ROLE OF GEOLOGICAL, GEOTECHNICAL AND STRUCTURAL FACTORS FOR SETTLEMENT SITE SELECTION: A CASE STUDY OF ISIKLI TOWN IN CIVRIL GRABEN (DENIZLI, SW TURKEY)

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Abstract - Land use and development plans require geological and geotechnical studies which are vital for a modern urbanization. Microzonation studies for development plans are decisive for safe environment and sustainable development. Most of the urbanizations in many parts of Turkey, were established on the graben edges controlled by active faults. The situation in the Civril graben is also similar case. The poor ground conditions in this basin, where seismic activity is high and very close to the faults, and shallow ground waters increase the destructive power of the earthquakes. This study is focused on settlement suitability of Isikli (Denizli) Municipal area. The area is on an alluvium plain where is located on west of Isikli Lake and surrounded by active fault lines. The area has been divided into three parts in terms of urbanizations.

Index Terms - Active tectonics, Civril graben, geotechnics, SW Turkey.

I. INTRODUCTION

Geological, geotechnical and structural characteristics of the region are the most important factors affecting the cost and safety in settlement site selection, designing of constructions and development plans. Geological and geotechnical studies constitute one of the first and most basic stages of modern urbanization. Such studies are even more important in seismically active areas. The study area is located at 85 km northeast of Denizli, which is very close to the junction with the NW-SE trending Dinar graben, on the north-eastern end point of NE-SW trending the Civril graben (Figure 1). In this study, seismicity and geotechnical properties which are factors in the selection of settlements are evaluated together. Geological survey, field and laboratory tests supported by geological, geotechnical and groundwater surveys have been carried out for urbanization suitability assessments of Isikli town under risk of earthquake.

II. GEOLOGICAL SETTINGS

The study area and the Western Anatolian Region is one of the most seismically active and fastest areas of continental extension in the world [1]. The amount of opening is about 35 mm/year in the N-S direction [2]. In general, this direction of opening in the region under the effect of a tensile stress in the NNE-SSW direction is also compatible with the direction of the T axis, which is the result of the focal mechanism solutions of the earthquakes.



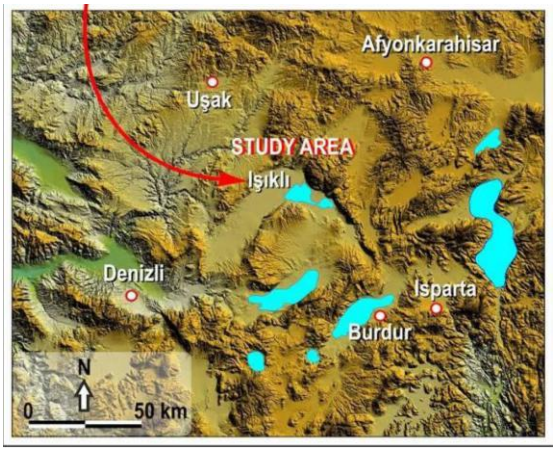


Figure 1. Location map of the study area

The initial time of the extensional stress in the region is controversial and has been discussed by various researchers as Late Eocene- Early Oligocene [3], Early Oligocene [4], Late Oligocene-Early Miocene [5], Early Miocene [6], Late Miocene [7] and Pliocene-Pleistocene [8], [9], [10].

Block-faulting tectonics, constitutes the main fracture systems in the study area, are related to the neotectonic development of Western Anatolia [11]. The Aegean region is currently under active NE-SW stress deformation. The Anatolian plate bounded by the North Anatolian Fault and the East Anatolian Fault between the Arabian and Eurasian plates is escaping from the Bitlis-Caucasus zone to the Aegean region. At the same time, the influence of the roll-back of the African-Mediterranean lithospheric crust subducting northward under the Anatolian plate along the Cyprus-Aegean trench, pulls the western Anatolian region to the south and expands in the NE-SW direction [12].

2.1 Geology

The Civril graben is located between the Menderes

massif on the north and tectonostratigraphic units of the Lycian nappes on the south. Western Anatolia is continental rift area on the basement is that is actively expanding on the rocks of the Menderes massif and Lycian nappes. The exposed rocks in the study area and its vicinity are cover schists of Upper Palaeozoic Menderes metamorphics [13], [14], the Mesozoic aged marbles belonging to Lycian nappes tectonically located on the underlying schists, the Miocene-Pliocene aged sedimentary rocks, Quaternary talus and alluvium (Figure 2).

Menderes massif is tectonically overlain by Mesozoic aged Lycian nappes composed of thick-bedded, crystallized limestones / marbles and recrystallized pelagic limestones and phyllites reaching the Lower Eocene age [15]. The tectonic settlement over the Menderes Massif of the Lycian Nappes occurred in the Middle Eocene [15].

2.2 Tectonics

The NE-SW directed depression area, about 60 km in length and 15 km in width, is called Çivril graben basin. The Çivril graben coupled with NW-SE directed the Dinar graben to the east of the Isikli Lake in a reverse V-shaped geometric structure (Figure 2). The inverted V-shaped geometric graben structure indicates the two-axis opening in the region [16], [11]. On the contrary, [17] stated that the Civril-Dinar graben developed as cross-graben with uniaxial opening in NE-SW direction during Plio-Quaternary in the light of morphological, structural, drilling and geophysical data obtained from Çivril and Dinar grabens. The axes of the Acıgöl and Burdur grabens are parallel to the axis of the Çivril graben in the south, and these 3 basins are bounded by dipping southwestward and the NW-SE directed Dinar fault and (Figure 1). The NE-SW trending Civril Fault Zone, especially along the northeastern end sections, shows that some of the hanging valleys, terraces, colluvium fans hanging on faults (Figure 3), and small-scale earthquake epicentres concentrated along a line (Figure 4), indicating that this fault zone is now seismically active. The total amount of vertical displacement on this fault is at least 200m, according to topographic heights. The Civril Fault Zone is bounding the Civril graben to the northwest, which is not a single fault but consists of several fault segments with lengths ranging from 3-10 km separated by relay ramps (Figure 2).

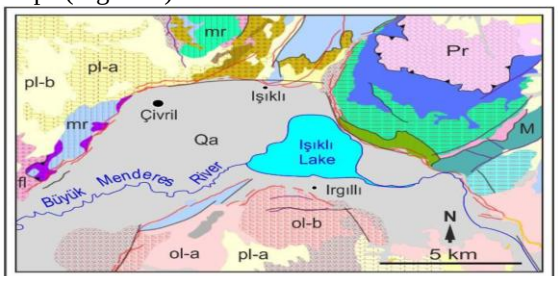




Figure 2. Geological map of the study area (from modified General Directorate of Mineral Research and Expolaraion, MTA, GeoScience MapViewer and Drawing Editor, [18].

The presence of the historical earthquakes in Civril and Dinar grabens and their surroundings are known to date from the Byzantine period to the Seljuk and Ottoman periods [19].

In the study area, a large part of the historical and instrumental earthquakes are related to the activity of NW-SE trending the Dinar fault (Figure 3a), with dipping to SW and NE-SW trending the Baklan fault, with to dipping NW, which is bounding the Civril graben to the south-eastern (Figure 2).



-a-



Figure 3. Active faults in the area a) NW-SE trending Dinar fault, b) E-W trending Isikli fault.

When historical and instrumental earthquake activities in the study area and its vicinity are examined; B.C. 400, B.C. 88 and A.C. 53 (VIII) historical earthquakes destroyed Apamea Kibotos, which is the old settlement of Dinar [20], [21].

An earthquake occurred in 1875 on the Baklan fault, where intensity of earthquakes was IX-X and 1300 people lost their lives [22]. Subsequent studies related

to this earthquake revealed that a surface rupture zone of 20 km length occurred in a region between Dinar and Civril [23].

The Civril graben and the surrounding area were devastated by destructive earthquakes of medium size. These;

In 1925 there was an earthquake at the VII-IX intensity (M = 6) on the Baklan fault and 330 people died in this earthquake [22].

The Çivril earthquake that broke out on 19 July 1933 was in the intensity of VIII (M = 5.7) and 20 people lost their lives in this earthquake and more than 200 houses were seriously damaged (Figure 4, [24].

The Dinar earthquake on October 1, 1995 was a very devastating earthquake with a magnitude of Mw = 6.2, in the Dinar district of 35 km east of the study area on the Dinar fault [25]. In this earthquake, 96 people were killed, 260 people were injured and more than 25.000 people were homeless (Pınar 1998). After the earthquake, a 10 km long surface rupture was observed [26].

The ancient city of Eumania, which remained around the Isikli springs in the eastern part of the town of Isikli, was founded in the name of Eumenes of the king of Bergama, perhaps destroyed by historical earthquakes.

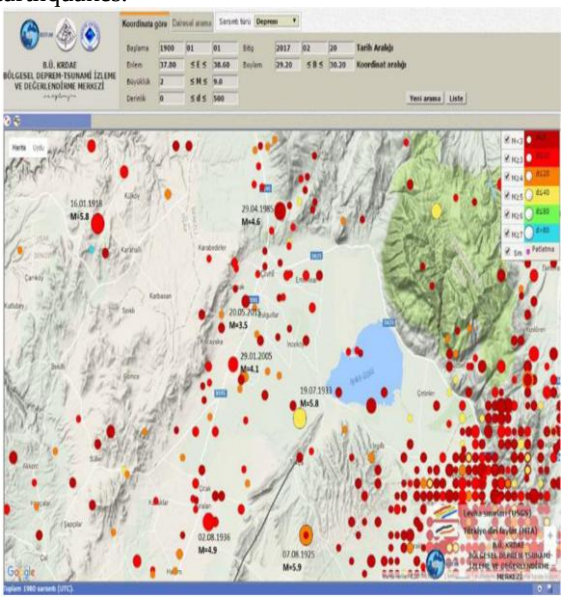


Figure 4. Distribution of 2 and larger magnitude earth- quakes between 1900 and 2017 in the study area and its surroundings, [27].

2.3 Hydrogeology

The study area is located in the south of Isikli Lake. This lake is largely fed by a stream comes from Dinar, which is called Menderes, and the minor source from the southern part.

The water levels in some of the boreholes drilled during this study and the locations of natural springs indicate that groundwater is closer to the surface in the southern parts of the area. The depth of the underground water level is increasing towards western parts. It is about 2.30 meters in the shallowest eastern section. Maximum depth is about 9.5 meters.

2.4 Geotechnical Study

During geotechnical studies, twenty geotechnical boreholes have been drilled and in-situ (SPT, Menard pressuremeter etc.) has been implemented at several levels. Additionally, twenty pits were opened to visualize the ground profile in the area. Observation pits and boreholes were at the same locations in order to compare the ground features (Table 1).

The liquid limit and the plastic limit values range from 21.0% to 44.0%. and from 14.0% to 38.0% respectively. Plasticity index values were between 1 and 14. The natural unit weigth was found to be minimum 15,2 kN/m^3 and maximum 21,0 kN/m^3. The natural water contents range from 6% to 40.0%. The modulus of elasticity (E) and the pressuremeter limit pressure (PL) are varies from 3.2 to 19.0 MPa and the from 0.06 MPa to 1.67 MPa respectively (Table 2). The results of the pressurometer test are given in Figure 5.

Tablo 1: Lab test results (samples obtained from pits)

Pit No	Attergberg Limits			Sieve Analysis			USC
	LL	PL	PI	% Gravel	% Sand	% Silt + clay	
1 (2m)	29	27	2	27	26	47	GM
2 (2m)	30	25	5	37	36	27	GM
2 (3m)	27	N		55	38	7	--
3 (2m)	23	N		52	38	10	--
4 (2m)				62	30	8	--
5 (2m)	37	23	14	7	46	47	SC
6 (2m)	25	22	3	38	23	39	GM
6	27	21	6	3	21	76	CL-M
7 (2m)				2	77	21	--
7 (2m)	33	20	13	1	12	87	CL
8 (2m)				2	77	21	SP
8	33	20	13	1	12	87	CL
9 (2m)				0	49	51	--
10 (2m)	38	31	7	1	3	96	ML
10	44	38	6	1	15	84	ML
12 (2m)	21	14	7	3	39	58	CL
13 (2m)	30	23	7	1	14	85	ML
14 (2m)	29	22	7	58	12	30	SM-S
15 (2m)	30	23	7	0	15	85	ML
15	24	23	1	17	29	54	ML
16 (2m)	28	19	9	46	35	19	GC
17 (2m)	26	21	5	0	10	90	ML
18 (2m)	35	32	3	0	3	97	ML
18	32	25	7	1	10	89	ML
19 (2m)	39	N		17	24	59	--
20 (2m)	27	20	7	11	18	71	CL

Table 2: Menard pressuremeter tests

Borehole no	E (MPa)	P_L (MPa)	Test depth (m)
1	6,8	0,41	2-3
2	15,2	1,23	2-3
3	14,6	1,23	1,5-2,5
4	0,54	0,06	1-2
5	5,6	0,73	1-2
6	1,86	0,55	2-3
7	6,8	0,80	1-2
8	3,2	0,75	2,5-3,5
9	13,2	1,67	1,5-2,5
10	1,88	0,28	1-2
11	1,94	0,40	2,5-3,5
12	13,8	0,34	2,5-3,5
13	5,4	0,43	2,5-3,5
14	0,28	0,06	1,5-2,5
15	3,2	0,39	1,5-2,5
16	19,0	0,06	1,5-2,5
17	0,3	0,06	1,5-2,5
18	12,2	1,03	0,5-1,5
19	3,6	0,43	2,5-3,5
20	5,6	1,00	1,5-2,5

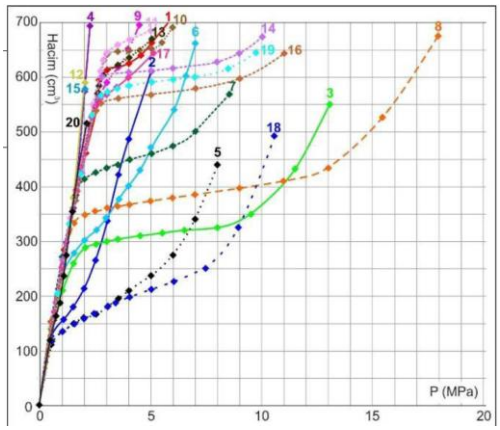


Figure 5. Menard pressuremeter test results

The units in the study area are composed mostly different sized granules ranging from clay to rock. The distribution of the soil types are illustrated in Figure 6.

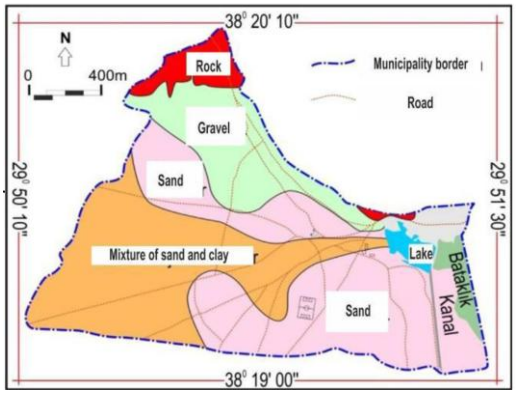


Figure 6. Soil types in the study area

III. DISCUSSION AND RESULTS

The study area has been classified as "suitable", "suitable with precaution" and "not suitable". As it can be understood from the description, urbanization is not allowed in the "not suitable" zones based on geological and geotechnical parameters. The areas "with precaution" are required more detailed geological and geotechnical studies.

Rock and coarse grained units generally provide a more appropriate soil conditions for the construction. On the contrary, fine grained units generally exhibit a lower bearing capacity. When the values given in Tables 1 and 2 are taken into account, it is observed that the low modulus of elasticity and the limit pressure are lower in the northern sections and increase towards the south. If the slope is too much in the face of this, the settlement is classified as an unsuitable area, although it is geologically appropriate to increase the cost of construction.

In the light of these evaluation criteria, "suitable", "suitable with precaution" and "not suitable" areas are shown in Figure 7 in terms of settlement suitability in the study area. The south-eastern sections of the study area are classified as "non-suitable" while the northern sections are designated as "suitable". The section between these two sections is a transitional zone and it is the area where the design should be made before the construction and / or the necessary geotechnical precautions should be taken.

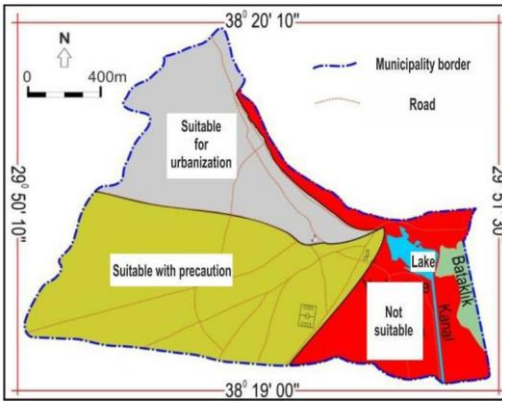


Figure 7. Settlement suitability map of the study area

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