Determination of Soft Lithology Causes The Land Subsidence in Coastal Semarang City by Resistivity Methods

by Sugeng Widada

Determination of Soft Lithology Causes The Land Subsidence in Coastal Semarang City by Resistivity Methods

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Abstract. Semarang City is located in the northern coastal plain of Java which is geologically composed of alluvial deposits. The process of the sediment diagenesis has caused a land subsidence. On the other hand, the development of the industrial, service, education and housing sectors has increased the number of building significantly. The number of building makes the pressure of land surface increased, and finally, this also increased the rate of land subsidence. The drilling data indicates that not all layers of lithology are soft layers supporting the land subsidence. However, vertical distribution of the soft layer is still unclear. This study used Resistivity method to map out the soft zone layers of lithology. Schlumberger electrode configuration with sounding system method was selected to find a good vertical resolution and maximum depth. The results showed that the lithology layer with resistivity less than 3 ohm is a layer of clay and sandy clay that has the low bearing capacity so easily compressed by pressure load. A high land subsidence is happening in the thick soft layer. The thickness of that layer is smaller toward the direction of avoiding the beach. The improvement of the bearing capacity of this layer is expected to be a solution to the problem of land subsidence.
Keywords: Land subsidence, Semarang, Resistivity

1. Introduction

Semarang City which is located in Central Java Province is one of the cities with many problems regarding with the process of land subsidence. As the effect of the land subsidence, some areas have been in below the sea level so it will be flooded with coastal flooding (rob) [1]. It results in disturbing the activity of the people and several infrastructures facing a fast defect. The handling of this situation has been managed to be conducted by arranging the function of the area by paying attention to all behaviors of land subsidence, but it is not completely succeed yet.

The land subsidence rate that happens in Semarang is varied between one place and another, and the biggest one reached 16 cm/year [1]. The measurement of land subsidence in Semarang City based on *Levelling, Interferometric Synthetic Aperture Radar (InSAR)* methods, *Microgravity* and survey using *Global Positioning System (GPS)* method, showed that the rate of land subsidence in Semarang City is more than 19 cm/year from 1999 to 2011 [2]. That rate of land subsidence was affected by the process of alluvial consolidation and added by the exploitation of overflowing ground water and the building construction in some points [3],[4]. Although there area fault geological structure in Semarang City [5] [6]. Tectonic activity is not related to the land subsidence so that the bedrock does not decrease [7]. The effect of land subsidence is predicted to cause the flooded area increases from 2,162.5 Ha (5.6%) to 3,896.3 Ha (10.1%) in the next ten years [8]. Even though the previous research

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had stated some factors of land subsidence, it was not yet explained the type and thickness of lithology layer which is contributing in the land subsidence.

This research aimed to map the spread of lithology with soft and asunder characteristics, so it is consolidated which resulting in the land subsidence by identifying the soft lithology layer and mapping the spread spatially according to the data of resistivity measurement.

2. Methods

Resistivity method is one of the geophysical methods that uses resistivity as characteristic of rock to observe subsurface of earth condition [9]. Measurement is conducted on the land surface by injecting electricity current (in milliamperes) along two current electrodes (C1 and C2) then gaining potential difference (in millivolts) from two potential electrodes (P1 and P2). There is a positive connection between the rare electrode with the current penetration into the earth. The widest electrodes space could get a deep current penetration. Hence the physical characteristics of deeper rock layer can be analyzed [10]. The location points of resistivity measurement can be seen in Figure 1.

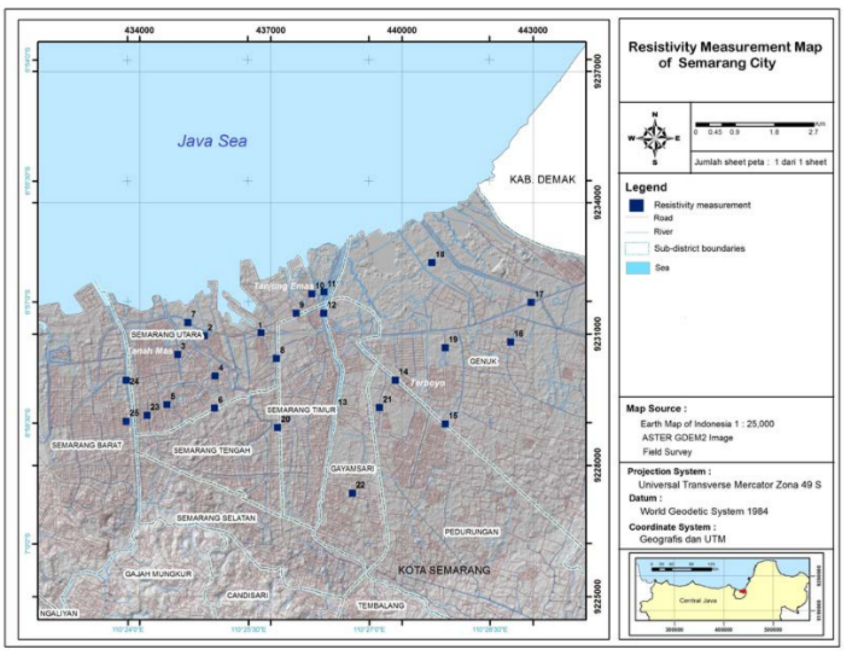

Figure 1. Resistivity measurement map

In the field implementation using Schlumberger configuration [9]. The distance of the electrode is arranged so R1 = R4 = (b – ½ a) and R2 = R3 = (b + ½ a), where a is the distance between the two potential electrodes and b is the distance from the center point to the current electrode (Figure 2). In this state, the range of potential electrode P1 – P2 is started from 1/3 of a range of the current electrode C1 – C2. Furthermore, the measurement was done by only moving the current electrode to a distance where the measurement result of the potential difference P1 – P2 is already small, then P1 – P1 is extended step by step.

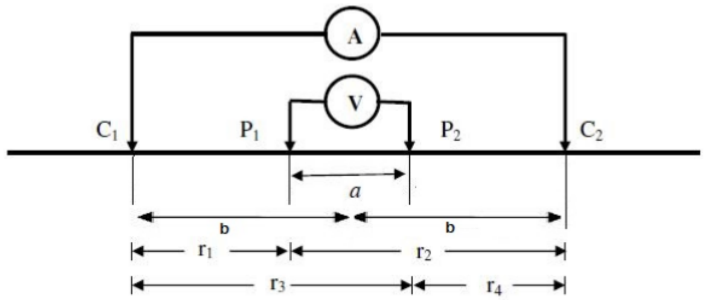

Figure 2. The scheme of the electrode arrangement of Shclumberger configuration [11].

The field data that were obtained from the resistivity measurement were the distance of current electrode, a distance of potential electrode, current (i), and the potential difference (ΔV). The resistivity of the medium is calculated from the quotient of the ΔV/I using a modified Ohm's law. Based on the data, the apparent resistivity was measured for every current injection, so the value of apparent resistivity was obtained for every electrode spread. The graphic of the spacing electrode and the apparent resistivity then were used as the basic in determining the thickness and the true resistivity by using the Ip2Win software. The results found were the thickness and the resistivity of every lithology layer [9].

The resistivity of every lithology layer that was obtained in the data processing has then interpreted the type of lithology by referring to the resistivity of lithology type from the references and correlated to the type of lithology based on the geotechnical drilling data. In the geotechnical drilling data, besides the description of the type of lithology, also listed the physical characteristics of lithology related to its ability to accept the burden so that it could be interpreted the behaviors of lithology related to the land subsidence. From the interpretation result in every point of resistivity measurement, a contour map was made to depict the position of soft lithology layer causing the land subsidence in the research area.

3. Result and Discussion

The result of resistivity measurement showed that there were several types and thickness of lithology in Semarang City. According to the correlation of the drilling data (Figure 3), it was found that the soft lithology had a resistivity < 3 ohm, which was layers of clay and sandy clay. That lithology was soft to medium consistency as a part of coastal alluvial deposit in forms of clay, silt, sand, and granule [12]. The layer of clay will be prone to have smaller resistivity than the sand, especially if it contains water [13]. The thickness of that layer in each resistivity measurement point pairing with the data of land subsidence measurement [4] was presented in Table 1.

The map of land subsidence overlayed by the map of soft layer thickness with the resistivity value less than 3 ohms is presented in Figure 4. Based on the figure, it can be seen that the rate of land subsidence in the location around Tanah Mas, Tanjung Emas Port, and Terboyo are higher than another areas and generally the farther from the coast, the rate of land subsidence is getting the smaller. The same pattern can also be found on the map of soft layer thickness, which is the highest thickness in those three locationss and decreasing to the south avoiding the coast.

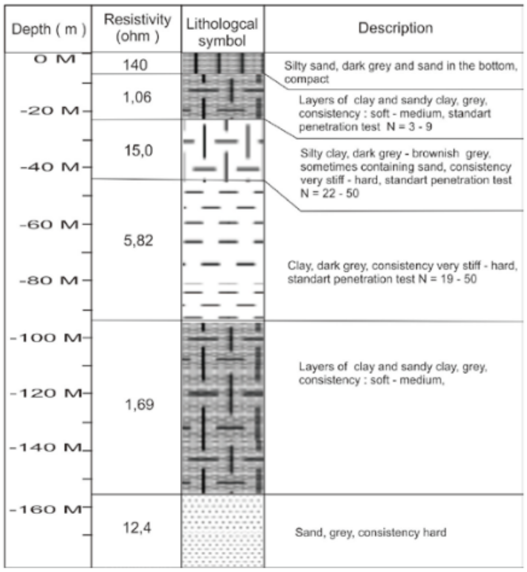

Figure 3. The correlation of the resistivity data and the drilling data in point 09

Table 1. The thickness of soft lithology layer based on the resistivity data and the rate of land subsidence in Semarang City

Point No.	East	North	Lithology thickness with ρ < 3 Ohm	Rate of land subsidence (cm/year)
1	433697	9229943	67.15	5.77
2	435485	9230954	71.98	3.50
3	434868	9230527	109.00	5.28
4	435731	9230038	54.75	8.51
5	434629	9229383	70.90	10.69
6	435719	9229303	21.08	0.47
7	435105	9231261	74.19	9.90
8	437136	9230440	68.53	3.50
9	437583	9231474	82.30	10.45
10	437942	9231918	49.10	3.50
11	438217	9231957	41.98	9.80
12	438215	9231470	47.62	10.45
13	438464	9229248	80.81	7.00
14	439857	9229941	39.50	7.00
15	440994	9228939	26.80	5.09
16	442496	9230815	61.80	5.09
17	442960	9231722	34.70	8.81
18	440693	9232628	79.80	8.58
19	440992	9230686	50.40	5.76
20	437161	9228864	7.87	4.02
21	439486	9229312	20.80	7.00
22	438870	9227356	21.69	5.09
23	434170	9229137	52.10	10.69
24	433697	9229943	24.70	9.90
25	433697	9229000	Not recorded	0.50

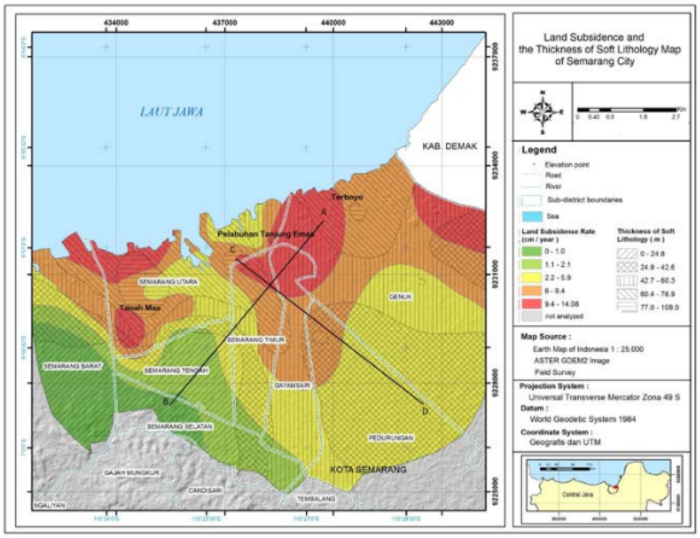

Figure 4. Map of the land subsidence and the thickness of soft lithology in Semarang City

That figure was also showed that the land subsidence was about 1-14.08 cm/year. The location around Tanjung Emas Port and Tanah Mas in North Semarang Sub-district had the higher land subsidence than the other areas at 9.4 - 10.08 cm/year. In that location, it was found that the lithology layer thickness with the resistivity < 3 ohm was also thicker than another area at 60-108 m in Tanah Mas and 42 – 108 m in around Tanjung Mas Port. In the point 23 of resistivity measurement located in Krobokan with the land subsidence of 10.69 cm/year also had a lithology layer thickness with the resistivity of < 3 ohms more than 60 m. The location with a slightly higher rate of land subsidence was also found in around Terboyo, at 8.58 cm/year, and it had a lithology with resistivity < 3 ohms for 79.8 m. The spread of soft layer can be found in all research areas with the thickness varied to 108 m.

The slice by the AB and CD points as shown in Figure 5 showed that the higher rate of land subsidence, the thicker the layer of soft lithology.

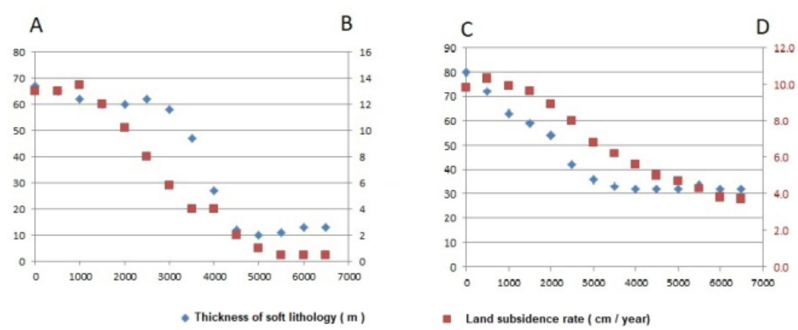

Figure 5. Graphic of land subsidence and the thickness of soft lithology layer

A high land subsidence is happening in the thick, soft layer. It happened because that soft layer is compressed when given the load from the above layer or several buildings and infrastructures above the ground [2], [4] and [15]. The consolidation process in the alluvial deposit is natural and surely happen (13). The core drilling data illustrates that on layers of clay and sandy clay there is the presence of sand entering the clay, so the compression became higher. It made the rate of land subsidence higher in the area of clay and sandy clay thick.

4. Conclusion

The rate of land subsidence in Semarang City is getting higher in the location with the thickness of soft lithology layer detected as the lithology with resistivity < 3 ohms. The thickness of that layer is smaller toward the direction of avoiding the coast. The thickness of the soft layer in Tanah Mas, Tanjung Emas Port and the area around Terboyo were about 42 – 108 m, and the rate of land subsidence was about 9.4 - 10.08, higher than other areas. The consolation process and inclusion of sand into soft clay layers beneath became the cause of the land subsidence.

5. Acknowledgement

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