Data 6

Geological Survey

THE GEOLOGICAL SURVEY OF THE SOFULU SITE
FOR
THE STUDY ON REGIONAL SOLID WASTE MANAGEMENT
FOR
ADANA – MERSİN IN THE REPUBLIC OF TURKEY
REPORT

Executed and issued
as per the specification prepared by

KOKUSAI KOGYO CO.
on behalf of JICA
(Japan International Co-operation Agency)

Adana – April – 1999
YER-BİL Co. Adana

INDEX

CHAPTER I – GENERAL

TABLES AND FIGURE

ABBREVIATIONS :

w_n	: natural moisture content of a soil, (%)
γ_n	: bulk densities of a soil, (t/m^3)
γ_s	: unit weight of a soil, (t/m^3)
k	: permeability of a soil Poor graded sand
w_l	: liquid limit, (%)
w_p	: plastic limit, (%)
CH	: medium dry density of a soil, (t/m^3)
CL	: low plasticity inorganic clay
CL – CH	: medium to low plasticity inorganic silty clay
SP	: poor graded sand

CHAPTER I

I. INTRODUCTION AND SCOPE OF THE SURVEY

I.1. Survey Area involved in the survey is located about 25 km north-east of Adana city, adjacent to the old Kozan Road, known as "Sofulu Waste Dumping Area"

I.2. Scope of the survey

It has been envisaged to define, basing on the geoelectric observations, the structure of the ground, complete with the depth, thickness and resistence of the stratifications as well as their phisical and impermeabilition particulars.

II. GEOLOGICAL ASPECTS OF THE SURVEYED AREA

The surveyed area presented carbonated formation specimen giving the particulars of limestones pertaining to the Pliocene Age as well as loose and scatteredly and densly cemented gravels along with gravel compositions. Their thickness is not so high. These formations, relatively permeable for the underground water, are topping the series of Eocene flisch, which is the formation of clay, marl, siltstone and sandstone.

The clay as well as the marl are acquiring the characteristics to prevent penetration down of the ground surface water.

III. UTILISED GEO-ELECTRIC INSTRUMENTS AND METHODS OF EVALUATION

Locating the survey points: Special care was devoted to locate the survey points along two axes on such points that the findings could be controlled and compared with the data derived from the other geological observations. These data were approached with four boreholes (2x15 mt, 20 mt and 7 mt deep) drilled within the scope of the surveys, and also those available from the previous borings executed in the vicinity. Another advantage was the possibility of conducting a highly efficient visual inspection because there are many quarries operating to excavate stabilising material around the site and with vertical sides exposed to the public view by such deep excavations general stratification particulars could be detected and evualuated with no problem at all.

Hence, the locations chosen for geo-electric survey were defined to support as much as possible such data and observation results.

Yet, it has not been easy to make observations at the required points form time to time. For instance, the points JF 8 and 9 are quite distant. A closer position could not be applied because it has been impossible to overcome the phisical conditions to work.

Notwithstanding, for the said section, the other survey results have been assesed and used to plot the relevant section of the profiles appended hereto.

III.1. GEO-ELECTRIC SURVEY INSTRUMENT

The utilised instrument operates by low freqency alternative current (0,3cps), composed of three units, the power generator, induction unit and recepting unit.

The power generator has been coupled with an inverter fed by a 12 volt battery, adjustable to apply the current as rated as necessary into the ground.

The current from the source is then converted in to AC of 0,3 CPS, by means of a relay, was applied to the ground on the observation points adopted. The reception unit, adjusted to the same frequency as the Induction unit was rated. Round stainless steel bars have been used as the electrodes for both the induction and reception.

III.2. Adopted geo-electric method

The adopted method was the Schlumberger Electrical Ground Survey Method. The latter is conducted by means of your electrodes. The electrodes were positioned such that the two in the middle have been the potential ones (receptacles). These were kept inert whilst the outer two inducters were mobilised in order to actieve deeper electrification. During the Surveys the AB/2 (Half distance between the induction electrodes) has been 25 metres. Taking into account both the applied current and the measured reflection of the same, the values giving the Apparent Resistance Values, for every AB/2,using the formula of ($= K \frac{\Delta V}{I}$).

In consideration of that the Apparent Resistence Values were the function of the half distance of the induction electrodes, the electrical survey curves were provided by plotting on a double-logaritmical diagram.

These curves have been subjected to an evaluation by the three layers reference diagrams of Orellana Mooney, applying two layers theoretical curves with partial overlapping, in order to obtain and record the depth, thickness and the resistance values. Moreover, all these data have been re-evaluated on the computer using the program developped by Gewin V.T., a Dutch expert.
It is worthy to mention that this program has been reflecting a wide reputation upon its ability to add refined evaluations on the compiled records.
Definition of the underground formation layers were made by means of pre-recorded Resistivity values, visual observations on the area and the data obtained from the 4 boreholes drilled at the involved site.

IV. RESULTS OF THE GEO-ELECTRIC SURVEY

Evaluations resulted from the surveys have leaded to obtain the depth, thickness and resistance values as well as the nature of the underground formation layers. These are presented beneath the Electrical Survey Curves at the double-logaritmical diagram in the form of logs. Furthermore, vertical longitudinal profiles over two axes are established. All these are appended hereto. The longitudinal profiles (AA' and BB') have been drafted with adding the borehole results at the points where the geo-electric survey point and the borehole are almost at the same location. This, too, has shown that the geo-electric evaluations are confirmed by the boreholes almost at a full sensivity.

VERTICAL GEO-ELECTRICAL PROFILE AA' : The Profile acquires a scale of 1/2000 horizontally, whereas the vertical scale is 1/400. It is involving the electrical observation points JF1, JF2, JF3, JF4, JF5 as well as the boreholes B1, B2, B3, and B4.

The geo-electric surveys reflect mainly 3 underground levels:

LEVEL NO. 1 : It is the most upper level of the area. The thickness has been measured to be 4,5 mt at JF 1, **1,2 mt at JF 2,** 4,2 mt at JF 3, **5,7 mt at JF 4,** 3 mt at JF 5. The resistence is varying between 30-80 Ohm-metre.

Relatively high resistence represents the carbonated formations as well as cemented coarse gravels domination, whereas the low resistence show the formations with gravels and sand.

LEVEL NO. 2 : Is the level of clay as shown on the profiles. It takes place **between 4,5-8,7 mts at JF 1**, upto 13,7 mt., under a thin soil cover of 1,2 mt at JF 2, **between 4,2-7 MTS at JF 3**, between 5,7-8,9 mt at JF 4 and **between 3-5,9 mt at JF 5.**

Resistence is varying between 4-8 Ohm-metre.

It acquires the particulars of an impermeable layer.

LEVEL NO.3 : This is the stratification called to be the marl as shown on the profile. The level has been entered into at **8,7 mt at JF 1,** 13,7 mt at JF 2, **7 mt at JF 3,** 8,9 mt at JF 4, **5,9 mt at JF 5**. Its resistence is varying between 12 and 24 Ohm-Metre. This, too, is an impermeable layer.

VERTICAL GEO-ELECTRICAL PROFILE BB' : This profile has been plotted with 1/2000 scale horizontally and 1/400 scale vertically. It involves the borehole B4 and the geo-electric survey points JF 6, JF 7, JF 8 and JF 9. The main levels have the following particulars :

LEVEL NO.1 : 6,9 mt thick at JF 6, **4,8 mt thick at JF 7** ***(together with the waste stock),*** 6,5 mt thick at JF 8 *(together with the waste stock),* **8,5 mt thick at JF 9.** The relevant resitence values have been found to be between 17-180 Ohm-Mt. This layer is relatively permeable.

LEVEL NO.2 : It is taking place **between 6,9-13,6 metres at JF 6,** 4,8-11,8 metres at JF 7, **3-6,5 metres at JF 8**. It is an impermeable layer.

LEVEL NO.3 : It has been approached at **13,6 mt at JF 6,** at 11,8 mt at JF 7, **at 6,5 mt at JF 8,** and **at 12 mt at JF 9.** It has been defined to be marl layer. The resistence is varying between 11-30 Ohm-metre.

AYTAÇ BİLGEN
Jeoloji Mühendisi Dip. No: 2722
YERBİL Yeraltısuyu Etüd Proje
Sondaj Taahhüt
5 Ocak Cd. Saliye Akcan Apt. NO: 44/19 ADANA

CHAPTER II

LABORATORY TEST RESULTS

V INTRODUCTION

This report has been prepared in accordance with the application of Aytaç Bilgen to the Faculty of Engineering and Architecture, the University of Çukurova on 16.04.1999.

The field which is under investigation will be the waste disposal site (where Adana, Seyhan, Sofulu District) of Adana City.

Main concept to write the report is to present the laboratory test results, carried out on fill material and borehole samples, and to propose some necessary recommendations on the basis of the test results. A total number of 3 boreholes were opened at the construction site. The stratification and some engineering properties of soil have been determined from visual inspection and standard penetration tests (SPT) done in the borehols. Soil samples were collected from the borings for laboratory testing. Fill materials taken from nearby soil pits to the site were also brought to the Civil Engineering Laboratory.

The location plan and the logs of borings, drilled previously, are presented in the final report. From the comparison of borings, a variation of soil profile was observed for about the first 7.0m-8.0m. The ground surface at the site is covered by about 0.0 to 2.0m thick top soil in general and underneath the top soil there exists about 0.5-2.2m thick sandy and gravelly clay. The following is caliche (a conglomeration of sand, gravel, silt and clay bonded by carbonates) and silty clay. Clay and cemented claystone layer with calcerous are observed below these.

VI. LABORATORY TESTING

Representative undisturbed and disturbed soil samples from different soils at various depths from the investigation site and fill material samples from the nearby soil pits were taken. The samples were subjected to necessary laboratory tests in the soil mechanics laboratory of Civil Engineering Department of the University of Çukurova in accordance with ASTM and related Turkish Standards (TS – 1900). The description, classification and compressibility characteristic of soils have been obtained from experiments. Most of the laboratory test results, tabulated and plotted, are given in pages 13 to 39.

VI.1. Boring Samples :

The moisture content of the soils were determined on undisturbed and disturbed samples. It has been found that the moisture content of the soil samples, taken from various depths, varies between

$$W_n = \%5 - \%43$$

The results are given in Table 2 and 7.

The bulk densities of the soils were obtained from the undisturbed soils and the results are shown in table 2 and 5. The bulk densities of soils vary between.

$$\gamma_n = 1.70 - 1.98 \text{ ton/m}^3$$

The unit weights of the soils were obtained from Pycnometer tests and the results are shown in Table 2 and 6. The unit weights of soils vary between

$$\gamma_s = 2.65 - 2.72 \text{ton/m}^3$$

Grain size distribution of the soil samples were determined by sieve and hydrometer analyses. Soils named clay or claystone in the field were pulverized after drying them in an owen. The results of the tests are shown together with the grain size curves in pages 16 to 21.

The consistency limits of clay soil samples were determined and the results are presented in pages 22 to 26. The Atterberg Limits vary between

Liquid Limit	W_l = %48 - %55
Plastic Limit	W_P = %24 - %27

From the sieve and hydrometer analyses it has been found that the borehole soil samples consist of mainly clay and silt size fine materials(over 95%). And, gravel - sand size coarse materials are less than about 3%. But the soil sample taken from borehole B 4 between 10.50m-10.95m appeared to be different from other results since it consists mainly coarse materials (about 100%). Except this granular soil layer the soil type at the site was 'medium to low plasticity inorganic silty clay (with the group symbol CL-CH). It is known that the permeability of this type of soils are very low.

VI.2. Fill Material Samples from a Nearby Pit:

The Moisture content of the fill materials were determined on undisturbed and disturbed samples. It has been found that the water content of these samples, taken from different depths, varies between

$\mathbf{W_n}$ =%3.5-%24.4.

The test result are given in page 27.

The bulk densities of the fill materials were obtained from the undisturbed soils and the results are shown in page 27. The bulk densities of these samples vary between

$$\gamma_n = 1.62 - 1.87 \text{ ton/m}^3.$$

The unit weights of the fill materials were obtained from Pycnometer tests and the results are shown in page 27. The unit weights of these soils vary between

$$\gamma_s = 2.57 - 2.72 \text{ton/m}^3.$$

Grain size distribution of the soil samples were determined by sieve and hydrometer analyses. Two different types of fill materials were observed from the tests. The results of the tests are shown together with the grain size curves in pages 28 to 33.

In order to determine the compressibility characteristics of the soil, hydrometer compaction (Proctor) tests were performed on the fill material samples. Two different types of fill materials were observed from the tests. The results of the tests and the dry density – moisture relationships were plotted by minimum five points and the curves are given in pages 34 to 39. The values of optimum water content and maximum dry density obtained from these tests are shown in Table 1, below.

Table 1 Standard Compaction (proctor) tests on Fill Material

Samples No	Y_{kmax}(ton/m3)	W_{opt} (%)
1	2.05	9.0
2	1.57	22.0
3	1.98	8.0

As seen from the table, the optimum water content and maximum dry density values of the fill material samples 1 and 3 were found to vary between 8.0% - 9.0% and 1.98 – 2.05 ton /m^3, respectively. The result of sample 2 gave considerably different values. The difference was also observed in the grain size distributions.

From the sieve analyses it has been found that the soil imported from a nearby pit consists of mainly gravel size and sand size coarse materials. And, fine materials are less than 1%. It can be concluded that these soil samples are non-plastic.

The soil type of this fill material in mainly well-graded gravel with the group symbol GW. According to Liu and Evett, (Soils and Foundations, Prentice Hall) GW type soil is an excellent as subgrade material, good as base course, very stable as embankment material and has almost none compressibility and expansion properties after compaction. Also, according to Koerner (1985) this soil type is one of the best fill material to use in rolled earth dams, foundations etc. (Koerner R.M. 1985, Construction and Geotechnical Methods in Foundation Engineering). Based on laboratory frost-heave tests, Andersland and Ladanyi (1994), (An Introduction to Frozen Ground Engineering) have concluded that frost susceptibility of this type of soils is varying in between negligible to low.

VII. CONCLUSION AND RECOMMENDATIONS

Investigations were carried out to get the soil properties of the waste deposit site (where Adana, Yüreğir, Sofulu) of Adana and the properties of the fill material which will be used in the site. The following suggestions need to be considered.

VII.1. The soil type at the site was 'medium to low plasticity inorganic silty clay (with the group symbol CL-CH). Clay and cemented claystone layer with calcerous are observed below these soils. It is known that the permeability of these type of soils are very low.

VII.2. From the fill material samples, sample no 1 and 3 are suggested to be used. A soil with these properties can be used as a suitable fill material (since high strength and low compressibility are required from the fill). Since well-graded gravel soil with the group symbol GW will be used as fill material, the best type of compaction equipment is a vibratory roller. The fills should be done in 30cm thick layers. Compacted layers should be tested more often by in-situ density testing in order to confirm minimum 95% compression ratio. In the compaction control tests for each compacted layer the Proctor compaction values of maximum dry density and optimum water content should be considered as 2.0 ton/m^3 and 9%, respectively. So, for the relative compaction ratio of 95%, the value of maximum dry density shouldn't be less than the value of 1.90 ton/m^3. The values of optimum water content can vary in the range of 7.0%-11.0%. In order to prevent having loose parts in slope ends, fill area should be kept larger than planned and then cut as planned.

VII.3. It is suggested for safety that control tests should be carried out whether the objectives of modifying the ground have been achieved. There is a great variaty of tests possible for evaluating the effect of mechanical ground modification, such as plate loading test and some laboratory tests on representative samples taken from the site.

VII.4. Fills should be protected against any water including the ground water (in case of rise in ground water level) by means of a suitable drainage system. After the complition of fill if there is need to excavate the fill for any reason, no water should permit to flow into the excavated holl.

05.05.1999

Prepared by

Assist. Prof. Dr. Mustafa LAMAN

Table 2 The results of sieve and Hydrometer Analyses for Borehole samples

Project : Adana Büyükşehir
Location : Sofulu

Bore No	Depth(m)	$\gamma n(t/m^3)^*$	$\gamma s(t/m^3)^{**}$	W(%)***	Soil Type****
B-1(1)	6.00-6.45	1.72	2.69	43	CL-CH
B-1(2)	12.00-12.45	1.98	2.67	30	CL-CH
B-2(1)	7.50-7.95	1.85	2.68	23	CL-CH
B-2(2)	12.00-12.45	1.86	2.72	27	CL-CH
B-4(1)	10.50-10.95	1.70	2.67	5	SP
B-4(2)	15.0-15.10	1.81	2.65	31	CL-CH

* *Bulk density (measured in laboratory, test data is given in Table 5)*

** *Unit weight (obtained from pycnometer test in laboratory, test data is given in Table 6)*

*** *Natural Moisture Content(measured in laboratory, test data is given in Table7)*

****CL-CH** : *Medium to low plasticity inorganic silty clay*; **SP** : *Poor Graded Sand*

Table 3 The results of sieve Hydrometer Analyses for Fill Material samples

Sample No	$\gamma n(t/m^3)$	$\gamma s(t/m^3)$	W(%)	Soil Type
1	1.87	2.72	5.0	GW *
2	1.62	2.57	24.4	GW *
3	1.74	2.67	3.5	GW *

(*)GW : *Well graded gravel*

Determination of coefficient of permeability by using falling head test method.

The equation applicable to this test is given as

$$k = \frac{a.L}{A.(t_2 - t_1)} \ln \frac{h_1}{h_2}$$

Where;

a: cross-sectional area of buret (cm^2)

A: cross-sectional area of soil sample (cm^2)

h_1: hydraulic head across sample at beginning of test ($t=t_1=0$)

h_2: hydraulic head across sample at end of test ($t=t_2$)

L: sample length (cm)

ln: natural logarithm to base

The results of the tests are given in the table.

Table 4 The values of k (in cm/sec)

Borehole No	B 1	B 1	B 2	B 2	B 3	B 3
Depth (m)	7.50-7.95	13.50-13.95	4.50-4.95	13.50-13.95	3.00-3.45	6.00-6.45
K (cm/sec)	$3.46x10^{-7}$	$7.40x10^{-7}$	$4.62x10^{-8}$	$5.20x10^{-7}$	$3.23x10^{-7}$	$6.00x10^{-7}$

The consolidation test was also used to estimate the coefficient of permeability and the values of k were found in the order of $1x10^{-7}$ cm/sec.

As seen from the results, the value of permeability is small enough.

Table 5 BULK DENSITY

Bore No	Depth(m)	Can + Soil (gr)	Can (gr)	Volume (cm^3)	γ_n (t/m^3)
B-1(1)	6.00-6.45	140.40	73.00	39.25	1.72
B-1(2)	12.00-12.45	102.00	0.00	51.58	1.98
B-2(1)	7.50-7.95	146.70	0.00	79.35	1.85
B-2(2)	12.00-12.45	146.20	73.00	39.25	1.86
B-4(1)	10.50-10.95	139.70	73.00	39.25	1.70
B-4(2)	15.0-15.10	144.00	73.00	39.25	1.81

Table 6 SPECIFIC GRAVITY

Bore No	Depth(m)	M1	M2	M3	γs(t/m^3) *
B-1(1)	6.00-6.45	228.80	728.60	872.40	2.69
B-1(2)	12.00-12.45	197.50	728.60	852.20	2.67
B-2(1)	7.50-7.95	300.00	728.60	916.80	2.68
B-2(2)	12.00-12.45	215.00	728.60	864.50	2.72
B-4(1)	10.50-10.95	250.00	728.60	884.90	2.67
B-4(2)	15.0-15.10	50.00	143.80	174.90	2.65

(*) *Unit weight (when it is divided by Water Unit Weight, it is called Gravity)*

M1 : Mass of soil (gr)

M2 : Mass of bottle+Water (gr)

M3 : Mass of bottle+soil+water(gr)

Table 7 WATER CONTENT

Bore No	Depth(m)	MASS OF Can (gr)	Can+WetSoil(gr)	Can +Dry Soil (gr)	Wn (%)
B-1(1)	6.00-6.45	28.91	108.5	84.5	43
B-1(2)	12.00-12.45	34.74	127.4	105.8	30
B-2(1)	7.50-7.95	40.81	114.6	100.8	23
B-2(2)	12.00-12.45	39.45	97.7	85.3	27
B-4(1)	10.50-10.95	31.56	105.8	102.1	5
B-4(2)	15.0-15.10	33.66	105.5	88.50	31