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Engineering Geology and Bearing Capacity Calculation of Soil in Karacadağ Region

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Karacadağ, Rock soil, Engineering geology, Ultimate bearing capacity, Plaxis

Abstract: Geotechnical investigations are highly essential for optimal planning of quality, time, and cost management in engineering structures. Geotechnical analysis is used to determine the physical and chemical properties of soils by performing laboratory and field tests. This study examines the geotechnical engineering of the Karacadag region in the Southeast Anatolia region of Turkey by analyzing soil data from the study area in Diyarbakır city, Sur County, Yukarıkılıctası district and block no 7018, parcel 1. The aim is to obtain general information about the soil in this area and to produce faster and more practical solutions in terms of quality and economic aspects in construc-tion projects. Drilling was performed in the field using UD and SPT tubes, and various laboratory tests such as sieve analysis and Atterberg limits were conducted on the samples taken. Using the parameters obtained from these tests, the bearing capacity of the basalt-rock soil related to the Karacadag Volcanism was calculated using the Turkish Building Earthquake Regulation (TBDY) and Plaxis 2D geotechnical modeling program. The bearing capacity calculation was performed using different methods, and the results were compared and evaluated in terms of safety and the effect of the parameters considered in the calculation.

Karacadağ Bölgesi Zemininin Mühendislik Jeolojisi ve Taşıma Gücü Hesabı

Anahtar Kelimeler
Karacadağ, Kaya zemini, Mühendislik jeolojisi Nihai taşıma kapasitesi, Plaksis

Öz: Mühendislik yapılarında kalite, zaman ve maliyet yönetiminin optimum şekilde planlanması için jeoteknik araştırmalar son derece önemlidir. Geoteknik analiz, laboratuvar ve arazi testleri yapılarak zeminlerin fiziksel ve kimyasal özelliklerinin belirlenmesi amacıyla kullanılmaktadır. Bu çalışma, Türkiye'nin Güneydoğu Anadolu bölgesindeki Karacadağ bölgesinin geoteknik mühendisliğini, Diyarbakır ili, Sur ilçesi, Yukarıkılıçtası semti ve 7018 ada, 1 parseldeki çalışma alanından elde edilen toprak verilerini analiz ederek incelemektedir. bu alandaki toprakların işlenmesi ve inşaat projelerinde kalite ve ekonomik açıdan daha hızlı ve pratik çözümler üretmektir. UD ve SPT tüpleri kullanılarak sahada sondaj yapılmış, alınan numuneler üzerinde elek analizi, Atterberg limitleri gibi çeşitli laboratuvar testleri yapılmıştır. Bu testlerden elde edilen parametreler kullanılarak Karacadağ Volkanizmasına ilişkin bazalt-kaya zeminin taşıma kapasitesi Türkiye Bina Deprem Yönetmeliği (TBDY) ve Plaxis 2D jeoteknik modelleme programı kullanılarak hesaplanmıştır. Taşıma kapasitesi hesaplaması farklı yöntemler kullanılarak yapılmış olup, sonuçlar güvenlik ve hesaplamada dikkate alınan parametrelerin etkisi açısından karşılaştırılarak değerlendirilmiştir.

1. INTRODUCTION

The construction industry, which is rapidly evolving today, emphasizes creating more durable and environmentally friendly structures from an engineering perspective. In this process, understanding the physical and mechanical properties of the soil—the load-bearing foundation of any structure—is crucial. Geotechnical investigations are vital for determining these properties, as they reveal the engineering geology and mechanical characteristics of the soil using various analytical methods. These analyses yield critical parameters such as the soil's bearing capacity, which significantly influences the durability and stability of structures (Chen et al., 2023a; Amin Soltanianfard et al., 2023).

Bearing capacity is a fundamental parameter in structural design, determining the soil's ability to support loads without failure. Various theoretical models and empirical methods, such as Terzaghi (1943), Meyerhof (1951), Hansen (1970), and Vesic (1973), are applied to calculate the bearing capacity from field and laboratory test data (Zhao et al., 2023). Recent advancements, such as semi-analytical methods incorporating three-dimensional strength factors, provide enhanced accuracy for complex geological settings (Chen et al., 2023a). Additionally, modern machine learning techniques have emerged as efficient tools for predicting end-bearing capacity, offering alternatives to traditional methods (Chen et al., 2023b).

Research conducted on the Dicle University campus and its surroundings focused on the Karacadağ Basalt formations, examining the lithological sequence and dominant lithology types in the area. Soil samples underwent sieve analysis and Atterberg limit tests to classify them according to the Unified Soil Classification System. High-plasticity clays (CH) with significant swelling properties were identified, which can affect volume stability (Xu et al., 2023). Experimental studies on basalt samples from the Diyarbakır region characterized their mechanical properties, such as uniaxial compressive strength and Young's modulus, revealing correlations essential for predicting the behavior of basalt as a construction material (Zhao et al., 2023).

Geotechnical investigations extend to addressing challenges such as soil swelling, which can lead to material loss and structural instability. For instance, swelling soils in the Diyarbakır region have been studied, revealing significant issues due to clay mineral expansion (Xu et al., 2023). Advanced field and laboratory techniques, including pressuremeter and seismic tests, have refined bearing capacity estimates, enabling safer structural designs (Chen et al., 2023a).

The seismicity of the Diyarbakır region has been highlighted, emphasizing the influence of fault lines and historical earthquake data on soil properties. The fault lines passing through the Diyarbakır province and plate tectonics have been specified. Studies have also examined the geotechnical characteristics of pumice soils in the Nevşehir region, noting similarities to sandy soils and applying Standard Penetration Tests (SPT) to evaluate bearing capacity (Xu et al., 2023). Additionally, swelling and shrinkage issues caused by high-plasticity clays were discussed, highlighting challenges in maintaining volume stability.

In conclusion, advancements in geotechnical engineering, including modern computational techniques and experimental studies, continue to refine our understanding of soil mechanics. These developments not only ensure safer and more sustainable structural designs but also expand the applications of geotechnical principles to diverse geological contexts.

1.1. Investigation Area

Diyarbakır is situated on the eastern edge of a vast basalt plateau that stretches between Karacadağ, an extinct volcano located 100 meters above the Diyarbakır Valley, and the Dicle River. The city is renowned for its ancient walls, mosques, churches, temples, caravanserais, baths, fountains, houses, and palaces. With a history dating back over 5,000 years, Diyarbakır began to expand beyond its historical walls in the 1950s. One of the reasons basalt stone is prevalent in the construction of many buildings in the city is due to its location on an extinct volcanic terrain (Karakaya et al., 2022; Çetin & Acar, 2023).

The Eastern Anatolian Fault, which connects to the North Anatolian Fault and runs through the regions of Hatay, Kahramanmaraş, Malatya, and Bingöl, is the primary fault system responsible for land movements in Diyarbakır (Çetin & Acar, 2023; Kaya et al., 2021). The city lies approximately 90 km away from the East Anatolian Fault, within a second-degree earthquake zone, and is also about 60 km from the Bitlis Zagros Fault. This places Diyarbakır in a geologically active area, where the interaction between the East Anatolian Fault and the Arabian Plate significantly influences seismic activity (Aksu & Yılmaz, 2021). The North Anatolian Fault - Eurasian Plate form a boundary, is shown in Figure 1.

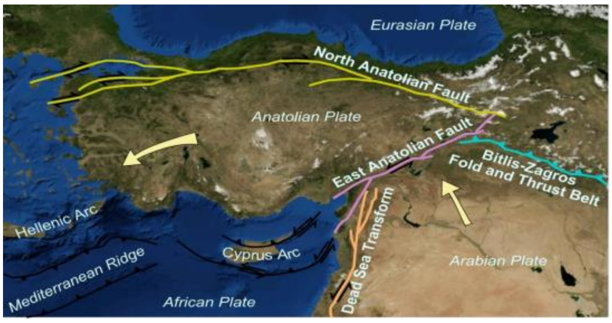


Figure 1. Anatolion Plate

Geological maps obtained through geological research allow us to learn about the age of rocks and soil, as well as the rocks found in the depths of the underground. Geological maps made at different scales reveal important regional characteristics, various geological time periods' paleogeography, and geodynamic events (MTA).

The Karacadag region is an area with significant potential for soil engineering. The geological and topographical features of the region should be taken into consideration when engineers design and implement construction projects.

Karacadag is a region shaped under the influence of volcanic activity. The rock structure is generally composed of volcanic origin materials such as basalt, andesite and tuff. These volcanic rocks have mountainous areas shaped by erosion and other natural effects over time.

The study area is located in Diyarbakir City, Sur County, Yukarıkılıctası District, block no. 7018, parcel 1. Neighboring cities; Elazig, Mus, Mardin, Adiyaman, Malatya, Bingol, Batman, Sanliurfa. Counties; It has counties: Cermik, Cungus, Egil, Hani, Kocakoy, Lice, Silvan, Bismil, Cinar, Dicle, Ergani, Hazro, Kulp. It is located in the north of Mesopotamia. Surrounded by the cities of Elazig, Mus, Mardin, Adıyaman, Malatya, Bingol, Batman and Sanliurfa, Diyarbakir has all the characteristics of the region (Figure 2).

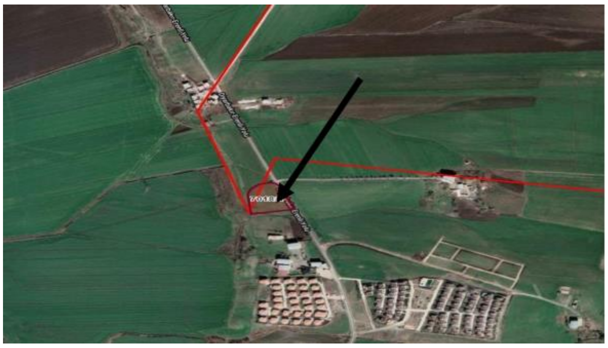


Figure 2. Site location map of investigation area

2. MATERIAL AND METHOD

2.1. Turkey Building Earthquake Regulation (TBDY) Bearing Capacity in Basic Design

The Turkish Building Earthquake Regulation (TBDY) is a technical regulation prepared to ensure that buildings in Turkey are constructed in an earthquake-resistant manner and thus reduce the risk of earthquakes. This regulation contains guidelines that ensure that the bearing capacity calculations of buildings are made according to certain criteria. The bearing capacity of the structure is calculated based on the results of the analysis. The bearing capacity calculation is made to determine the bearing capacity of the structure, and how it can behave under specified loads without exceeding the damage limit.

In the design of shallow and deep foundations, the design bearing capacity of the foundation soil will be evaluated according to the following equation in the design against failure:.

$$Et \ Rt \qquad (1)$$

Where Et: Design effects related to loading conditions including static and seismic and Rt: Representing the design strength against deformation mechanism.
The vertical bearing capacity of the foundation base will meet the design axial force and bending moment. Design strength; in the design strength calculation, the characteristic strength is divided by the strength factor is taken as at least 1.4 in the calculation according to Table 1.

$$Rt = Rk/yRy \qquad (2)$$

where Rt: Design strength related to loading conditions including static and seismic Rk: Characteristic strength and ɣRv: Strength factor.

Table 1. Strength Factor for Shallow Foundations

Strength Type	Strength factor Symbol	Strength factor Value
Foundation Bearing Capacity	ɣRv	1.4

Bearing Capacity of Shallow Foundations;

when loading conditions including static and seismic effects are taken into account, the following equation will be considered as:

$$q_o \leq q_t \qquad (3)$$

q_o: Vertical load, shear and moment effects that cause foundation base pressure at the foundation level.
q_t: found by dividing the characteristic strength by the strength factor:

$$q_t = q_k / \gamma_{RV} \qquad (4)$$

Foundation bearing capacity characteristic strength will be found from the following equation.

$$q_k = c.N_c.s_c.d_c.i_c.g_c.b_c + q.N_q.s_q.d_q.i_q.g_q.b_q + 0.5\gamma.B^I.N\gamma.s\gamma.d\gamma.i\gamma.g\gamma.b\gamma \qquad (5)$$

$$N_q = e^{\pi tan\varphi'} \tan^2(45+\varphi'/2);\ N_c = (N_q - 1)\cot\varphi';\ N\gamma = 2(N_q - 1)\tan\varphi' \qquad (6)$$

Where;
Nq, Nc, Nɣ : Bearing capacity factors sc, sq, sɣ : Shape factors
dc, dq, dɣ : Depth factors ic, iq, iɣ : inclination factor
gc, gq, gɣ : Ground Factors (Base on slop bc, bq, bɣ : base factors (tilted base)

2.2. Plaxis Soil Modelling

Plaxis is a geotechnical engineering simulation software that can perform deformation analysis of soil and rock. The program can model finite element analysis, limit equilibrium, dynamics, transient groundwater flow and thermal applications with its different version. With Plaxis, soil structures can be designed, construction-excavation, topography, borehole and piezometer, and field applications can be visualized and optimized using geotechnical data. The necessary parameters are taken into account when modeling, and consolidation and safety analysis calculations are performed (Figure 3).

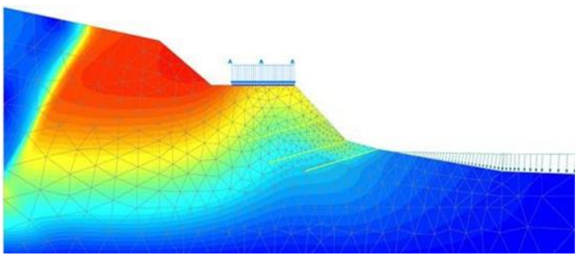


Figure 3. Example of Plaxis Modeling

2.3. Available Soil Data

2.3.1. Boring datas

A soil investigation was conducted by drilling 14 boreholes, each 20 meters deep and 280 meters in total. Standard Penetration Test (SPT) was conducted at 1.5 meter intervals to determine the consistency of the soil layers (Table 2).

Table 2. Coordinate and Depth Data in Boring

Boring No	Depth(m)	Grade(m)	Coordinate X	Coordinate Y
SK1	20	611	37.968542°	40.262508°
SK2	20	611	37.968734°	40.262395°
SK3	20	612	37.968891°	40.262289°
SK4	20	614	37.969075°	40.262207°
SK5	20	616	37.969249°	40.262115°
SK6	20	614	37.969192°	40.261835°
SK7	20	612	37.969023°	40.261899°
SK8	20	611	37.968835°	40.261972°
SK9	20	610	37.968656°	40.262020°
SK10	20	608	37.968479°	40.262058°
SK11	20	606	37.968454°	40.261755°
SK12	20	608	37.968634°	40.261716°
SK13	20	610	37.968835°	40.261694°
SK14	20	611	37.969016°	40.261660°

The dominant lithological units observed in the current site are a dark brown to red clay unit in the upper layers and as the depth increases, a sandy unit belonging to the Selmo Formation is observed.

2.3.2. Standard Penetration Tests (SPT)

SPT (Standard Penetration Test) is a geotechnical engineering test used to determine the strength and bearing capacity of soil. This test is performed to evaluate the resistance and compressibility of the soil. The SPT test is particularly used for estimating the bearing capacity of soil and for the design of building foundations.

On the current site, Standard Penetration Test (SPT) was conducted every 60 meters to determine the consistency or density of fine- and coarse-grained soils. The SPT test is conducted by driving a standard 2-inch diameter and 1 3/8-inch inside diameter sampler into the soil, by a 63.5 kg hammer falling freely from 76 cm height, for a total of 45 cm, in three equal 15 cm increments. The number of blows required to advance the sampler 15 cm is recorded as N-value. The first 15 cm of penetration is considered as the seating level and the last two 15 cm of penetration is combined and recorded as soil penetration strength (N-value).

The following table, which shows the empirical relationship between SPT-N and qu (one-axis pressure result in soils), has been used to classify the consistency class of cohesive soils.

According to Terzaghi and Peck (1948), the consistency of fine-grained soils was determined as very stiff and hard from Table 3.

Table 3. Standard Penetration Test (SPT) Boring Data

Boring No	SPT Depth(m)	15 cm	30 cm	45 cm	$SPTN_{30}$	Consistency	Lithology
SK1	1.50-1.95	10	7	8	15	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	11	8	9	17	Very stiff	
	4.50-4.95	12	12	13	25	Very stiff	
	6.00-6.45	13	13	14	27	Very stiff	
	7.50-7.95	14	15	15	30	Very stiff	
	9.00-9.45	14	15	16	31	Hard	
	10.50-10.95	16	17	18	35	Hard	
	12.00-12.45	17	18	20	38	Hard	
	13.50-13.95	20	21	21	42	Hard	
	15.00-15.45	20	21	22	43	Hard	
	16.50-16.95	21	22	22	44	Hard	
	18.00-18.45	22	23	22	45	Hard	
	19.50-19.95	22	24	24	48	Hard	
SK2	1.50-1.95	9	10	11	21	Very stiff	
	3.00-3.45	7	8	15	23	Very stiff	
	4.50-4.95	10	12	12	24	Very stiff	
	6.00-6.45	11	13	15	28	Very stiff	
	7.50-7.95	8	14	16	30	Very stiff	
	9.00-9.45	9	16	17	33	Hard	
	10.50-10.95	10	15	19	34	Hard	
	12.00-12.45	9	15	22	37	Hard	
	13.50-13.95	11	18	21	39	Hard	
	15.00-15.45	12	20	20	40	Hard	
	16.50-16.95	12	21	22	43	Hard	
	18.00-18.45	15	23	24	47	Hard	
	19.50-19.95	15	25	24	49	Hard	

SK3	1.50-1.95	7	8	10	18	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	8	9	10	19	Very stiff	
	4.50-4.95	9	11	12	23	Very stiff	
	6.00-6.45	11	13	14	27	Very stiff	
	7.50-7.95	13	15	19	34	Hard	
	9.00-9.45	15	17	19	36	Hard	
	10.50-10.95	16	18	20	38	Hard	
	12.00-12.45	17	19	20	39	Hard	
	13.50-13.95	20	21	21	42	Hard	
	15.00-15.45	20	21	22	43	Hard	
	16.50-16.95	21	22	23	45	Hard	
	18.00-18.45	22	23	24	47	Hard	
	19.50-19.95	23	24	24	48	Hard	
SK4	1.50-1.95	7	8	15	23	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	10	12	12	24	Very stiff	
	4.50-4.95	12	12	13	25	Very stiff	
	6.00-6.45	13	14	14	28	Very stiff	
	7.50-7.95	14	15	16	31	Hard	
	9.00-9.45	15	16	17	33	Hard	
	10.50-10.95	16	18	18	36	Hard	
	12.00-12.45	18	18	19	37	Hard	
	13.50-13.95	20	21	21	42	Hard	
	15.00-15.45	20	21	22	43	Hard	
	16.50-16.95	21	22	22	44	Hard	
	18.00-18.45	22	23	22	45	Hard	
	19.50-19.95	22	24	24	48	Hard	
SK5	1.50-1.95	7	8	9	17	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	8	10	12	22	Very stiff	
	4.50-4.95	9	12	14	26	Very stiff	
	6.00-6.45	9	12	15	27	Very stiff	
	7.50-7.95	11	13	15	28	Very stiff	
	9.00-9.45	12	15	15	30	Very stiff	
	10.50-10.95	14	16	17	33	Hard	
	12.00-12.45	17	18	19	37	Hard	
	13.50-13.95	19	20	21	41	Hard	
	15.00-15.45	18	20	22	42	Hard	
	16.50-16.95	20	22	23	45	Hard	
	18.00-18.45	20	23	25	48	Hard	
	19.50-19.95	22	25	25	50	Hard	
SK6	1.50-1.95	9	10	11	21	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	7	8	15	23	Very stiff	
	4.50-4.95	10	12	12	24	Very stiff	
	6.00-6.45	10	12	13	25	Very stiff	
	7.50-7.95	13	15	15	30	Very stiff	
	9.00-9.45	14	16	18	34	Hard	
	10.50-10.95	15	19	17	36	Hard	
	12.00-12.45	148	17	18	35	Hard	
	13.50-13.95	15	20	20	40	Hard	
	15.00-15.45	19	19	20	39	Hard	
	16.50-16.95	20	21	20	41	Hard	
	18.00-18.45	23	19	25	44	Hard	
	19.50-19.95	24	23	25	48	Hard	
SK7	1.50-1.95	10	12	14	26	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	12	13	14	27	Very stiff	
	4.50-4.95	13	15	14	29	Very stiff	

	6.00-6.45	15	14	16	30	Very stiff	
	7.50-7.95	17	18	18	36	Hard	
	9.00-9.45	19	20	21	41	Hard	
	10.50-10.95	20	22	26	48	Hard	
	12.00-12.45	15	17	18	35	Hard	
	13.50-13.95	16	17	23	40	Hard	
	15.00-15.45	17	20	22	42	Hard	
	16.50-16.95	20	20	21	41	Hard	
	18.00-18.45	20	21	22	43	Hard	
	19.50-19.95	21	22	23	45	Hard	
SK8	1.50-1.95	10	12	13	25	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	13	15	15	30	Very stiff	
	4.50-4.95	14	16	18	34	Hard	
	6.00-6.45	15	19	17	36	Hard	
	7.50-7.95	18	17	18	35	Hard	
	9.00-9.45	15	20	20	40	Hard	
	10.50-10.95	19	19	20	39	Hard	
	12.00-12.45	20	21	20	41	Hard	
	13.50-13.95	23	19	25	44	Hard	
	15.00-15.45	20	20	26	46	Hard	
	16.50-16.95	19	21	25	46	Hard	
	18.00-18.45	18	22	26	48	Hard	
	19.50-19.95	20	25	24	49	Hard	
SK9	1.50-1.95	8	9	10	19	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	10	11	12	23	Very stiff	
	4.50-4.95	12	12	12	24	Very stiff	
	6.00-6.45	11	13	12	25	Very stiff	
	7.50-7.95	10	12	13	25	Very stiff	
	9.00-9.45	12	13	15	28	Very stiff	
	10.50-10.95	13	15	16	31	Hard	
	12.00-12.45	15	16	17	33	Hard	
	13.50-13.95	18	19	20	39	Hard	
	15.00-15.45	20	21	23	44	Hard	
	16.50-16.95	20	23	23	46	Hard	
	18.00-18.45	22	24	24	48	Hard	
	19.50-19.95	23	24	26	50	Hard	
SK10	1.50-1.95	9	10	11	21	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	7	8	15	23	Very stiff	
	4.50-4.95	10	12	12	24	Very stiff	
	6.00-6.45	10	12	13	25	Very stiff	
	7.50-7.95	12	13	13	26	Very stiff	
	9.00-9.45	11	13	15	28	Very stiff	
	10.50-10.95	12	14	16	30	Very stiff	
	12.00-12.45	13	15	16	31	Hard	
	13.50-13.95	15	16	16	32	Hard	
	15.00-15.45	18	19	20	39	Hard	
	16.50-16.95	21	22	22	44	Hard	
	18.00-18.45	23	24	25	49	Hard	
	19.50-19.95	24	25	25	50	Hard	
SK11	1.50-1.95	9	10	11	21	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	7	8	15	23	Very stiff	
	4.50-4.95	10	12	12	24	Very stiff	
	6.00-6.45	12	12	13	25	Very stiff	
	7.50-7.95	12	12	13	25	Very stiff	
	9.00-9.45	11	11	12	23	Very stiff	
	10.50-10.95	14	15	15	30	Very stiff	
	12.00-12.45	18	18	20	38	Hard	

	13.50-13.95	20	22	23	45	Hard	
	15.00-15.45	22	23	24	47	Hard	
	16.50-16.95	23	24	24	48	Hard	
	18.00-18.45	22	24	25	49	Hard	
	19.50-19.95	20	25	25	50	Hard	
SK12	1.50-1.95	8	9	10	19	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	10	11	12	23	Very stiff	
	4.50-4.95	10	12	12	24	Very stiff	
	6.00-6.45	12	14	12	26	Very stiff	
	7.50-7.95	11	13	15	28	Very stiff	
	9.00-9.45	12	15	15	30	Very stiff	
	10.50-10.95	14	15	17	32	Hard	
	12.00-12.45	15	16	17	33	Hard	
	13.50-13.95	18	19	20	39	Hard	
	15.00-15.45	18	19	22	41	Hard	
	16.50-16.95	20	20	21	41	Hard	
	18.00-18.45	20	21	22	43	Hard	
	19.50-19.95	21	22	23	45	Hard	
SK13	1.50-1.95	11	13	14	27	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	13	15	18	33	Hard	
	4.50-4.95	16	17	18	35	Hard	
	6.00-6.45	18	18	19	37	Hard	
	7.50-7.95	19	20	20	40	Hard	
	9.00-9.45	20	21	21	42	Hard	
	10.50-10.95	17	20	23	43	Hard	
	12.00-12.45	19	21	24	45	Hard	
	13.50-13.95	21	22	25	47	Hard	
	15.00-15.45	22	23	27	50	Hard	
	16.50-16.95	22	23	23	46	Hard	
	18.00-18.45	22	24	24	48	Hard	
	19.50-19.95	23	25	25	50	Hard	
SK14	1.50-1.95	12	13	14	27	Very stiff	Dark brown reddish clay/gravelly sand
	3.00-3.45	13	14	14	28	Very stiff	
	4.50-4.95	14	15	15	30	Very stiff	
	6.00-6.45	15	16	17	33	Hard	
	7.50-7.95	16	16	18	34	Hard	
	9.00-9.45	18	20	20	40	Hard	
	10.50-10.95	21	22	23	45	Hard	
	12.00-12.45	20	21	23	44	Hard	
	13.50-13.95	22	23	24	47	Hard	
	15.00-15.45	22	23	23	46	Hard	
	16.50-16.95	20	21	24	45	Hard	
	18.00-18.45	22	23	24	47	Hard	
	19.50-19.95	24	25	25	50	Hard	

2.3.3. Mechanical properties of soil

Dark brown reddish clay and gravel units have been observed in the area under investigation. Natural density, water content, consistency limits (Liquid Limit, Plastic Limit, Plasticity Index), soil class, etc. of the soil were determined by performing grain size distribution (Sieve Analysis) on soil samples taken from boreholes both disturbed (SPT) and undisturbed (UD), triaxial compression test, consolidation and direct shear test (Table 4).

Table 4. Laboratory Test Results

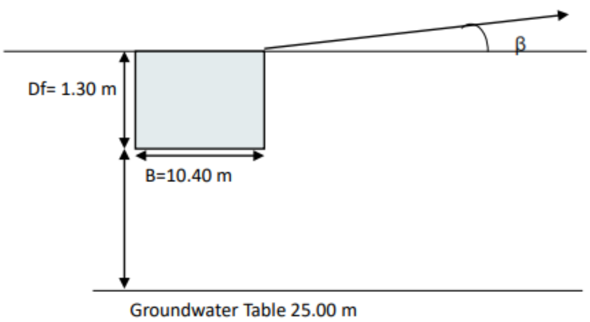
Boring No	Sample No	Depth (m)		Natural density	Triaxial Compression Test(UU) C (kgf/cm^2)	φ (o)	Consolidation Percentage of Swelling	Swelling Pressure (kgf/cm)	Sieve Analysis No:4 Retained (%)	No:200 Passing (%)	Atterberg Limits LL (%)	PL (%)	PI (%)	Soil Class
SK1	UD	1.00	23.25	1.78	0.56	6			4.17	61.96	55.6	22.1	33.5	CH
SK1	SPT	4.50	14.23						32.18	30.14	40.1	20.2	19.9	SC
SK2	UD	2.00	20.54	1.78	0.52	6			0	75.57	59.2	23.2	36	CH
SK2	SPT	6.00	11.5						17.56	28.87	34.6	18.5	16.1	SC
SK3	UD	1.50	22.29	1.74	0.60	5	2.20	0.198	2.23	73.03	57	19.4	37.6	CH
SK3	SPT	3.00	16.34						19.09	45.16	41.2	18.2	23	SC
SK4	UD	2.00	23.76	1.79	0.55	5			4.1	55.16	54.6	20.5	34.1	CH
SK4	SPT	4.50	12.21						16.2	35.02	36.5	21.2	15.3	SC
SK5	UD	1.50	28.74	1.77	0.57	6			4.17	73.42	53.6	20.3	33.3	CH
SK5	SPT	4.50	14.17						17.41	33.6	42.6	21.5	21.1	SC
SK6	UD	2.00	16.43	1.76	0.56	7			2.26	70.54	59.9	25.5	34.4	CH
SK6	SPT	4.50	6.53						10.14	24.71	39.6	23.2	16.4	SC
SK7	UD	1.50	18.35	1.72	0.54	5			0	70.7	60.2	27.5	32.7	CH
SK7	SPT	6.00	13.98						13.52	28.88	45.5	24.3	21.2	SC
SK8	UD	1.00	21.23	1.80	0.54	5			1.43	53.06	57.5	24.6	32.9	CH
SK8	SPT	4.50	14.28						19.82	36.73	48.3	26	22.3	SC
SK9	UD	1.00	20.96	1.79	0.53	6			6.62	69.98	58.8	24.1	34.7	CH
SK9	SPT	6.00	12.2						17.77	45.17	29.6	25.3	14.3	SC
SK10	UD	2.00	27.56	1.80	0.58	6			2.03	60.75	59.6	27.5	32.1	CH
SK10	SPT	3.00	16.43						20.21	44.05	33.5	20.5	13	SC
SK11	UD	1.00	23.54	1.72	0.56	5	2.47	0.245	1.45	62.26	56.6	23.4	33.2	CH
SK11	SPT	4.50	14.22						16.63	36.98	37.4	18.5	18.9	SC
SK12	UD	1.00	20.76	1.75	0.60	5			1.37	61.41	59.2	19.9	39.3	CH
SK12	SPT	6.00	14.06						10.35	26.02	40.3	22	18.3	SC
SK13	UD	1.00	22.02	1.77	0.57	5			1.22	58.23	54.2	21.6	32.6	CH
SK13	SPT	4.50	13.34						12.76	27.54	38.8	19.5	19.3	SC
SK14	UD	1.00	27.92	1.69	0.54	7			1.06	70.15	53.3	19.6	33.7	CH
SK14	SPT	4.50	11.45						14.98	33.01	39.6	20.2	19.4	SC

The average value for the undrained shear strength and the internal friction angle was taken from the samples taken from the boreholes as a result of laboratory and field tests;

$$C_u = 55 \text{ kPa} \quad \varphi = 5\,0 \qquad (7)$$

2.3.4. Bearing Capacity Analysis

Turkey Building Earthquake Regulation;



Cohesion Cu = 55 kPa Angle of Internal Friction φ = 5 0
Width of Foundation B = 10.40 m
Length of Foundation L = 12.90 m
Depth of Foundation Df = 1.30 m
Ground Water Table Dw = 25 m
Angle of soil with horizontal β = 0
Angle of base with horizontal η = 0
Natural unit Weight ɣN = 16 kPa
Saturated unit weight ɣsat = 20 kPa
Df= 1.30 mβ   B=10.40 m
Groundwater Table 25.00 m
Unit Weight of water ɣw = 9.81 kPa Strength Factor ɣRv = 1.4
Effective unit weight ɣl = 16 kPa
Bearing capacity factors; (Meyerhof) inclination factor; (Meyerhof)
Nq = tan2
(45+φ/2) = 1.57 İc = [1- (β/90)]2 = 1.00
Nc = (Nq – 1)cotφ = 6.54 İq = İc = 1.00
Nɣ = 2(Nq – 1)tanφ = 0.45 İɣ = [1- (β/φ)]2 = 1.00
Shape factors ;(De Beer,1970) Ground Factors (Base on slope);(Vesic)
Sc = 1+[(B/L)*(Nq/Nc)] = 1.19 gc = β/147 = 1.00 (φ = 0 icin)
Sq = 1+[(B/L)*tanφ] = 1.07 gc = [1- (β/147)] =1.00 (for φ 0)
Sɣ = 1-[(B/L)*0.4] = 0.68 gɣ = gq = [1- (tan β)2] = 1.00

Depth Factor;(Hansen)
dc = 1+[0.4*(D/B)]= 1.05 (for D/B 1)
dc = 1+[0.4*atan(D/B)] = 1.05 (for D/B 1)
dq = 1+[2*(tanφ)]*[(1-sinφ)2]*[(D/B)] = 1.02 (for D/B 1)
dq = 1+[2*(tanφ)]*[(1-sinφ)2]*[atan(D/B)] = 1.17 (for D/B 1) dɣ = 1.00
base factors (tilted base);(Vesic)
bc = η/147 = 1.00 (φ = 0 icin) bc = 1-(η/147) = 1.00 (for φ 0)
bɣ = bq = [1-(η*tanφ)/57)]2 = 1.00
Surcharge load (ql) for Dw B+Df; ql = (Df* ɣn) = 20.8 kPa
qk = (c.Nc.sc.dc.ic.gc.bc) + (ql.Nq.sq.dq.iq.gq.bq)+ (0.5ɣ.B.l.Nɣ.sɣ.dɣ.iɣ.gɣ.bɣ)
qk = (55*6.54*1.19*1.05*1.00*1.00*1.00) + (20.8*1.57*1.07*1.02*1.00*1.00*1.00) + (0.5*16*10.40*0.45*0.68*1.00*1.00*1.00)
qk = 511.54 kPa
qt = qk / ɣRv = 511.54/1.4 = 365.39 kPa

According to the Turkish Building Earthquake Regulation (TBDY), the design strength of the foundation bearing capacity was found to be 365.39 kPa.

The soil was modeled by transferring the values of parameters such as cohesion cu, internal friction angle φ, natural unit weight ɣ natural, saturated unit weight ɣ saturated to Plaxis 2D program from the samples in the existing field and the data obtained from the laboratory and field conditions. Thus, the final bearing capacity analysis of the existing land has been made (Figure 4-7).

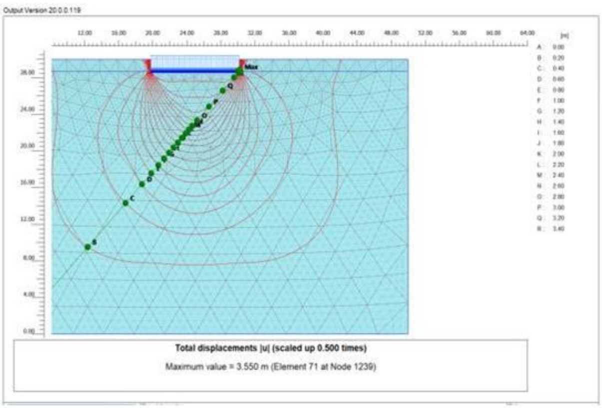


Figure 4. Plaxis 2D Soil Modelling and Displacements

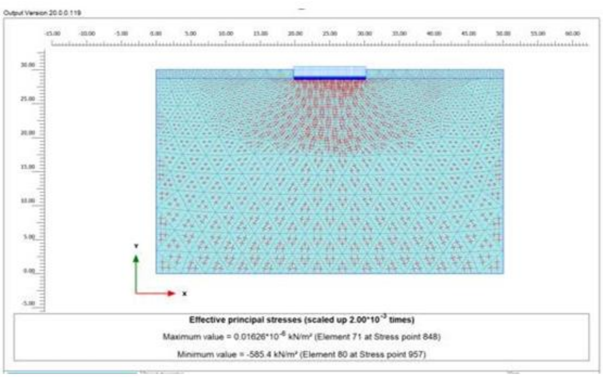


Figure 5. Plaxis 2D Effective Principal Stresses

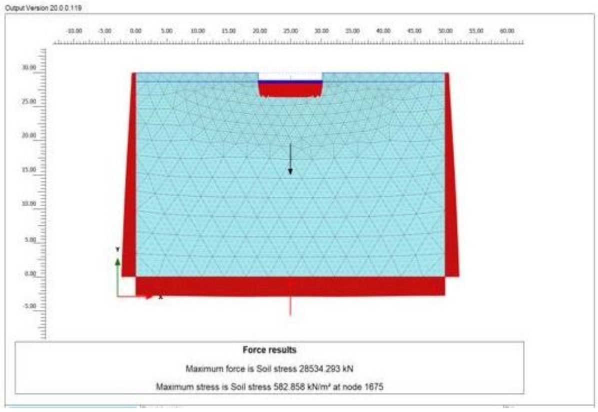


Figure 6. Plaxis 2D Soil Stress Values

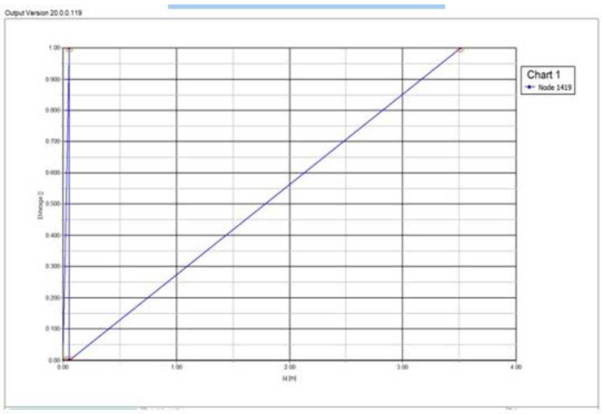


Figure 7. Total Displacement Curve at Soil

With the Plaxis 2D modeling program, the design strength of the foundation bearing capacity was found to be 457.2 kPa.

3. RESULTS

Within the scope of this study, field and laboratory tests were conducted in Diyarbakır City, Sur County, Yukarıkılıctası District, block no. 7018, parcel 1, and a soil investigation report was created. Additionally, previous studies on the engineering geology of the soil in the Karacadag region examined the basaltic lava flows outcropping the soil and the high plasticity clay with swelling properties (CH) by considering the soil class (Karakaya et al., 2022; Çetin & Acar, 2023). According to the soil investigation data report, it was observed that the soil cover on the basalt unit in the investigation area is composed of high plasticity clays in some places. The dominant lithology in the region was found to be dark brownish-red clay/gravelly sand, and the consistency of fine-grained soils was very stiff and hard.

It was noted that the high plasticity clay soil experiences swelling and shrinkage due to seasonal changes. These volumetric changes in the soil can lead to instability, causing differential settlements that may result in structural issues and financial challenges. To mitigate these effects, the use of geosynthetic clay liners (GCLs) with high tensile strength is recommended. These liners provide durability against cracking caused by freezing and thawing. Additionally, GCLs serve as effective hydraulic barriers, making them a low-cost solution for improving soil strength and preventing changes in soil water content (Aksu & Yılmaz, 2021; Kaya et al., 2021).

During the calculation of bearing capacity, the stress value necessary to prevent sliding displacement of the foundation soil was determined. The undrained shear strength and internal friction angle, which affect the ultimate bearing capacity in the study area, were measured. Using these parameters and the calculation method outlined in the Turkish Building Earthquake Regulation, the design bearing capacity was calculated. Furthermore, the soil was modeled in the Plaxis 2D software using the parameters obtained from field and laboratory tests. The program helped determine the stress value for the ultimate bearing capacity. The values of the soil's bearing capacity design strength in the study area, as determined by both the Turkish Building Earthquake Regulation and Plaxis 2D, are shown in Table 5.

Table 5. Ultimate Bearing Capacity Design Strength

	TBDY	PLAXIS 2D
Ultimate Bearing Capacity Design Strength	365.39	457.20

When the bearing capacity design strength obtained from the Turkish Building Earthquake Regulation is taken as a reference, a 25.13% difference is observed between the design strength obtained through the Plaxis 2D program.

One reason for this significant percentage difference is that the design strength is determined by dividing the characteristic strength value found in TBDY with the strength factor. The bearing capacity found in Plaxis 2D is determined to be 326.57 kPa by performing this calculation with 457.20/1.4= 326.57 kPa.
457.20-365.39=91.81

$$25.13=(91.81x100)/(365.39)$$

The reason for this significant percentage difference is that the design strength is determined by dividing the characteristic strength value found in the Turkish Building Earthquake Regulation by the strength factor. When this calculation is performed for the bearing capacity found in Plaxis 2D, it is determined to be 326.57 kPa, thus, a lower percentage difference is considered.

4. DISCUSSION AND CONCLUSION

Based on the comprehensive analyses and evaluations conducted in this study, the final bearing strength value was determined, leading to the conclusion that calculations based on the Turkish Building Earthquake Regulation (TBDY) should be prioritized to ensure optimum design strength and structural safety. The TBDY norms specify how structures should respond under earthquake and other dynamic loads, aiming to achieve the highest safety standards. Thus, performing bearing capacity calculations in line with TBDY standards is crucial for maintaining the strength and durability of buildings (Çetin & Acar, 2023; Kaya et al., 2021).

In this study, the most appropriate approach was found to be evaluating the design bearing capacity at 365.39 kPa, which represents the critical bearing strength value. It is essential that any structure to be constructed in the study area is designed according to this value to ensure both stability and compliance with engineering standards. The results emphasize the importance of aligning structural design with TBDY guidelines, as these not only enhance the safety of the structure but also ensure that the design meets established engineering practices (Aksu & Yılmaz, 2021; Karakaya et al., 2022). Therefore, it is strongly recommended that bearing capacity calculations be based on TBDY standards, as they form the fundamental framework for safe and reliable structural design.

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