CHAPTER V

GEOPHYSICAL INVESTIGATION

Drilling generally offers the best subsurface information as data could be gathered down the hole. However it is also an expensive way is complete information in a large area is needed. Recently, geophysical techniques are used in the site investigation as the more effective and economic means while drilling is minimized to only for subsurface checking. In the present study an electrical resistivity investigation was carried out over the embankment failure area to identify not only the soil layers but also the hidden failure surface. The principle of this particular geophysical technique in finding such surface as given by Sowers and Royster (1978) is as follow.

> " The shear surface within a landslide frequently exhibits a marked lower electrical resistance than the surrounding intact soils, probably because of the disturbance of the minerals and the accumulation of water along the shear surface. ..... "

5.1 Theoretical Background of Resistivity Method.

In the resistivity method, an electric current is applied into the ground through the electrodes. Any subsurface variation in the electrical conductivity of the underground alters the form of the current flow and the potential distribution detected at the ground surface.

In the study performance, the current is applied through two current conducting electrodes being inserted into the ground. The potential drop between a second pair (potential electrodes) placed in the line between the conducting electrodes is measured. The resistivity sounding consists of a series of measurements, each with increasing separation of current electrodes while the center of the configuration stays at the same place. In the Schlumberger configuration the distance between the measuring electrodes is always kept small, usually less than L/3 (Figure 5.1).

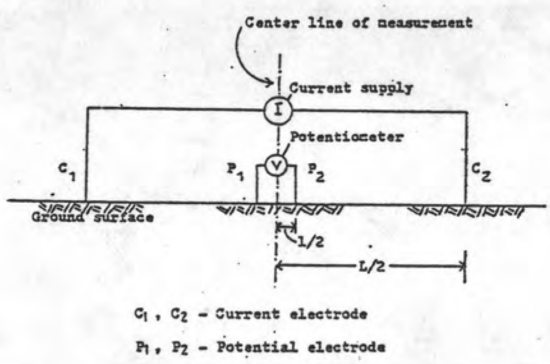

Figure 5.1 Schlumberger's Configuration for the resistivity survey.

As a result, the resistivity of a soil formation usually depends on the resistivity of the contained electrolyte and is inversely related to the porosity and degree of saturation of the formation. Change in apparent resistivity (ρ_a) regularly reflects change in soil/rock type and moisture content. The plot of ρ_a verses L/2 is called the field curve.

5.2 <u>Electrical Resistivity Survey in the Present Study</u>.

In colluvium, a large amount of large boulders and cobbles is usually occurred in the mass of smaller-size particles. As a consequence, drilling is very difficult and take time. Thus an electrical resistivity investigation was carried out in order to obtain the subsurface information, i.e. the thickness of colluvial soil, the depth to buried failure surface, and the shape and type of the failure surface. The method was viewed to be appropriate according to the previously mentioned principle.

5.2.1 Procedure of resistivity survey.

The resistivity survey was done in March 1987 at thirteen locations with known surface elevation (see Plate 6.2). The resistivitymeter, Terrameter-ABEM AB5310, was used to measured the vertical change in the resistivity by means of "electrical drilling" method. The electrodes were placed at a certain distance apart according to Schlumberger's configuration. The respective series of electrodes spacing were L/2 of 1, 1.5, 1.75, 2, 2.5, 3, 4, 5; 5, 6, 7.5, 10, 12.5, 15; 15, 17.5, 20, 25, 30, 40, 50 meters with respected to l/2 of 0.5, 1.5 and 5 meters. The distance between the electrodes was increased for each measurement. By multiplying the calculated resistance obtained at each measurement by a factor appropriate to the electrode configuration and separation, a series of apparent resistivities (ρ_a) is obtained. The graph of apparent resistivity versus electrode spacing (L/2) were plotted and the interpretation of the resulting curve yielding an estimate of the thickness and apparent resistivity of the layers was performed. The field curves of this resistivity survey were presented in Appendix C.

5.2.2 Interpretation of a resistivity survey result.

5.2.2.1 Method of interpretation.: The interpretation was carried out by partial curve matching technique. This technique requires matching of small segments of the field curves with theoretical curves for two horizontal layers, together with an aid of Ebert Auxilliary Graph (Orellana and Mooney, 1966). Briefly the procedures of the method are as follow. The first step is to determine the thickness and resistivity h_1 and ρ_1 of the first layers and the resistivity ρ_2 of the second layer. Next these two layers are combined into a replacement layer which, together with the third stratum, constitutes a two layer problem again. Consequently the thickness of the replacement layer and ρ_3 can be determine by means of two-layer master curves. Therefore the three upper strata are combined into a replacement layer and the thickness of thus and ρ_4 are determined, and so on. Thus the resistivity of the individual layers is obtained successively during the calculation process while the thickness is obtained by appropriate correction of the thickness of the replacement layers by the auxiliary curves.

5.2.2.2 Result of interpretation.: The interpretation of resistivity results were compiled with the knowledges of geology of the study area and borehole information in order to correlate lithology of the interpreted layers. The results of the quantitative interpretation were as follows:

a) Stratigraphy.: There were 3 majors break in strata with the apparent resistivity range from 80-100, 180-550 and 1-43 ohm-meters respectively. These layers are:

- Top layer.: The thickness of this layer ranges from 0.7 to 2.7 meters with apparent resistivity values usually ranging from 80 to 110 ohm-meters. This layer is equivalent to upper soil of filled materials.

- Middle layer.: The thickness of this layer ranges from 5.87 to 11.80 meters with the apparent resistivity ranging from 180 to 550 ohm-meters. However, in the place where large sandstone boulders exist, the apparent resistivity of more than 1,000 ohm-meters was observed.

The middle layer was noted to be the colluvial-originated filled material, gravel-drain material and the general colluvial soils.

- Lower layer.: This layer was easily detected with a sharp break in resistivity value distinctively less than the upper layers. The resistivity value ranges from 1 to 43 ohm-meters. This layer, about 1.5 meters thick, was marked as that of clayey soil of sheared zone or mudstone-siltstone bedrocks.

b) Depth to bedrock.: The depth to mudstone-siltstone bedrocks or shear zone soil is detected by the sharp break of low resistivity value to locate at the base of the middle layer. The depth to bedrock over the landslide area irregularly varies from 7.20 to 12.80 meters.

c) Shape of failure surface.: The break in resistivity value between middle layer and lower layer was interpreted as interface between colluvium /bedrocks or colluvium-shear zone soil. The failure surface was considered to occur along shear zone/bedrocks interface or within shear zone layer. As illustrated in Plate 6.2, the depth (or elevation) to the top of shear-zone layer varies with a much wider range than the thickness of the layer, and as the failure surface was suggested within or at the base of this shear-zone soil layer, thus this failure surface was noted to be very irregular. Its irregular nature was used in the slope stability analysis.

The results of interpretation of electrical resistivity sounding over the study area were summarized and presented in Table 5.1.

It should be noted that in this study that the interpretation of resistivity results agree with the borehole information. The interface between colluvium and underlying materials was recognized to match the markedly detectable zone of low electrical resistance, i.e. the zone of failure surface.

Table 5.1 Summary of the results of interpretation of electrical resistivity sounding.

Sounding No. & Ground elevation	Apparent resistivity (Ω m)	Interpreted layers	Thickness (m)	Depth from ground surface (m)	Elevation of Colluvium/Mudstone interface (m)
ES - 1	100	filled material	2.00	2.00	
96.20 m.	350	gravel drained & colluvium	6.00	8.00	
	43	mudstone bedrock	-	-	88.20
ES - 2	83	filled material	2.20	2.20	
94.00 m	442	gravel drained & colluvium	6.60	8.80	
	1	mudstone bedrock	-	-	85.20
ES - 3	85	filled material	1.60	1.60	
87.65 m	452	gravel drained & colluvium	9.40	11.00	
	3	mudstone bedrock	-	-	76.65
ES - 5	90	filled material	0.80	0.80	
82.58 m	403	gravel drained & colluvium	13.30	14.70	
	40	mudstone bedrock	-	-	67.88

Table 5.1 (Cont.)

Sounding No. & Ground elevation	Apparent resistivity (Ω m)	Interpreted layers	Thickness (m)	Depth from ground surface (m)	Elevation of Colluvium/Mudstone interface (m)
ES - 6	80	filled material	1.20	1.20	
96.15 m	835	gravel drained & colluvium	6.00	7.20	
	1	mudstone bedrock	-	-	88.95
ES - 7	12	filled material	1.60	1.60	
100.20 m	350	gravel drained & colluvium	5.87	7.47	
	2	mudstone bedrock	-	-	92.73
ES - 8	110	filled material	0.10	0.10	
100.25 m	547	colluvium	7.20	7.30	
	13	mudstone bedrock	-	-	92.95
ES - 9	85	filled material	1.05	1.05	
95.50 m	340	gravel drained & colluvium	9.03	10.08	
	10	mudstone bedrock	-	-	85.43

Table 5.1 (Cont.)

Sounding No. & Ground elevation	Apparent resistivity (Ω m)	Interpreted layers	Thickness (m)	Depth from ground surface (m)	Elevation of Colluvium/Mudstone interface (m)
ES - 10	90	filled material	0.98	0.98	
93.44 m	180	gravel drained & colluvium	11.80	12.80	
	27	mudstone bedrock	–	–	80.64
ES - 11	380	filled material	0.70	0.70	
93.48 m	454	gravel drained & colluvium	8.40	9.10	
	40	mudstone bedrock	–	–	84.38
ES - 13	245	top soil	0.76	0.76	
90.23 m	1715	large sandstone boulder	3.80	4.56	–
	80.5	colluvium	–		
ES - 14	80	filled material	2.70	2.70	
94.43 m	550	colluvium	8.73	11.46	
	11	mudstone bedrock	–	–	82.97

Table 5.1 (Cont.)

Sounding No. & Ground elevation	Apparent resistivity (Ωm)	Interpreted layers	Thickness (m)	Depth from ground level (m)	Elevation of Colluvium/Mudstone interface (m)
ES - 17	112	top soil	0.80	0.80	
104.86 m	4,480	large sandstone boulders	1.40	2.20	
	750	colluvium	8.90	11.10	
	29	mudstone bed rock	-	-	93.76