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Study of Soil Layer Stratigraphy Based on Georesistivity and Geological Techniques

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Abstract. The purpose of study was to determine the structure of the studied soil layer based on measurement of geo-resistivity with the Wenner configuration and geotechnical drilling method. Geotechnical drilling was one way of soil/rock investigations to determine the parameters soil layers. Based on the objective, field tests and laboratory tests were carried out to support scientific investigations. The results of measurements in the field using geo-resistivity were performed to a depth of 23 meters, resulted in 2 types of soil sediment layers namely clay and sand. At a depth of approx. 8 meters, the groundwater level was found and through laboratory tests, the results of geotechnical drilling gave 2 types of soil classification to a depth of 15 meters, i.e CH and ML. In general, the results of the geo-electrical and drilling tests represented the soil real conditions in developing the stratigraphy of the subsurface layer of the soil. It showed that in the first layer, the sediment layer resulting from the breakdown of the initial rock or sediment layer which had undergone transportation of sedimentary layers in the form of clay, silt or sand and did not experience compaction so that it has a large resistivity value. The next layer associated with regional geological maps are dominated by sand.

Introduction

Precise determination of engineering properties of soil is essential for proper design and successful construction of many structures [1]. The geoelectrical method was one method for soil investigation, this method had advantages in terms of accuracy also cheaper and faster. The principle was to distinguished the layer of rock/soil based on the differences of conductivity value of rocks /soil or found the anomaly between the physical quantities of the object sought with the soil that covered. The physical magnitude for the geoelectrical resistance type (resistivity) method is the electrical properties [2]. The practical application of ER surveys is to analyze the spatial pattern of subsurface resistivity, interpret features in the subsurface, and address geologic, environmental, and engineering questions [3].

The advantage of geoelectrical method is non-destructive method [4]. Therefore, to validate the results of geoelectrical measurement, it needed to be examined in more detail by using geotechnical drilling methods and testing investigation of soil physical properties in the laboratory. The use of geotechnical tests in order to define characteristics of the soils [5].

Research Methodology

The research methodology was carried out by observation and collected sample at location studied. The geoelectrical measurement was conducted to gain the resistivity values. Thereafter the geothecnical drilling was carried out for sample investigation in laboratory testing. The measured potentials depend on the magnitude of the current and of the conducting properties of the underlying soil [6]. The resistivity measurements are normally made by injecting current into the ground through two current electrodes, and measuring the resulting voltage difference at two potential electrodes [7]. Among the characteristics of each configuration that must be highly considered were the configuration sensitivity due to the changed in vertical and horizontal resistivity below ground level, the depth, horizontal data and signal strengths [8].

Wenner Configuration Method. The method introduced by Wenner was one configuration which often used in geoelectrical exploration with a spacing arrangement of equal length (r1 = r4 = a and r2 = r3 = 2a). This method will give us a velocity model for the subsurface [9]. The distance between the current electrodes was three times the distance of the potential electrode, the potential distance with the point of sounding was a / 2, then the distance of each current electrode with the point of sounding was 3a/2. The depth target that can be achieved in this method was a / 2. In matching data, the arrangement of current and potential electrodes was placed symmetrically with the sounding point [10].

In the Wenner configuration the distance between the current electrode and the potential electrode were uniform in a line as shown in Fig. 1 below.

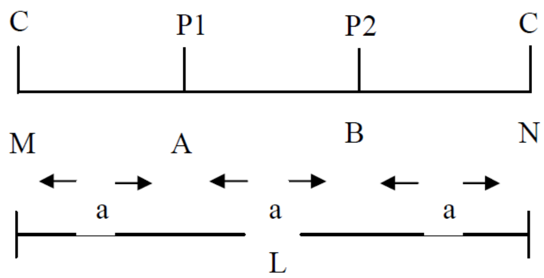


Fig. 1 Current and potential electrodes in the Wenner configuration

From the picture above, it could be seen that the distance AM = NB = a and distance AN = MB = 2a, using equation 4 was obtained :

$$K = \frac{2\pi}{\left\{\left(\frac{1}{a}-\frac{1}{2a}\right)-\left(\frac{1}{2a}-\frac{1}{a}\right)\right\}} \quad (1)$$

$$K = 2\,\pi\,a \quad (2)$$

Therefore the geometry factor for Wenner's configuration is:

$$Kw = 2\pi a \text{ and } \rho_w = K_w R \quad (3)$$

Deep Boring. Boring was carried out to 15 meters deep at each boring point. The purpose of geotechnical boring: to know the condition of the geological layer of rock / soil, identify the type of rock/soil, and to understand the engineering properties of rocks / soil, including level of the groundwater. Geotechnical boring consists of soil boring, identification of soil types and geotechnical drilling samples according to common national standards.

The location of study was focused on campus area of the Faculty of Engineering, Hasanuddin University, Malino Borongloe Bontomarannu Street, Gowa Regency, South Sulawesi Province, by research area in form of a 75m length line.

Results and Discussion

Geo-Resistivity Profiles. The results of the vertical geoelectrical measurements were carried out using the Wenner configuration. The direction of measurement was shown in Fig. 2, while data was processed and analyzed using RES2DINV software in form of 2D resistivity profiles. The profile of measurements that were displayed in form of resistivity values. The following was the result of measurement and software data analysis.

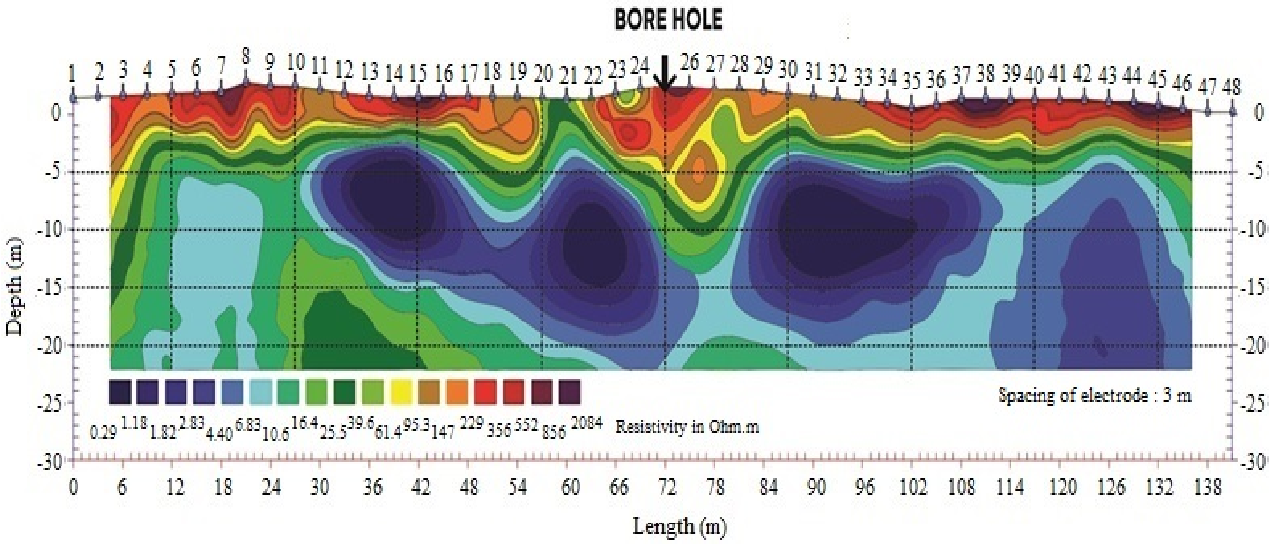


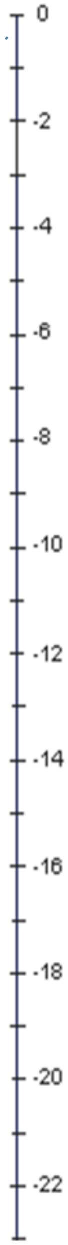
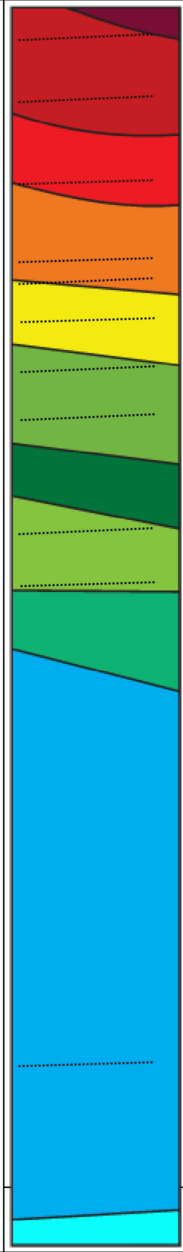
Fig. 2 Soil layer profile of survey line

The produced profile survey as shown in Fig. 2 were divided into 48 electrodes spaced by 3 m, spanned in 140 meters, horizontally. The results showed the depth of soil indicated by electrodes number 2 - 20 approximately at the depth of 0-4 meters, electrode 22-27 indicate a depth of 0 - 11 meters and electrode 28-45 indicate the soil depth of 0 - 4 meters. By the colors of profiles, resistivity of soils was also interpreted in unit of ohm.m, explaining the characteristics of soil, and revealing clay layers with high resistivity value between 16.4 - 2084 ohm.m. The fine sand layers containing water with low resistivity values between 6.83 - 16.4 ohm.m were also presented in the soil profile.

Soil Profile Based on Resistivity Value. Through the study, model of resistivity cross section at survey line, the intensity and the resistivity values were obtained in detail. From these results we could interpret the soil profile until depth of 23 meters of survey line which the detail results of measurement are shown in Table 1.

The georesistivity interpretation at elevation from 0 - 3.50 meters had the highest value of resistivity, produced between 229 to 2084 ohm.m compared to other layers. This was influenced by the composition of dry clay mineral contents. The next layer at elevation 3.50 - 5.50 meters had a resistivity value between 95.3 to 229 ohm.m, contained clay with less water. Next layer at elevation from 5.50 to 11.00 meters, the resistivity values ranged from 16.4 to 147 ohm.m in the form of clay mineral containing water, just before the water level found at depth of 8.53 meters. The last layer at the elevation 11.00 - 23.00 meters had the lowest resistivity value between 4.4 to 16.4 ohm.m in the form of fine sand with water content.

Tabel 1 Resistivity value of survey line

Elevation (m)	Layer Thickness (m)	GWL (m)	Resistivity Value		Interpretation of the Georesistivity Layer
			Intensity	ρ (Ohm-m)	
	0.75			856 - 2084	Dry clay
	1.05			356 - 552	Dry clay
	1.7			229 - 356	Dry clay
	1.6			147 - 229	Clay with less water
	0.4			95.3 - 147	Clay with less water
	0.95			61.4 - 95.3	Clay contains water
	1.05			39.6 - 61.4	Clay contains water
	1			25.5 - 39.6	Clay contains water
	2.5			16.4 - 25.5	Clay contains water
	1			10.6 - 16.4	Fine sand contains water
	10.1			4.4 - 6.83	Fine sand contains water
	0.9			6.83 - 10.6	Fine sand contains water

Profile Geological Technique. The results of laboratory analysis for investigation of soil layer properties in bore hole are presented in Table 2. There are no specific measurement on correlation of soil moistures and the depths, as the water ground levels (GWL) is indicated on the table. Other compositions of soils at each depths are well presented within the table.

Tabel 2 Interpretation of soil types based on engineering geology

Elevation (m)	Layer Thicknes s (m)	GWL (m)	Texture	Texture Description	Explanation							
					Specific Gravity	Gradation			Atterberg Limits			USCS
					Gs	Sand (%)	Silt (%)	Clay (%)	LL (%)	PL (%)	IP (%)	
	0.75			Reddish brown clay, soft with little dense	2.71	28.4	32.3	39.3	36.62	21.86	14.76	ML
	1.05			Brown clay, quite soft	2.74	29.60	29.10	41.30	57.99	28.10	29.89	CH
	1.7			Brown clay, fine sand but quite soft	2.75	30.60	29.10	40.30	62.56	28.44	34.12	CH
	1.6			Fine sand, clay, quite dense, brown	2.66	28.60	37.10	34.30	31.23	27.61	3.62	ML
	0.4			Sand, soft clay, grayish brown	2.64	29.20	38.50	32.30	34.52	30.96	3.56	ML
	0.95			Fine sand, clay, soft, grayish brown	2.65	30.40	40.30	29.30	57.58	36.69	20.89	CL
	1.05			Clayey sand, yellowish brown, fine sand but quiet soft	2.69	33.40	29.30	37.30	62.04	26.86	35.18	CH
	1	▼		Gray clay, slightly brown but soft	2.73	29.40	25.30	45.30	56.67	25.43	31.24	CH
	2.5			The clay mix with claystone, gray, soft medium, stones, soft rock	2.75	27.60	33.10	39.30	66.76	27.98	38.78	CH
	1			Clay stone, gray clay, rock	2.71	32.00	16.70	51.30	62.92	28.44	34.48	CH
	3			Clay stone, blackish gray, soft rock	2.69	28.80	24.90	46.30	53.50	26.70	26.81	CH

The results of laboratory test of geological technique combine with USCS standard, at the bore hole elevation from 0 - 0.75 meters, there were consistency limit values of silt with low plasticity (ML). Next, at the elevation from 0.75 - 3.50 meters were clay with high plasticity (CH), from 3.50 - 5.50 meters was a silt with low plasticity (ML). Further depth, of elevation from 5.50 – 6.40 meters there were low plasticity clay (CL) then lastly, with elevations from 6.40 - 15.00 meters were high plasticity clay (CH).

Conclusions

The top layer of study area was in the form of clay. This layer had a resistivity value with a large range which were from 10.6 Ohm.m to 2084 Ohm.m. This layer was greatly influenced by surface dynamics, influence of compacting, drying by heating which resulting a large value of material resistivity, while the influence of water at infiltration area, will result in low resistivity values of soil materials. Because of this phenomenon, the top soil layer in the cross section as explained above had a fairly large resistivity ranges.

The second layer was correlated to the results of drilling, it showed that the soil lithology was sandy clay. The sandy clays are aquifers layer which could hold and drain water very well, giving a low resistivity value. The lower the resistivity value, the more saturated the soil. If the resistivity value was very low, it was suspected that there was an influence by the conductive minerals or water infiltration on the layers of soils. The resistivity value in this layer had a small range at low resistivity, they were only ranged between 0.29 ohm.m to 25.5 ohm.m.

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