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Subsurface Analysis of National Road Bts. Sidoarjo City – Gempol Using Geophisycs Method and Geotechnical Tests

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ABSTRAK

National road segment Bts. Sidoarjo City – Gempol from Km 30+000 to Km 33+000 is located at west side of the Sidoarjo Mud (LuSi) embankment which still have an active eruption for more than 15 years from 2006 to the present. Based on the observations which conducted by PPLS, it found that the LuSi embankment had lowered around 6 cm/year. This phenomenon can cause damage to the infrastructure nearby. National road segment Bts. Sidoarjo City – Gempol, one of important infrastructure is experiencing severe damage and disturbed due to land subsidence. Therefore, it is necessary to conduct research on these national roads to understand the problem throughly. This research was carried out using both geophysical methods and geotechnical investigations. In advance, resistivity geoelectrical using Wanner-Schlumberger configuration and GPR were used as non destrcutive test. Meanwhile, SPT boring were applied to determine subsurface conditions. According to field and laboratory works, below 6 m of sample depth is classified as soft to very soft soils with high plasticity. There were also suspected 2 fractures in the geoelectric path beside the LuSi embankment. The results are expected to help the preservation planning for handling soil improvement on National Road segment Bts. Sidoarjo City – Gempol to prevent land subsidence.

Keywords : National roads, geophysical methods, geotechnical investigations, soft soils.

INTRODUCTION

The Sidoarjo Mud (LuSi) is a historical disaster that has occurred since 2006 until now, there has been no sign of stopping. This disaster certainly had an impact on the economic, social and infrastructure nearby. One of the impacts caused by the LuSi is the phenomenon of land subsidence around the area (Fulton, 2008). Based on the observations which conducted by PPLS from 2017 to 2022, it found that the LuSi embankment had lowered around 6 cm/year. National road section Bts. Sidoarjo City – Gempol is one of the important infrastructures which has been badly damaged and disrupted due to LuSi.

Figure 1 is the research location on national road Bts. Sidoarjo City – Gempol STA 0+050 – STA 0+800 near west side of the LuSi embankment. At this location, the worst floods occurred in February 2021, causing these national roads closed. Based on the geological map, the LuSi area and its surroundings are alluvium. The lithologys are clay, silt, sand, gravel, cobbles, and lumps. Alluvial has low permeability, contains a lot of organic and soft soils. Besides that, the location of the Sidoarjo Mudflow is also in the alignment of the Watukosek Fault system which leads Southwest – Northeast (PPLS, 2020).

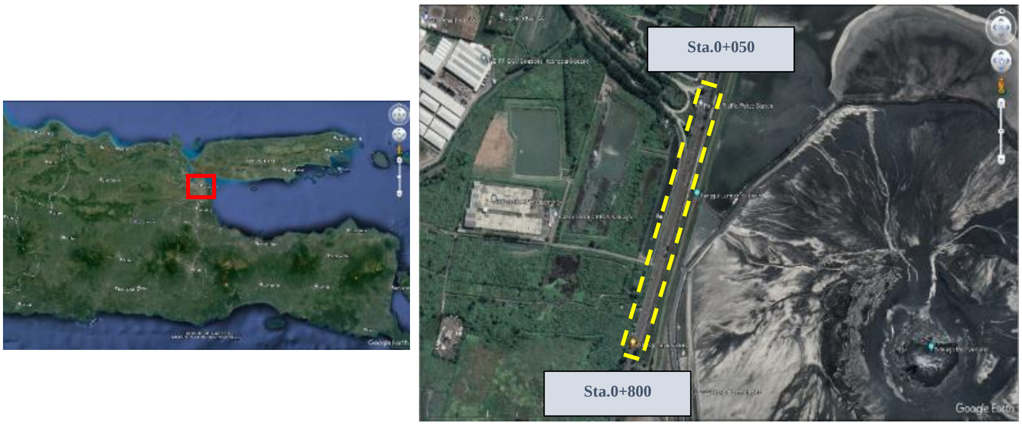


Figure 1. Location of the Natioan Road Bts. Sidoarjo City – Gempol STA 0+050 – STA 0+800

Figure 2. Geological Map of Lumpur Sidoarjo

Based on the description above, it is necessary to conduct research on these national roads to understand the problem throughly, namely, to analyze the subsurface conditions of national road Bts. Sidoarjo City – Gempol STA 0+050 – STA 0+800 using non-destructive geophysical methods and validated by geotechnical tests.

RESEARCH METHOD AND LITERATURE REVIEW

Data Collection

The data used are primary data and secondary data. Primary data collection includes the geophysical methods, namely Ground Penetrating Radar (GPR) and resistivity geoelectrical 2D. Geoelectrical data acquisition using Wenner-Schlumberger configuration. Line 1, 2 and 4 are 220 meters long with a distance between electrodes of 4 meters and a depth of up to 42.9 meters, while line 3 is 330 meters long with a distance between electrodes of 6 meters and a depth of up to 64 meters. GPR data acquisition using the SIR-4000 with a 350 MHz antenna for 2 longitudinal lines. The penetration depth is up to 12 meters.

The secondary data used are the geological map, bor SPT and laboratory test results of soil parameters.

Processing Data of GPR

The result of GPR data acquisition is a radargram. The raw data of radargrams that have not been filtered are considered not suitable for imaging the existing subsurface conditions, therefore several stages are carried out to obtain a representative radargram to describe the subsurface conditions using the RADAN 7 with the following steps:

a) Time Zero
Time zero correction is a process of moving the radargram to its true position. In GPR measurements, there is a difference lag time before the signal hits the surface during data acquisition, the signal delay must be removed in this process.

b) Background Removal
Background removal is the filter to remove the background caused by low-frequency noise. It is useful for reducing the average trajectory (trace range). This correction cleans the background on the GPR profile and eliminates the influence of low- lateral frequency. After background removal, the radargram usually experiences attenuation. Removing low-frequency noise will clarify the delineation of the soil layers.

c) IIR Filter
From this filter, channel parameters are set to determine the low pass and high pass values. The vertical low pass filter function is to remove high frequency noise that appears on the radargram. The instrument antenna used is 350 MHz. In filling the vertical low pass filter, a method of calculating 2 times the center frequency of the antenna is carried out. If it is known that the antenna is 350 MHz, then the vertical low pass filter = 2x350MHz= 700 MHz. Furthermore, vertical high pass filter = 1/4 x central frequency = 1/4 x 350 MHz = 87.5 MHz. The frequency displayed on the radargram is from the 87.5-700 MHz.

d) Gain
This process aims to improve the weak signal so that the results of the radargram will appear clearer. The type of gain used is exponential.

Processing Data of Resistivity Geoelectrical 2D

The result from resistivity geoelectrical 2D acquisition is apparent resistivity values. This apparent resistivity must be processed so that the true resistivity is obtained. Geoelectrical data processing uses the AGI Earthimager 2D program to model subsurface conditions in two dimensions based on the resistivity value of each layer of subsurface soil.

Geophysical Data Interpretation

Data interpretation was carried out descriptively on the results of subsurface structure modeling based on the geological information of the research area. Therefore, a regional geological map of the study area is needed to determine the type of soil and rock when interpreting the data.

Processing and Analysis of Geotechnical Investigation

From the SPT boring, undisturbed soil samples were obtained which tested in the laboratory. The results of this laboratory test are the physical soil parameters which used as a reference to determine the classification of the soil at that location.

Correlation of Geophysical Methods and Geotechnical Investigation

Data analysis was carried out by correlating the results of GPR data, resistivity geoelectrical 2D and SPT boring. It can be analyzed the structure of the subsurface layer. From the GPR and resistivity geoelectrical 2D data, we can identify the weak zones.

RESEARCH ANALYSIS

Bor SPT Data Analysis and Laboratory Test Results

The graph below is the physical parameters of soil laboratory test results. From these physiscal parameters, soil at the depth >6m classfied as soft soils.

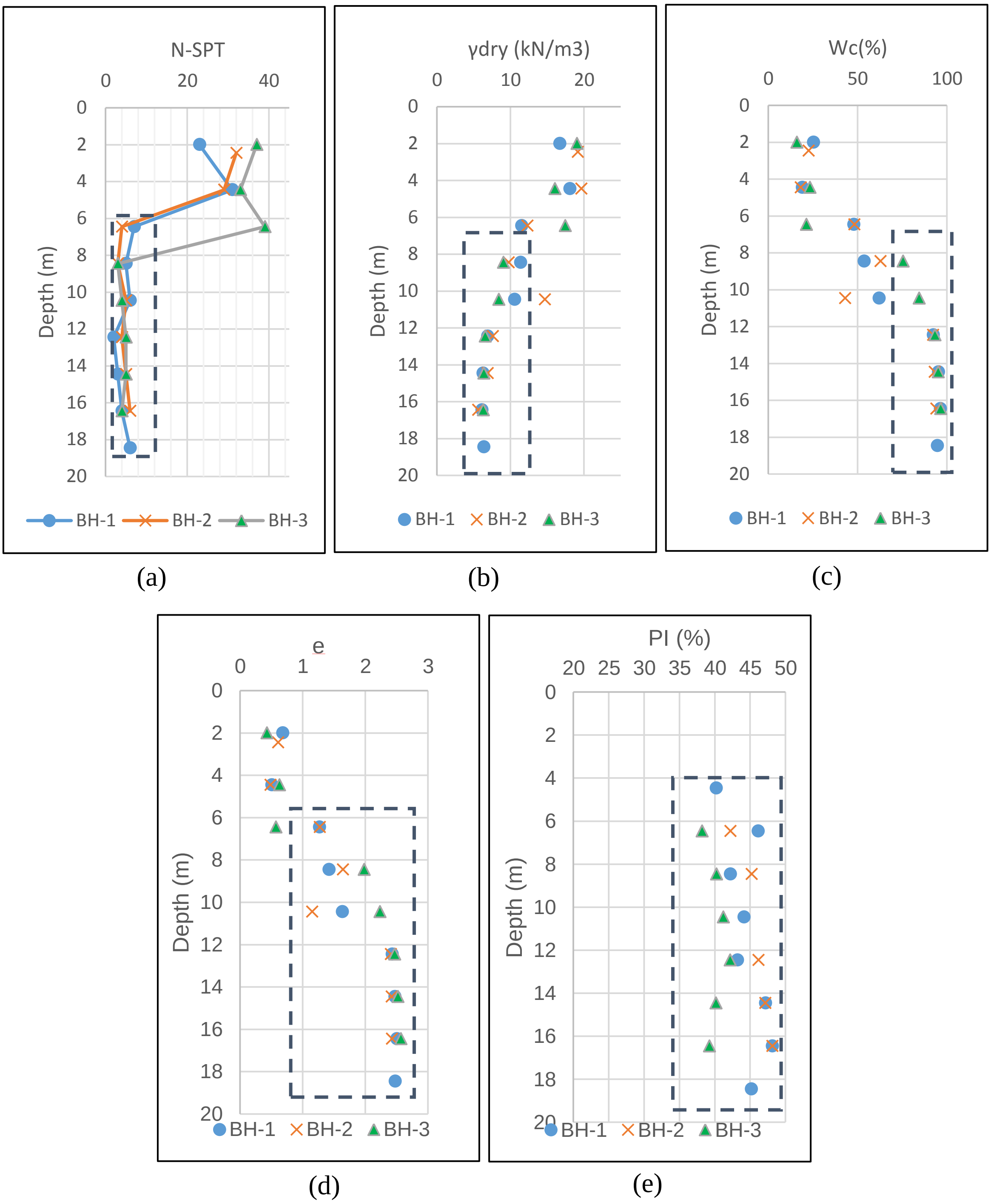


Figure 3. Physical parameters of soil (a) N-SPT (b)Υ_{dry} (c) Water Content (d) Void Ratio (e) Plasticity Index

From the laboratory tests result determined the soil classification based on the USCS method, obtained that the soil at the surface to a depth of 2 meters at BH-1 and 4,45 meters at

BH-2 and BH-3 is classified as silty sand. The soil at a depth below is dominantly clay with high plasticity.

Table 1. USCS Method of Soil Classification

Depth (m)	BH-1	BH-2	BH-3
2	SM	SM	SM
2,45	CH	SM	SM
6,45	CH	CH	CH
8,45	CH	CH	CH
10,45	CH	SM	CH
12,45	CH	CH	CH
14,45	CH	CH	MH
16,45	CH	CH	MH
18,45	CH		

GPR Data Analysis

Interpretation of GPR data is a subjective part of the processing methodology which is influenced by factors of knowledge, skill, and user experience (Annan, 2003). Based on the wave configuration generated in the GPR data processing and the GPR wave configuration of the stratigraphy which is used as a reference for interpretation based on Beres and Haeni, 1991.

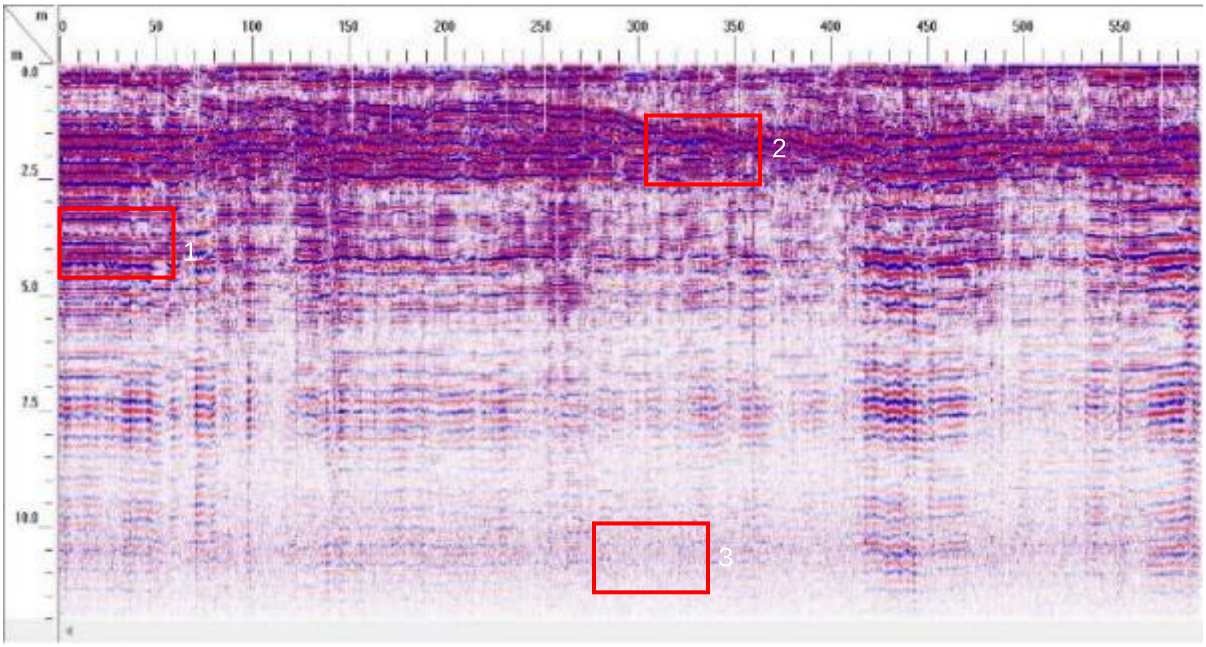
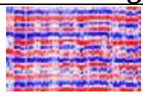
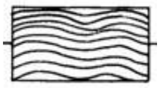
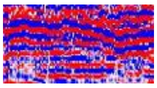
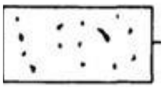
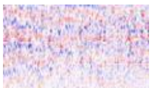


Figure 4. Radargram LIN1

Table 2. Interpretation of Radargram

No	Wave Reflection Pattern/Type	Reflection Pattern of Data Processing	Interpretation	Lithology
1	 Parallel		Sandy soil with layered reflections and thick layers	Sand
2	 Wavy		Silt and sand soil with wavy layered reflections	Silty Sand to Sandy Silt
3	 Reflection Free		Subgrade soils with high clay content, characterized by attenuation (no visible reflections)	Clay

The two GPR radargrams did not show any hyperbolic curves which indicated an anomaly along the GPR profile because the GPR measurements were focused on finding the distribution of soft soil layers. The results of the GPR radargrams tend to be homogeneous and there is a clear boundary between the fill soil and the subgrade soil on all the displayed GPR radargrams. The radargram shows a wavy pattern depicting layers of soil with an interpretation of silty sand. The GPR radargram at a depth of 2.5 meters - 12 meters show a free reflection pattern with an interpretation of clay. This shows that the subsurface layer of the national road Bts. Sidoarjo City – Gempol STA 0+050 -0+800 is dominated by clay from a depth of 2.5 meters – 12 meters.

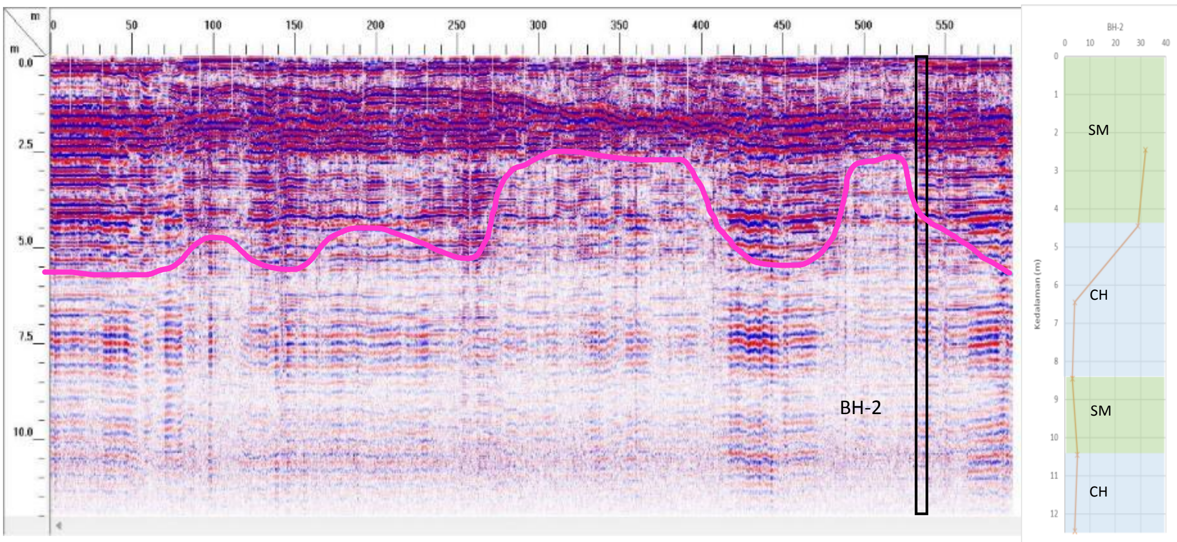


Figure 5. Radargram Correlation with Bor SPT BH-2

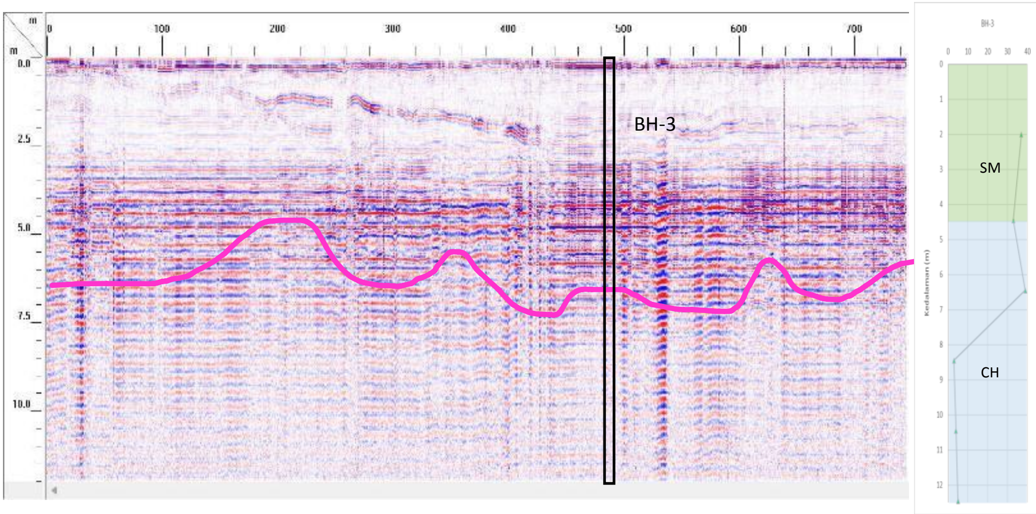
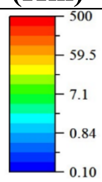


Figure 6. Radargram Correlation with Bor SPT BH-3

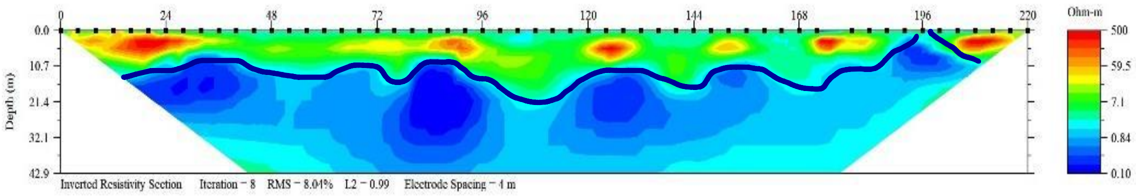
Resistivity Geoelectrical 2D Data Analysis

In this research, resistivitiy geoelectrical acquisition were carried out at LIN_1, LIN_2 and LIN_4 using Wenner-Schlumberger configuration with a track length of 220 m, 56 electrode points and a spacing of 4 m between electrodes. Meanwhile, LIN_3 uses the Wenner-Schlumberger configuration with a path length of 330 m, 56 electrode points and a spacing of 6 m between electrodes. The Wenner-Schlumberger configuration is used because this configuration is a combination of the Wenner configuration which is sensitive to lateral changes and the Schlumberger configuration, which is sensitive to vertical changes, so this configuration is recommended for deep investigations. From the results of geoelectrical data processing, it can be divided into 5 soil layers according to the resistivity values presented in the table below.

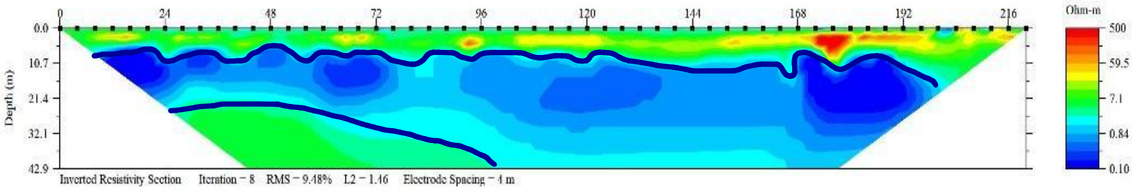
Table 2. Interpretation of Resistivity Value

No	Material	Resistivity (Ωm)	Resistivity Diagram (Ωm)
1	Sand and gravel with silt layer	>500	
2	Sand: moist to dry	59,5 - 220,25	
3	Silty Sand: moist to dry	33,3 - 59,5	
4	Silty Clay - Sandy Silt	3,97 - 33,3	
5	Clay	0,1 - 3,97	

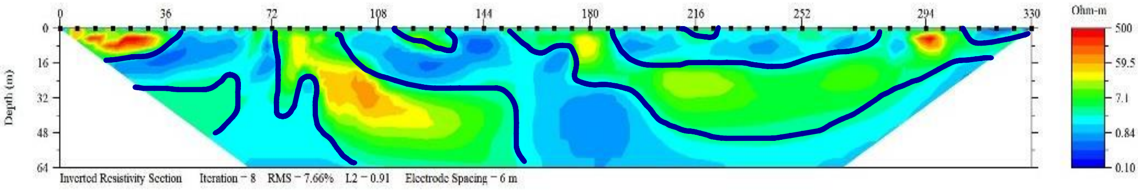
The results of the 2D resistivity model can be classified according to the measured resistivity value. Low resistivity values of 0.1 – 3.97 Ωm marked with dark blue to light blue colors can be classified as saturated clay soils with high water content. This layer is identified as the weak zone.



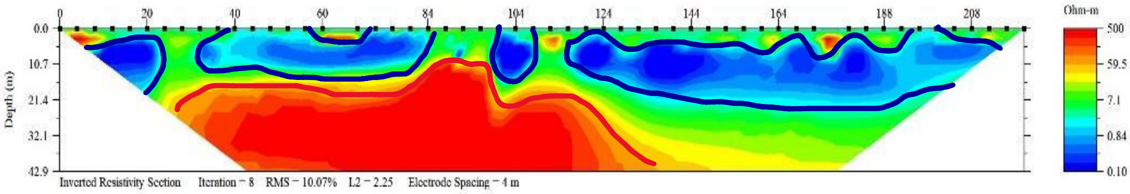
(a)



(b)



(c)



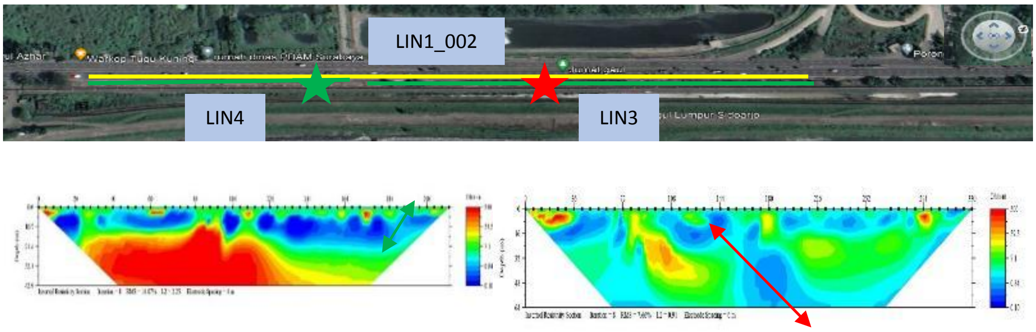
(d)

Figure 6. Weak Zone of (a) LIN1 (b) LIN2 (c) LIN3 (d) LIN4

LIN1 and LIN2 are tracks on the west side of main road, while LIN3 and LIN4 are tracks on the east side of main road that are closer to the LuSi embankment. The weak zone on the east side of the road is shallower than the weak zone on the west side of the road.

Identification of Fractures

The weak zone on the LIN3 geoelectric track from a depth of 0 – 64 meters and stretches at 100-216 meters is suspected as a shallow fracture, this can also be seen on the LIN1-002 radargram at 435m (STA 0+400). On the LIN1-002 radargram at 435m it is seen the presence of a fracture marked by a break in the radargram pattern. The weak zone on the LIN4 geoelectric track from a depth of 5.3 – 21.4 meters and extends at 118-208 meters is suspected as a shallow fracture, this can also be seen on the LIN1_002 radargram at 250m (STA 0+575). On the radargram LIN1_002 at 250m shows a fracture marked by a broken radargram pattern.



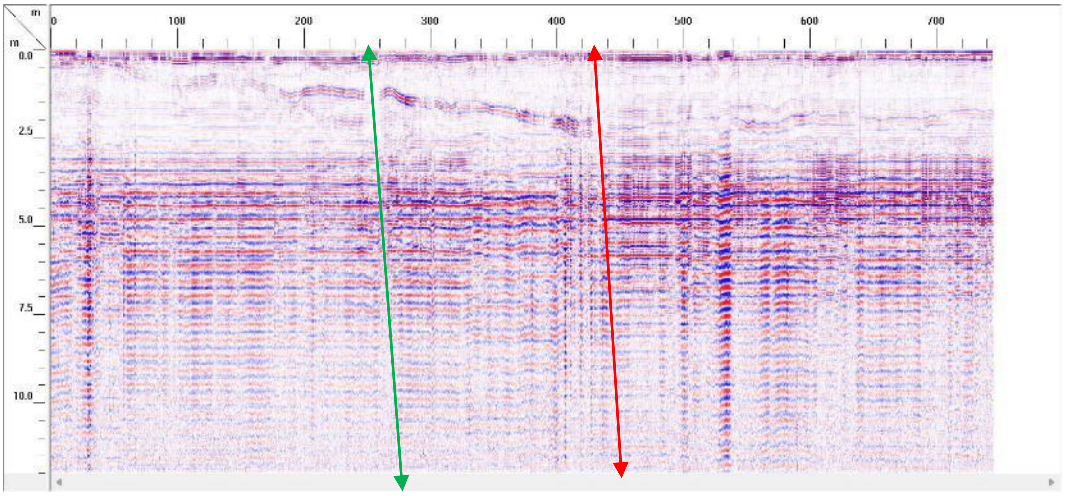


Figure 7. Fractures Identification

CONCLUSION

Based on the results of data collection and analysis that has been done, it can be concluded as follows:

1. The results of the GPR radargrams tend to be homogeneous and there is a clear boundary between the fill soil and the subgrade soil.
2. The weak zone is indicated by a low resistivity value of 0.1 – 3.97 Ωm. On the west side of National Road Bts. Sidoarjo City - Gempol it was identified at a depth of 10.7-42.9 meters along the track, while on the east side of Jalan Raya Porong it was identified shallower than west side starting from a depth of 0 meters.
3. There were 2 shallow fractures found on the east side of National Road Bts. Sidoarjo City - Gempol at STA 0+400 and STA 0+575 as shown from the results of the resistivity geoelectrical 2D and radargram GPR.

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