Engineering Geology Assessment of the Quaternary Alluvium and Pliocene Deposits in North-western Ankara (Kazan-Ankara, Turkey)

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Abstract: The study area is located at Kazan, in the North-western part of Ankara. Upper Pliocene aged Golbasi formation and Quaternary alluvium outcrop in the study area. Upper Pliocene deposits consist of light brown-pink silt and clay with sand and gravel lenses. Quaternary alluvium consists of gravel, sand, silt and clay of Ova creek sediments and covers the Golbasi formation uncomformably.

The engineering geology, groundwater level and liquefaction risk of the Pliocene and Quaternary deposits have been investigated. A total of 300 m., 25 geotechnical boreholes have been drilled in order to determine the horizontal and vertical distribution of the deposits, SPT performed, groundwater level fluctuation measured and representative samples obtained. The P and S wave velocity of the units have been measured by seismological site studies. The engineering geology map and cross-sections were constructed.

Upper Pliocene deposits are classified as low and high plasticity clay and silt. Quaternary alluvium is classified as low and high plasticity clay and silt, and clayey and silty sand. The engineering geological properties of the units are investigated and thier statistical distrubutions are calculated. Liquefaction potential of the sandy deposits in the third degree earthquake zone has been calculated according to the different procedures and there is no liquefaction risk in the studied units.

Resumé: La region d'etude se situe a 30 km nord d'Ankara. ci Le Pliocéne Superier formation de Gölba ı et les alluvions de Quaternairé existent. La formation de Gölba ı contient des argiles et des silts legerment bruns avec des lentilles des argiles, des silts sableux et des cailloux. Le Quaternaire qui possede des alluvions nouveaux et anciens couvre unconformablement la formation de Gölba ı dans le lit de ruisseau d'Ova, avec des cailloux, des sables, des silts et des argiles.

Dans cette étude, la geologie de Genie Civile des formations d'alluvions Quaternaire et du Pliocené Superier et la situation des eaux souterraines et le danger de liquidification ont été analysés. Pour determiner la distribution laterale et verticale des unités, 25 samptes ont été collectés dans les sondages geotechniques de 350 metres. Les particularités sismiques des ondes P et S ont été determineés par les sismiques refractions. La carte de et les sections de Genie Civile ont été prepareés.

Les unités du Pliocené Superieur se composent des silts et des argiles des plasticités faibles et eleveés. Par contre, les alluvions ont des silt et des dvec sables silteux ayant des plasticites faibles et eleveés. Aprés la determination des particularites geotechniques des unites, les statistiques de leur distribution ont été aussi determineés. La region qui se situe dans la troisieme categorie de seismicité n'a pas de danger de liquidification.

Key words : Classification, Drilling, Engineering geology, Liquefaction, Mechanical properties, Penetration tests

INTRODUCTION

The stability of the slopes, liquefaction of the geological units, slope degree and their geotechnical properties must be investigated by means of engineering geology for site selection purposes. Besides, the P and S wave velocities should be determined by seismic methods. The engineering geological investigation of the Technopark construction area of Ankara University has been carried out (Kilic, 2004). The D100 motorway passes through the study area in a SE direction (Figure 1). The geological, geophysical and geotechnical properties of the area have been determined in order to construct the engineering geological maps, cross-sections and the liquefaction potential has been evaluated by different methods.

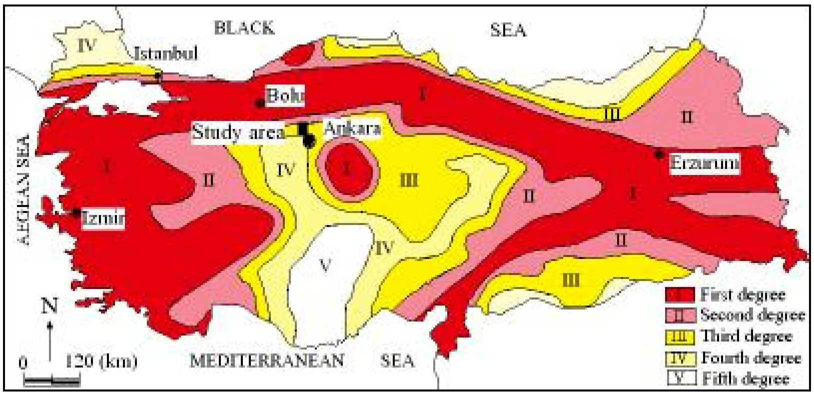

Figure 1. The location and earthquake map of the study area (GDDA, 1996)

GEOLOGICAL SETTING

The Upper Pliocene lacustrine Gölbasi Formation is extensively exposed in the study area. The engineering geological map has been prepared (Figure 2). This unit lies unconformable on the older units, mostly horizontal. This pinkish, light brown, clayey and silty unit sometimes includes lens-shaped bodies of gravel and sand. Quaternary aged alluvium deposited by the Ova creek cover a wide area on this unit. Alluvium is made up of gravel, sand, silt and clay. The North Anatolian Fault at 70 km north, has affected the province. However, Ankara has not been an epicentral location of important earthquakes. The slope degree reduces towards Ova creek on the west (Figure 3).

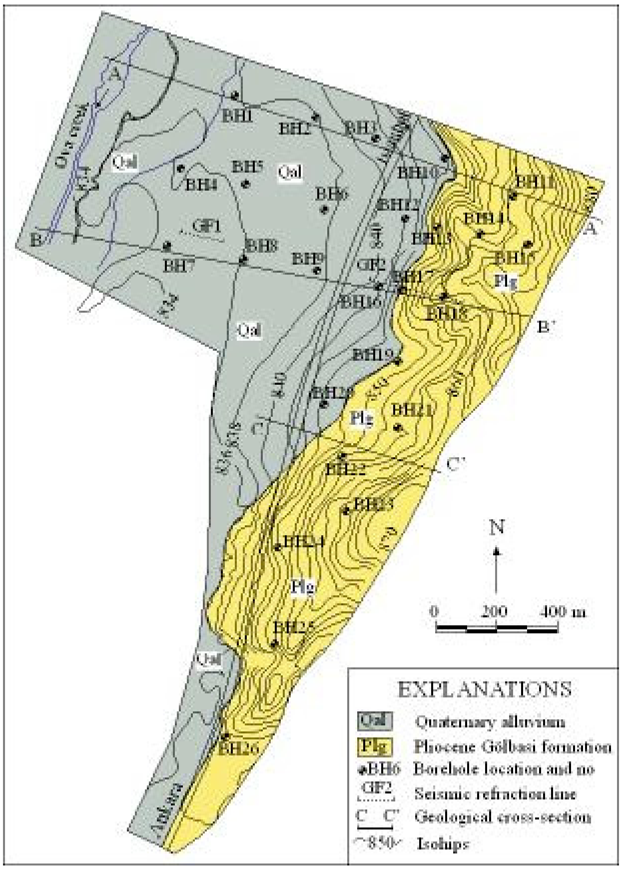

Figure 2. Engineering geological map of the study area

FIELD INVESTIGATIONS

A total of 25 boreholes (300 m) have been drilled (Figure 2). The engineering geological cross-sections exposing horizontal and vertical relations between the units have been prepared (Figure 4). Groundwater level ranges between 3.0-7.0 m in the boreholes drilled in Pliocene and Quaternary aged units. Geophone separations of 10m for the P-wave velocity, and 5 m for the S wave velocity measurements were used. The seismic recorder with 24 channels has been used for the seismic study. S wave velocity of the alluvium differs between 107-279 m/s, while ranging between 279-1839 m/s in Pliocene units. The classification, physical, geomechanical and consolidation properties of the representative samples have been analysed at Ankara University, Engineering Geology Laboratories using ASTM (1994) and TS-EN (1997) standards. Statistical distribution of the geotechnical properties of the units are presented in Table 1 and Table 2.

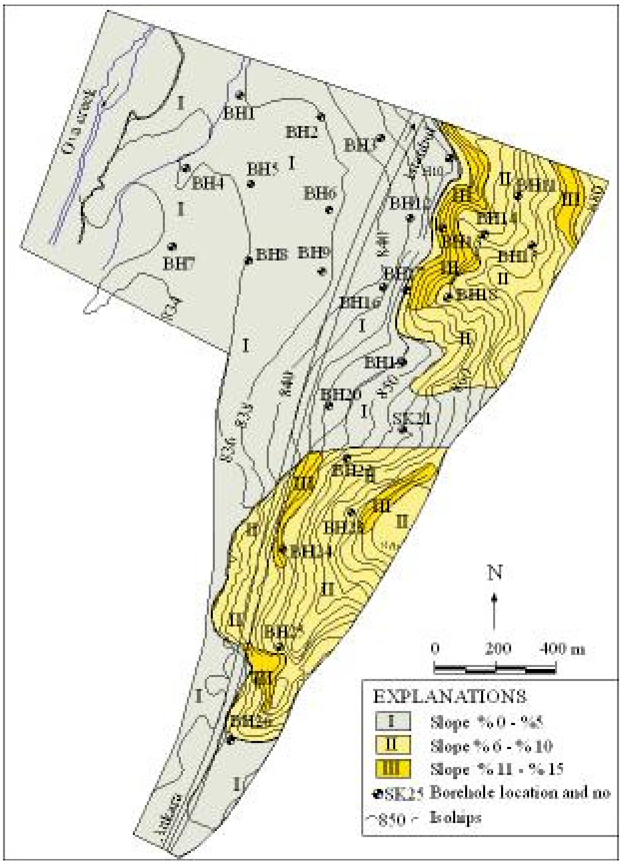

Figure 3. Slope map of the study area

GEOTECHNICAL EVALUATION

Quaternary aged alluvium was classified as: silty clay (SC), silty sand (SM), low plasticity inorganic silt (ML), low plasticity inorganic clay (CL), high plasticity inorganic silt (MH), and high plasticity inorganic clay (CH). The Pliocene units were classified as silty sand (SM), low plasticity inorganic silt (ML), low plasticity inorganic clay (CL), high plasticity inorganic silt (MH), and high plasticity inorganic clay (CH). The sand is lens-shaped in the Pliocene clay. The fine grained soils are plastic, hard, and very hard, based on SPT 'N' values. Pliocene aged fine soils are soft, plastic, but stiff based on SPT 'N' values.

Table 1. The maximum, minimum and mean geotechnical properties of Quaternary alluvium units

	CL, CH, ML and MH			SC and SM		
Property	Min	Max	Mean	Min	Max	Mean
Natural water content, (ω_n), %	15	39	24	10	27	18
Natural unit weight, γ_n, kN/m^3	17.8	18.5	18.1	-	-	-
Liquid limit, (LL), %	35	58	48	38	47	43
Plastic limit, (PL), %	17	39	26	18	21	19
Plasticity index, (PI), %	14	34	22	20	26	23
+ #4 sieve, %	0	10	4	0	20	9
- # 200 sieve, %	58	97	78	18	42	30
Cohesion, (c), kN/m^2	35	65	53	-	-	-
Friction angle, ϕ degree	6	13	10	-	-	-
SPT N blow count	10	>50	-	15	>50	-

Table 2. The maximum, minimum and mean geotechnical properties of Pliocene units

	CL, CH, ML and MH			
Property	Number of Samples	Min	Max	Mean
Natural water content, (ω_n), %	24	15	32	24
Natural unit weight, γ_n, kN/m^3	6	17.9	18.6	18.3
Liquid limit, (LL), %	24	36	68	51
Plastic limit, (PL), %	24	20	30	27
Plasticity index, (PI), %	24	11	38	24
+ #4 sieve, %	24	0	12	3
- # 200 sieve,%	24	60	97	78
Cohesion, (c), kN/m^2	6	55	70	60
Friction angle ϕ degree	6	8	14	11
SPT N blow count		15	>50	-

Liquefaction evaluation

The liquefaction potential of the units have been evaluated according Youd, et al. (2001) based on SPT 'N' values and the safety factors have been calculated by the Tokimatsu & Yoshimi (1983) procedures. The study area is within the third degree earthquake zone according to the "earthquake zoning map of Turkey" (GDDA, 1996) as shown in Figure 1. For this reason, the maximum horizontal acceleration a_{hmax} has been taken as 0.2 g. The moment magnitude (M_w) is 7.5 (the study area is close to NAFZ). The mid-level of the sandy layers have been taken into account. The results of the Youd, et al. (2001) evaluation are presented in Table 3 and Figure 4. Tokimatsu & Yoshimi (1983) calculations and results are presented in Table 4.

Table 3. Liquefaction potential of the units based on Youd, et al. (2001)

Borehole	z (m)	ρ_n g/cm3	ρ_{sat} g/cm3	GWL,m	σ_o(kgf/cm^2)	σ_o'(kgf/cm^2)	N	$N_{(60)}$	C_N	$N_{1(60)}$	CSR
BH1	5,90	1,92	2,02	8,4	1,13	1,13	28	21,00	0,96	24	0,12
BH3	14,05	1,93	2,00	12,8	2,72	2,60	50	37,50	0,65	29	0,11
BH4	7,80	1,92	2,02	5,2	1,52	1,26	29	21,75	0,92	24	0,15
BH5	7,00	1,96	2,09	1,3	1,45	0,88	29	21,75	1,04	27	0,20
BH7	3,20	1,91	2,01	5,0	0,61	0,61	37	27,75	1,15	38	0,13
BH8	4,85	1,89	1,99	8,0	0,92	0,92	26	19,50	1,03	24	0,13
BH9	1,25	1,91	2,02	8,0	0,24	0,24	11	8,25	1,34	13	0,13
BH21	4,00	1,92	2,05	2,7	0,78	0,65	35	26,25	1,13	36	0,15
BH22	2,00	1,89	1,98	2,4	0,38	0,38	22	16,50	1,26	25	0,13
BH25	10,75	1,94	2,10	1,1	2,24	1,27	50	37,50	0,92	41	0,20
BH26	3,75	1,87	1,96	2,3	0,71	0,57	39	29,25	1,17	41	0,16

Table 4. Tokimatsu & Yoshimi (1983) liquefaction evaluation results

Bore hole	z (m)	ρ_n (g/cm^3)	ρ_{sat} (g/cm^3)	Gwl	σ_o kg/cm^2	σ_o' kg/cm^2	FC	ΔN_f	N	N_1	$N_{1(80)}$	N_a	τ_δ/σ_0'	τ_λ/σ_0'	FS
BH1	5,90	1,92	2,02	8,4	1,13	1,13	28	6,80	28	26,06	15,60	22,40	0,12	0,31	2,64
	12,85	1,91	2,01	8,4	2,50	2,05	24	6,00	44	27,16	16,26	16,26	0,13	0,18	1,40
BH3	14,05	1,93	2,00	12,8	2,70	2,57	33	7,30	50	25,99	15,56	22,86	0,11	0,33	3.0
BH4	7,80	1,92	2,02	5,2	1,52	1,26	18	5,80	29	25,11	15,03	20,83	0,14	0,26	1,87
BH5	11,50	1,90	2,00	7,6	2,22	1,83	14	5,40	40	26,84	16,07	21,47	0,13	0,28	2,13
BH7	3,20	1,91	2,01	5,0	0,61	0,61	12	5,20	15	19,45	11,65	16,85	0,12	0,18	1,49
BH8	4,85	1,89	1,99	8,0	0,92	0,92	26	6,60	26	27,34	16,37	22,97	0,12	0,34	2,81
BH9	1,25	1,91	2,02	8,0	0,24	0,24	12	5,20	11	19,92	11,93	17,13	0,13	0,19	1,47
BH23	4,55	1,92	2,03	yok	0,87	0,87	18	5,80	33	35,65	21,35	27,15	0,12	0,67	3.0
BH24	2,87	1,93	2,02	yok	0,55	0,55	16	5,60	37	50,51	30,25	35,85	0,12	3,44	3.0
BH25	6,70	1,90	2,01	yok	1,27	1,27	7	2,00	50	43,08	25,80	27,80	0,12	0,76	3.0
BH26	4,65	1,91	2,01	yok	0,89	0,89	16	5,60	34	36,39	21,79	27,39	0,12	0,70	3.0

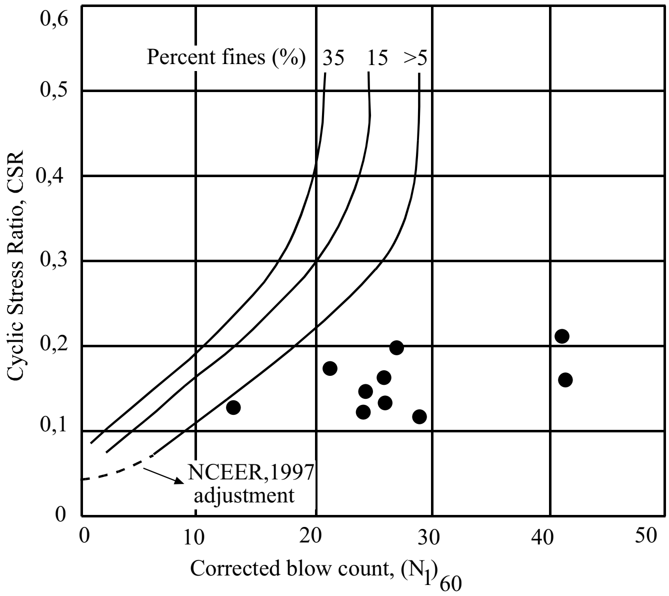

Figure 5. Relationship between CSR and SPT $(N_1)_{60}$ (Youd, et al. 2001)

According to the both procedures, no liquefaction is expected in the study area. The minimum factor of safety is 1.4. Liquefaction potential of the silty and clayey soils has been evaluated by the modified Chinese criteria (Figure 6) proposed by Seed et al. (2003). Some of the samples are in the "A" region, but the natural water content values are all smaller than the 0.8×LL boundary. That is why no liquefaction risk is expected in the finer soils.

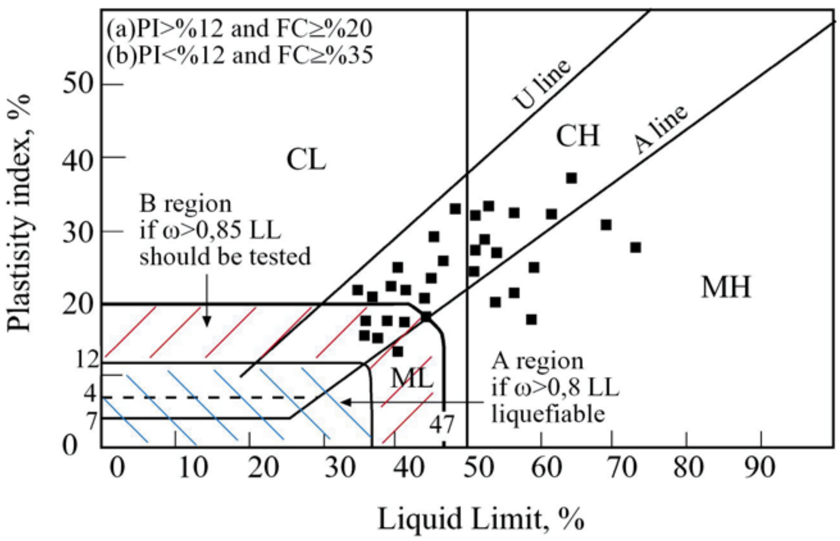

Figure 6. Plots on the modified Chinese criteria chart (After Seed, et al. 2003)

RESULTS AND RECOMMENDATIONS

1. The Pliocene aged light brown soils of CL, CH, ML and MH groups make up the basement of the area. Quaternary aged CL, CH, ML, MH, SC and SM group soils overlie the basement soils.
2. The sandy and gravelly levels contain groundwater at depths from 2.75-7.00 m. Pliocene units locally bear groundwater. It should be considered that, these levels might fluctuate seasonally. Drainage for groundwater and surface water should be constructed.
3. The CL, CH, ML and MH soils are soft, plastic and hard, plastic, and hard and very hard according to SPT 'N' values. Pliocene aged CL, CH, ML and MH soils are soft plastic and plastic, and very stiff and hard according to SPT 'N' values.
4. Differential settlement could occur because of the geological structures. No liquefaction is expected in sandy soils and fine grained ones.

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