of inclinometer into the borehole, determining direction inclinometer casing to the potential direction of soil movement, and grouting gap between inclinometer casing and borehole. Inclinometer readings use some additional tools, there are probe, reel, and PC field. The principle of inclinometer reading is to read the soil movement every 0.5 meters. The data generated of inclinometer reading is a graph that showing the state of the soil movement based on its depth. The advantage of this inclinometer tool is interpreting the failure plane that located when there is a significant difference of soil movement within a certain depth.

Keywords: Landslide, Inclinometer, Senipah, Soil Investigation

1. Introduction

Landslides can cause human injury, loss of life and economic devastation, and destroy construction works and cultural and natural heritage. The inclinometer is used in a variety of applications. Early usage, developed for monitoring landslide movement and slope stability, has evolved to monitoring the impact of excavations on nearby facilities, and deformations of structures.

Slopes in cuts or fill embankments can be monitored for stability during and after construction. In such cases, inclinometer casing is installed in vertical boreholes, following similar guidelines as for landslide investigations. Instrument locations are based on slope conditions and the importance of nearby facilities. Monitoring is made to verify performance and to identify whether unstable conditions are developing (Mikkelsen, 1996; Dunnicliff, 1988; and Cornforth, 2005).

PT. Total E&P Indonesie use inclinometer for monitoring soil movement on Senipah pipeline. Installation of inclinometer to protect this pipe from the risk of displacement or a blow out, that can becaused by soil displacement. A slope repair should be perform in a slope, that isestimated, had a potential of landslide.

2. Regional Geology
Based on Geological Map of SamarindaSheet, Kalimantan (1995), Senipah pipeline area, East Kalimantan, is located in Kampungbaru (Tpkb) Formation. Kampungbaru Formation consist quartz sandstone intercalation with clay, silt, lignite, commonly soft and easily broken. This formation overlies and locally unconformably the Balikpapan Formation.

3. Methods

There are several methods on specifically were used for inclinometer installation.

3.1 Drilling Activity

The first method is drilling activity to create a borehole. This method used drilling rig. The borehole is a place where the inclinometer placed. Dry coring is used as the drilling method in this research. The advantages of this method are get the soil samples in every layers and get the ground water level elevation accurately.

3.2 Soil Investigation

Soil investigation was conducted during the inclinometer installation. There are some investigation in this method, such as sampling method, insitu soil test, and laboratory test.

3.2.1 Sampling Method

There are three sampling methods in this research, such as core sample, UDS, and SPT sample. The three samples are used for completed the data and to analysis.

- **Core Sample**
  
  The core sample is obtained from the drilling. A tool used to take a core sample is a core barrel. The core sample typically consists of a short cylinder with a cutting edge. The core sample included in disturbed sample, because many distractions at the time of sampling. The core sample is placed in the core box, and then be described based on soil type, plasticity, color, inclusions, moisture and strength with help of a soil classification field guidance.

- **Undisturbed Sample (UDS)**
  
  Undisturbed sample keep the structural integrity of the in-situ soil and they have a higher recovery rate in the sampler. It’s actually tough to gather perfect undisturbed sample and the samplers may contain a small portion of undisturbed soil at the top as well as the bottom of the sample length. UDS are those which are retrieved from the soil mass without disturbing the structure, density and natural moisture content.

- **SPT Sample**
  
  Split spoon is the place to put the sample after SPT. After the SPT test has done bring the sampler to the surface and open the split spoon. Then, the sample recovery length was measured and labeled. The SPT sample is taken to the laboratory for testing the water content.

3.2.2 Insitu Soil Test

In soil investigation can be done by several ways to test the soil either insitu and offsite laboratory. The insitu soil test can be SPT, visual classification, pocket penetrometer, and torvane.

- **Standard Penetration Test (SPT)**
  
  The Standard Penetration test (SPT) is a common in situ testing method used to determine the geotechnical engineering properties of subsurface soils, and according to ASTM D1586. SPT involves driving a standard thick-walled sample tube into the ground at
the bottom of a borehole by blows from a slide hammer with standard weight and falling distance. This test uses a 63.5 kg hammer driving mass falling from a free fall height of 30 inches (762 mm). The test consists of the following activities:

- Advance the borehole, at the test location, using the auger. To start with, advance the borehole for a depth of 0.5 m and clear the loose soil from the borehole.

- Clean the split spoon sampler and apply a thin film of oil to the inside face of the sampler. Connect an A-drill extension rod to the split spoon sampler.

- Mark the drill rods in three successive 0.5-ft (0.15 m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 0.5-ft (0.15 m) increment.

- The penetration of the first 15 cm is considered as the seating drive and the number of blows required for this penetration is noted but not accounted in computing penetration resistance value. The total number of blows required for the penetration of the split spoon sampler by 2nd and 3rd 15 cm is recorded as the penetration resistance or N-value.

- After the completion of the split spoon sampler by 45 cm, pull out the whole assembly. Detach the split sampler from A-drill rod and open it out. Collect the soil sample from the split spoon sampler into a sampling bag. Store the sampling bag safely with an identification tag for laboratory investigation.

- Visual Classification (Lithology)

  Field drilling log is the sheet to record visual field observations. All drilling activities were noted in field drilling log, such as soil description, N-SPT, depth, PP value, torvane value, USC symbol, groundwater level, etc. The soil description consists of several parameters in the field drilling log, the parameters are soil type, grain size, plasticity, color, inclusions, moisture, and strength. This research used ASTM D2487 as the guidance to describe and classify the soil.

- Pocket Penetrometer Test

  The pocket penetrometer test can be done after the sample was successfully drilled. This test conducted on core sample and undisturbed sample. The procedure using this tool is to press the tip of tool into the sample until a predetermined boundary. After that, read the value that indicated by the needle on the appliance. The value of pocket penetrometer then recorded on the field drilling log.

- Torvane Test

  The torvane test also similar with the pocket penetrometer test, can be done after the sample was successfully drilled. The torvane test performed only on undisturbed sample. Torvane tool has three different diameters, the diameter used based on grain size of soil. The procedure using this tool are, first choose the diameter that will be used. Then, press the diameter tool into the sample until predetermined boundary. After that, torvane tool placed above the diameter tool. Then rotate the top of the tool up to 360 degrees. The last read the value that indicated by the needle on the torvane tool.

3.2.3 Laboratory Soil Test

The sample that obtained from the drilling, then conducted laboratory test. The samples can be analyzed in the laboratory are SPT sample and UDS. Laboratory tests are water content, density, motorvane, and triaxial.

- Water Content
Water content or moisture content is an indicator of the amount of the water present in soil. This test provides the water content of the soil, normally expressed as a percentage of the weight of water to the dry weight of the soil. The water content is according to ASTM D2216 in this research. The water content test performed on SPT sample and undisturbed sample in this research. The principle of water content test is measurement the weight of soil before and after drying. The soil dried in the oven until the soil is dry. We can get the value of water content of the soil by calculating the weight difference on both.

- **Density**
  The bulk density is according to ASTM D2937 in this research. The bulk density test performed on core sample and undisturbed sample. The bulk density test uses the ring mould tool to determine the value of density. First, we measure the weight of ring mould and wet soil. Then, we can determine the volume of ring mould use the formula. The wet density obtained from the calculation is weight of wet soil divided by volume of ring mould. The value of wet density and dry density is expressed in unit of kg/cm$^3$.

- **Motorvane**
  The motorvane test is to measure the shear strength for soil that has fine grain size, such as silt or clay. The motorvane test also include in offsite laboratory test. This test is used to quickly measure soil undrained shear strength. The motorvane test performed on undisturbed sample in this research.

- **Triaxial**
  The triaxial is according to ASTM D2850 in this research. The triaxial test performed only on undisturbed sample this research. The principle of triaxial test is to determine the shear strength value of soil based pressure exerted. The summary of this method are:
  - A full diameter specimen of soil, taken from either a pressed or driven soil sampler, is placed in a chamber with the appropriate confining pressure applied to it. The height to diameter ratio is to range between 2 and 3.
  - An axial load is applied to the specimen with data being recorded for stress and strain on the specimen.
  - The results are presented in the form of a stress versus percent axial strain. The peak values are determined. The compressive strength of the specimen is taken as one half of peak stress of the specimen.

### 4. Results and Discussions

An inclinometer is an instrument for measuring angles of slope (or tilt), elevation or depression of an object with respect to gravity. Principles of inclinometer are to read the movement of soil and monitoring the land movement. One of the benefits inclinometer is to minimize landslides. The inclinometer devices and how to install the inclinometer will be described below.

#### 4.1 Inclinometer Devices

There are three devices used when installation inclinometer and reading inclinometer. There are inclinometer casing, field PC, probe and reel.

- **Inclinometer Casing**
  Inclinometer casing is a special purpose, grooved pipe used in inclinometer installations. It is typically installed in boreholes, but can also be embedded in fills, cast into concrete, or attached to structures. Inclinometer casing provides access for the inclinometer probe, allowing it to obtainsubsurface measurements. Grooves inside the casing control the
orientation of the probe and provide a surface from which repeatable tilt measurements can be obtained.

- **Field PC**
  The Field PC is a rugged, handheld, easy to use instrument for reading inclinometer probes. The Field PC communicates with the cable reel by means of Bluetooth wireless technology. Readings are stored by tapping “Record”, or pressing the “Enter” button on the Field PC display. An audible beep indicates the completion of the reading storage. During the running of a deflection survey the Field PC has the capability of displaying the checksum on the LCD screen, a useful tool for checking the survey data in the field so that reading errors are minimized.

- **Probe and Reel**
  The probe and reel are used to survey the casing. The initial survey establishes the profile of the casing, and subsequent surveys will reveal changes in the profile if ground movement occurs. Biaxial probes contain two sensors oriented 90° apart to permit readings in orthogonal directions at the same time. Reel is an electrical cable connecting the probe and readout unit with distance markings.

4.2 Inclinometer Installation

An inclinometer is a device for monitoring subsurface movement. Inclinometers are often used to monitor the performance of slopes and embankments. They can provide early warning of developing instabilities, allow the assessment of pattern, depth and rate of movement, and help engineers make better and brave to take decisions on possible remedial actions to such sloping movements. Other applications include monitoring the impact of excavations on surrounding facilities, deformation of structures, and settlement of embankment fills and roadway. The followings are explanation of the installation inclinometer:

a. Select the casing materials that compatible with the environment conditions in the installation. Select the size of the casing that qualified the standard measurement requirements and conditions for the job. Store the casing material in a safe, secure place to prevent damage, the sunlight can damage the plastic casing.

b. Set all components required for the casing, including casing, joints, connectors, and end cap. Keep all components clean and free of foreign matter during assembly. Follow the manufacturer’s instruction for assembly of the casing. If required, use sealing mastic and tape to seal couplings to prevent later flow of soil particles into casing.

c. Drilling the borehole according to a predetermined depth. After that, clear the borehole of debris and check the borehole depth. Extend the borehole at least 5 m beyond the zone of expected movement.

d. Insert the casing into the borehole. Establish the reference orientation for the casing and align one set of groves with this reference. This orientation is commonly referred to as the A direction. The first length of casing shall be inserted, complete with bottom cap and attached inclinometer casing. Additional lengths of casing are added until the desired depth is reached, which does not necessarily have to be to the bottom of the hole. Depending on the coupling system used, tape may be considered to further seal the joints between lengths of inclinometer casing as an additional barrier to ingress of grout and water. This also keeps fine grained soils from getting around shear wires or threads and allows for easier disassembly of the casing if needed.
e. Once the inclinometer casing is lowered into the hole to the required depth, a pair of grooves should be aligned in the expected direction of ground movement. This should be done only if it can be accomplished without applying excessive torque to the casing.

f. Set to the direction inclinometer casing to match the potential direction of movement soil. This step uses the compass to determine the appropriate angle of the inclinometer casing direction.

g. Fulfill the annular space between the borehole wall and the inclinometer casing with a suitable filling material. Borehole can be pre-grouted or post-grouted. The grout may be a mixture of bentonite, cement, and water in which the proportions of each are chosen such that the grout is able to “set-up”, thereby bonding the inclinometer to the surrounding soils.

h. Upon completion of the installation, the inside of the casing should be kept clean so that the probe can travel accurately in the grooves all the way in and out of the casing. If the grooves become contaminated by grout, they should be cleaned by flushing with water.

i. After installation and curing of the grout, two sets of inclinometer readings should be taken to provide a reliable baseline. If the two sets show any apparent movement, a third set should be taken.

The principle of inclinometer reading is to read the soil movement every 0.5 meters. The data generated of inclinometer reading is a graph that showing the state of the soil movement based on its depth. The advantage of this inclinometer tool is interpreting the failure plane that located when there is a significant difference of soil movement within a certain depth.

5. Conclusions

Based on result, there are some conclusions of this research. The purpose of inclinometer installation is to monitoring soil movement on Senipah pipeline. There are two main methods during the inclinometer installation, drilling activity and soil investigation. The main step of installation inclinometer are setting up the casing of inclinometer into the borehole, determining direction inclinometer casing to the potential direction of soil movement, and grouting gap between inclinometer casing and borehole.

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References


Figure 1. Geological Map – Senipah Pipeline Area (The red rectangle shows area of research), that located in Kampungbaru (Tpkb) Formation

Figure 2. Sampling method in this research, SPT sample in the bag (a); core sample (b); undisturbed sample (c)
Figure 3. Standard Penetration Test (SPT), the principle of this test is the hammer was pulled by hydraulic machine and dropped accordance with standard size.

Figure 4. Tools of insitu soil tests are pocket penetrometer (left) and torvane (right).

Figure 5. Oven for water content test, the principle of water content test is measurement the weight of soil before and after drying. The soil dried in the oven until the soil is dry.

Figure 6. Triaxial tool for triaxial test in laboratory.
Figure 7. Motorvane tool for measure the shear strength of soil

Figure 8. Inclinometer casing is pipe that used in inclinometer installations

Figure 9. Probe and Reel, reel is an electrical cable connecting the probe

Figure 10. Field PC, the tool for monitoring the soil movement
**Figure 11.** First length of casing should complete with bottom cap when installation

**Figure 12.** Use sealing mastic and tape to seal couplings to prevent later flow of soil particles into casing

**Figure 13.** Set direction inclinometer casing with compass

**Figure 14.** Grouting, fulfill the annular space between the borehole wall and the inclinometer casing with a suitable filling material