Geological and geotechnical review of gas and mudflow area as mitigation efforts in the risk of failure on Toll Road Project, Banten

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Abstract. The toll project in Banten shows that there is an area of gas burst at one of the locations. The embankment road passes through the gas burst. The geoelectric results that there is a silt/sandy soil layer and rock on the surface (10-20m), the second layer is soft silt to silt (20-40m), and then a rock layer. The second layer has gaps towards the first layer from the bottom layer, which is identified carrying gas and water, which is passed through the gaps to the surface. The seismic refraction also results that there are basins with gaps through the top and bottom of soil layers. The layer which indicates the gas and water carrier line is volcanic, sandy, forming a layer that has undergone deformation and partly a water-bearing layer (sand). The result of LEMIGAS explained that the gas bursts are also not methane that comes from the humus decomposition. The gas bursts are originated from depth and related to petroleum activity. The CO_2 content is up to 97.87%, which is poisonous. However, the burst area is open, and the morphology is flat and does not form a cup, this gas spreads out so that the impact is not too pronounced.

1. Introduction

A toll road has been constructed in Banten. The toll road has 80 km length passing various areas such as rural, city, forest, and swamp. In one of a specific area, there is gas and mudflow, located in the Walantaka, Serang. The gas and mudflow covers some rice field areas. These areas are not only passed by embankment toll road design but also a pedestrian bridge. The location of the gas and mudflow is indicated in the potential hydrocarbon area according to the hydrocarbon distribution map as below.

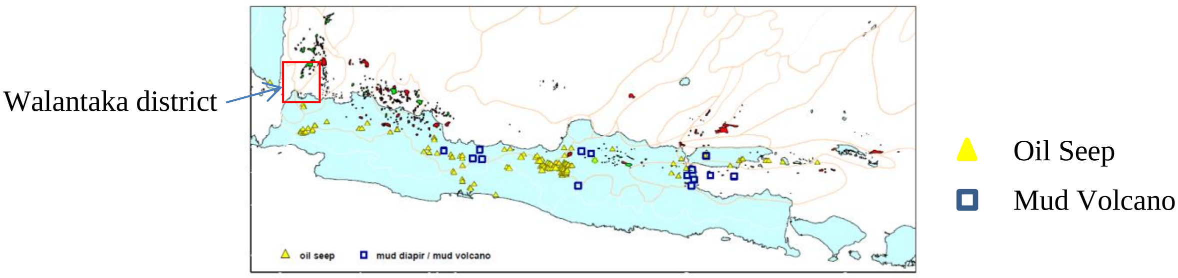

Figure 1. Map of distribution of the emergence of "oil seep" as a trace of hydrocarbons and mud volcanoes on the island of Java [1].

The danger of indicating gas such as carbon dioxide are discussed in literature; Harper [2] explains CO_2 is commonly thought of as posing a threat to life through asphyxiation when it displaces the oxygen in air down to dangerously low levels. Linde [3] discusses if the air, which we breathe, contain 3 – 5 vol.% CO_2, we will experience headache, respiratory disturbances, and discomfort. If CO_2 is at 8 – 10 vol.%, it will cause cramps, unconsciousness, respiratory arrest, and death. At this point, the oxygen content of the air is still 19 vol.%, which is still sufficient. The physiologically harmful effect of these high CO_2 concentrations, therefore, results not from lack of oxygen, but from the direct effect of carbon dioxide. A maximum workplace concentration (equivalent to TLV) of 0.5 vol.% has therefore been defined for CO_2.

Muni Budhu [4] explains that geotechnical engineers have to pay particular attention to geology, surface drainage, groundwater, and shear strength of soils in assessing slope stability. Robert D. Holtz and Schustera [5] mentions that geological reconnaissance is an important part of preliminary project development for many transportation design studies. This reconnaissance should note any evidence of potential stability problems due to poor surface drainage, seepage existing natural slopes, hill slope creep, and ancient landslides.

This study examines the result of field observations (Geoelectric and seismic refraction) of gas release based on the literature which are adjusted to the existing conditions. The embankment that passes through the gas burst is 5 m high by 30 m wide. In the burst area, there is a pedestrian bridge that connects the area cut off by the toll road.

The embankment has soil embankment dead load and vehicle live load. This load becomes the total load above the gas burst. So this study analyses the handling of gas bursts under the embankment so that the gas burst can flow and not get clogged. In addition, the study also discusses the handling of bridge foundations because there are indications of corrosion.

2. Preliminary Survey

Geologists and geotechnical engineers conducted preliminary surveys of the gas burst, which the toll road passed through. The results of field observations indicated that the area of gas and water bursts is station 0 + 300 to station 0 + 900 m.

The water, soil and gas were sampled by simple testing of areas near the center of the largest burst. Samples were taken to determine the gas content, the possible origin of the gas and the nature of the gas. Samples were tested by LEMIGAS. In the location, Geologists and geotechnical engineers conducted a simple test by means of the relationship between the gas burst and the flame that is brought closer to the center of the burst. Tests were carried out at the two largest gas burst locations.

Furthermore, Geologists and geotechnical engineers survey the location for preparing to conduct geoelectric tests (resistivity) and seismic refraction. SRT and ERT techniques have been used to investigate volcanic and geothermal areas, landslides, seismotectonic structures, hydrogeological phenomena, environmental problems, as well as the deposition and flow of impact melt and breccia [6-11]. Electrical resistivity tomography is a non-invasive survey technique recently developed for imaging subsurface features from electrical resistivity measurements made at the earth's surface, in cross-holes (boreholes), or underwater. ERT uses four electrodes for subsurface imaging in order to minimize the effect of contact resistance [11,12]. Seismic refraction method measures the travel times of seismic waves refracted at the interfaces between subsurface layers of different velocities. The development of powerful computer technology used for earthquake location and in the determination of seismic body waves travel times from near-surface to deep earth's interior led to the modern field of seismic tomography, a powerful technique for the determination of depths and velocities of overburden constituents and the refractors within the Earth's subsurface [11,13-14].

3. Review Result

Geoelectric and seismic refraction pathways are carried out in the gas burst area.

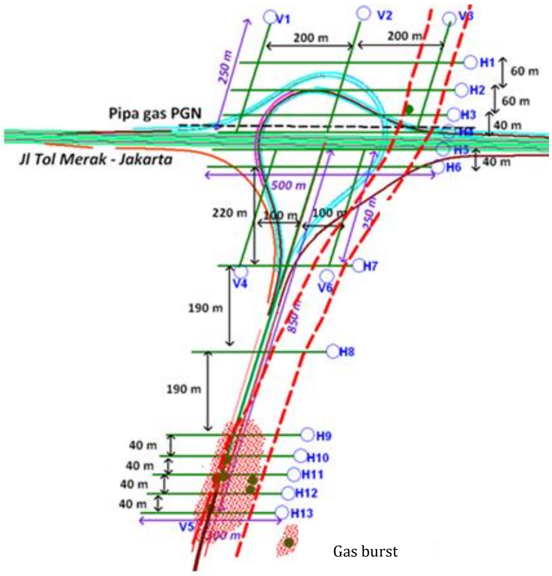

Figure 2. Geolistric and seismic refraction paths

Geoelectric and seismic refraction paths are carried out transversely and lengthwise to determine the overall soil condition in the burst area. The transverse line is 13 lines with the symbols H1-H13. While the longitudinal line is eight lines with symbols V1-V8.

3.1. Geoelectric

The majority of colours in the geoelectric map are purple, red, brown and yellow. The colour is representative of the ohm waves, which can be correlated with the type of soil / rock.

Table 1. Correlation between resistivity and soil/rock [15]

Soil/Rock	Resistivity (Ohm)
Soft Saturated Clay	1.5-3
Soft Saturated Silt	3-15
Silt, sand	15-150
Bedrock from saturated soil	150-300
Sand, Gravel, with silt	300
Bedrock from unsaturated soil	300-2400
Bedrock	>2400

The geoelectric results have several types of Waves value groups with representative colours and soil types as follows

Table 2. Results correlation between resistivity and soil/rock in the case

Colour	Waves (Ohm)	Soil
Purple	10	Soft Silt
Red	30	Silt
Brown	60	Silt/Sand
Yellow	350	The bedrock is filled with saturated soil
Green	600	The bedrock is filled with dry soil

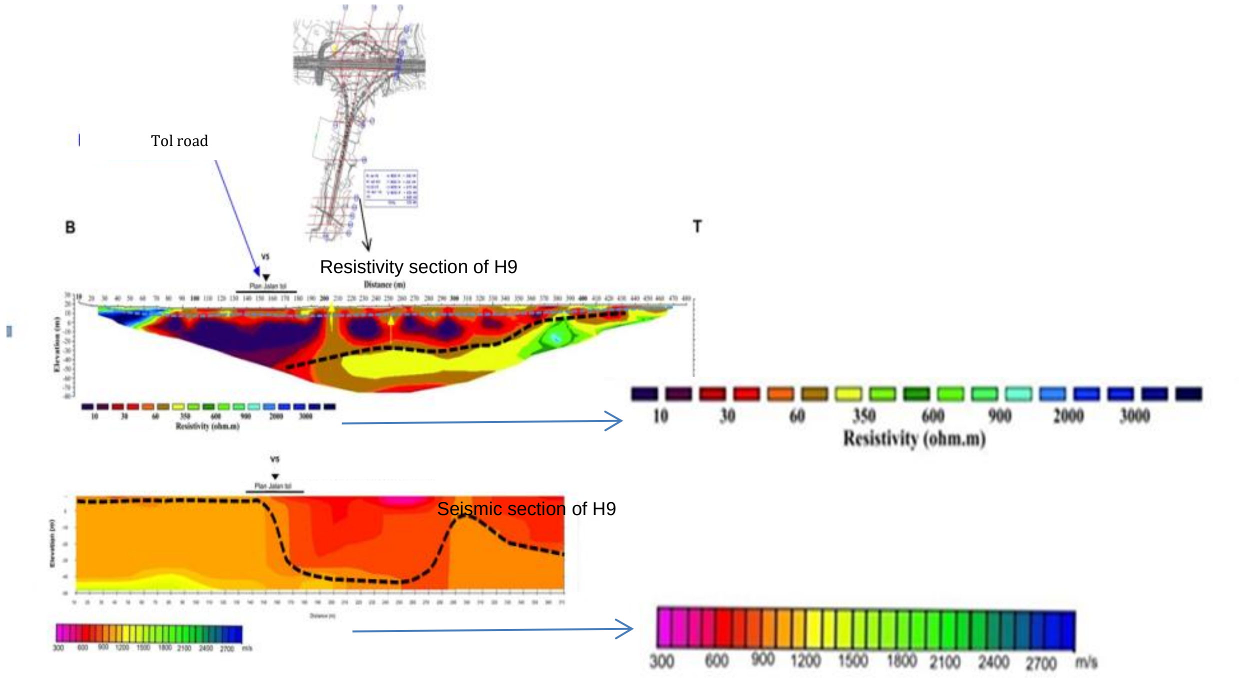

Figure 3. Section of resistivity and seismic refraction of the H - 9 path.

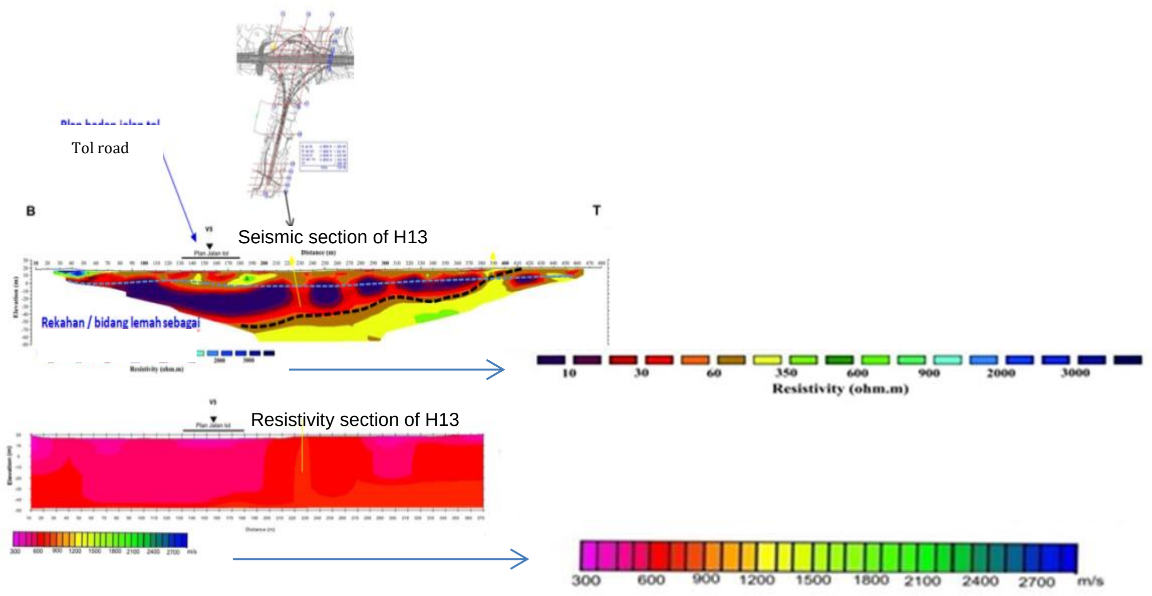

Figure 4. Section of resistivity and seismic refraction of the H - 13 path.

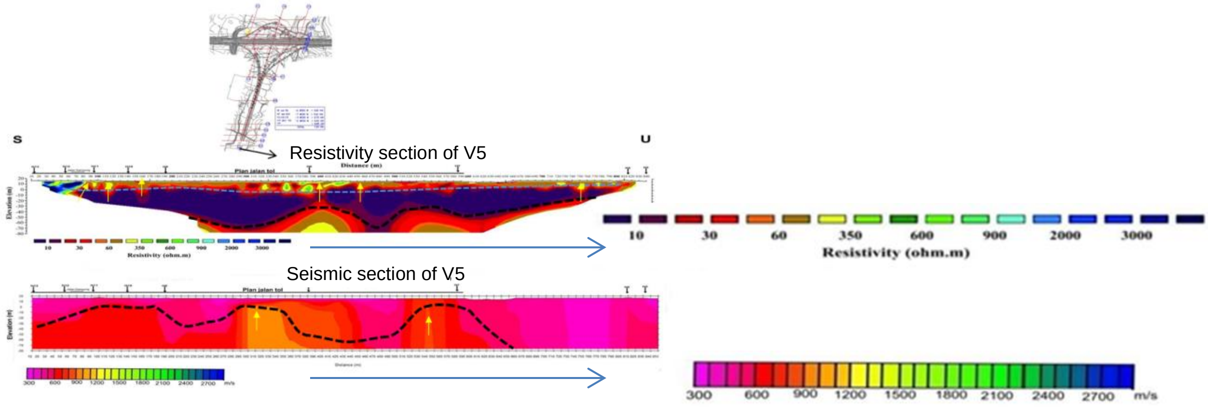

Figure 5. Section of resistivity and seismic refraction of the V - 5 path.

The geoelectric results of H9, H13 and V5 paths indicate that there is a silt/sandy soil layer and rock on the surface with representative brown (60 Ohm) and yellow (350 Ohm) with a thickness of the layer approximately 10-20 m. Then the second layer is soft silt to silt soil with representative purple (10 Ohm) and red (30 Ohm) with a thickness of layer approximately 20-40 m. The next layer is a rock layer with representative green (600 Ohm) and yellow (350 Ohm). The second layer has gaps towards the first layer (surface) and has gaps from the bottom layer. The second layer is identified carrying gas and water, which is passed through the gaps to the surface layer.

3.2. Seismic refraction

The majority of colors in the refractive seismic map are pink, red, orange and yellow. The color is representative of the velocity that can be correlated with the type of soil/rock.

Table 3. Correlation between velocity and material [16]

Material	Velocity (m/s)
Air	331.5
Water	1400-1600
Weathered Layered	300-900
Soil	250-600
Alluvium	500-2000
Clay	1000-2500
Sand (Unsaturated)	200-1000
Sand (saturated)	800-2200
Sand and Gravel Unsaturated	400-500
Sand and Gravel saturated	500-1500
Glacial Till Unsaturated	400-1000
Glacial Till saturated	1500-2500
Granite	5000-6000
Basalt	5400-6400
Metamorphic Rock	3500-7000
SandStone and Shale	2000-4500
Limestone	2000-6000

Table 4. Result correlation between velocity and soil in the case

Colour	V(m/s)	Soil
Pink	300	Weathered layered/Sand/Alluvium
Red	600	Weathered layered/Sand/Alluvium
Orange	900	Clay
Yellow	1200	Clay

The seismic refraction results of lines H9, H13, and V5 show that there are basins with gaps through the top and bottom of soil layers. This soil type is weathered layered/sand which is indicated to carry gas and water in the soil with representative pink and red colours (300-600 m/s) with a thickness of layer approximately 20-30 m thick. This soil type is surrounded by clay with representative colors of orange and yellow (900-1200 m/s).

The cross-section of the layer which indicates the gas and water carrier line is volcanic, sandy, forming a layer that has undergone deformation and partly a water-bearing layer (sand). In addition, subsoil densities range from low to high. Thus, the gap zone from below to the surface is a major factor in the release of gas and water bursts because the pressure that comes out from below the surface is thought to come from a deep enough depth because the water has the potential to form hydrocarbons.

3.3. Lemigas Testing

Table 5. The lemigas test results

No	Composition	Percentage (% mol)
1	Nitrogen	0.59
2	Carbon Dioxide	97.87
3	Methane	1.28
4	Propane	1.14
5	Ethane	0.04
6	Iso Butane	Nil
7	N Butane	Nil
8	Iso Pentane	Nil
9	N Pentane	Nil
10	Hexane Plus	0.09

A simple test between the burst of gas and the flame which is brought closer to the center of the burst. The tests were carried out at the two largest gas burst locations. When the flame is brought closer to the center of the gas burst, the flame does not enlarge which is common happen in biogas burst.

The result of lemigas testing explained that the gas burst does not come from geothermal activities because the H2S content is relatively small and does not smell like what is common in volcanic areas. The gas bursts are also not methane gas that comes from the decomposition of the humus. It is likely that the gas bursts originated from a depth that is related to petroleum activity. The high CO_2 content of up to 97.87% is one indication.

However CO and CO_2 gases are poisonous, but the burst area is open and the morphology is flat, so when this gas spreads out, the impact is not dangerous. This can also be seen from field observations that the presence of these gas bursts does not interfere with life around the gas bursts, both plants, and animals.

Besides being poisonous, CO and CO_2 gas are also acidic and it is these acidic properties that need attention because they will affect the resilience of infrastructure due to the effects of corrosion.

4. Conclusion

The geoelectric results to the gas burst that there is a silt/sandy soil layer and rock on the surface (10-20 m). Then the second layer is soft silt to silt soil (20-40 m). The next layer is a rock layer. The second layer has gaps towards the first layer (surface) from the bottom layer. The second layer is identified carrying gas and water which is passed through the gaps to the surface layer. The seismic refraction also results that there are basins with gaps through the top and bottom of soil layers. This soil type is weathered layered/sand which is indicated to carry gas and water in the soil (20-30 m thick). The layer which indicates the gas and water carrier line is volcanic, sandy, forming a layer that has undergone deformation and partly a water-bearing layer (sand). The result of lemigas testing explained that the gas bursts are also not methane gas that comes from the decomposition of the humus. It is likely that the gas bursts originated from a depth that is related to petroleum activity. The high CO_2 content of up to 97.87% is one indication. However CO and CO_2 gases are poisonous, but the burst area is open and the morphology is flat, so when this gas spreads out, the impact is not dangerous. This can also be seen from field observations that the presence of these gas bursts does not interfere with life around the gas bursts, both plants, and animals.

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