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BEARING CAPACITY OF SOILS IN THE CITY CENTER OF BARTIN

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Abstract

Due to economical problems, the population of the cities has been dramatically increased in recent years. It causes distorted and uncontrolled construction developments. In addition, limited amount of suitable construction site compels the constructors to increase the height of the superstructures. Working loads of multistory-constructions reach up to considerable high values and lead to excessive pressure underneath the foundation system and settlement problems. Therefore, before designing the foundation systems of the constructions, bearing capacity of the foundation soils should be estimated precisely, and considering the bearing capacity of the soils, convenient foundation system, tolerating the working loads, must be chosen. It is very important to obtain engineering properties of the foundation soils with conducting a comprehensive geotechnical investigation and to realistically clarify any challenging or difficulties in the foundation soils. In this study, soil samples from total eleven different locations in the city center of Bartın were obtained to represent all soil types of the city center and then the numbers of the soil samples were reduced to five by means of eleven soil samples classified. Engineering properties of the soils were assessed by extensive laboratory experiments and allowable bearing capacities of the soils were calculated for different types of shallow foundation systems. The allowable bearing capacity values of the soils vary between 147 and 882 kPa. The factors causing big range difference between the highest and the lowest values are discussed and some of the critical points to take into account in the calculation of the bearing capacity are presented.

Key Words: Shallow Foundations, Allowable Bearing Capacity, Silty Sand, Bartın

1. Introduction

The goals of geotechnical and foundation investigations, which are crucially essential for residential areas, urban planning and structural design, are specified as determining the bearing capacity and settlement; planning soil stabilization studies; and deciding upon a new construction site selection if a current site has problematic soil strata. In order to clarify all foundation problems it is also important to be realistically aware of the engineering properties of soil layers under the foundation system of structures by means of geotechnical and foundation investigations. Due to insufficient knowledge of ground-conditions and differences between the investigation techniques using various assumptions have role in construction cost and stability. Until 1999s catastrophic Marmara Earthquake, new development residential areas were established without doing any geotechnical investigations and high-rise buildings were constructed with no technical inspection whatsoever. After the earthquake, it was observed that buildings were collapsed or were seriously damaged although they were built in accordance with Turkish standards but the soils beneath the foundations were not taken into consideration. Therefore a new construction supervising regulation (dated 13 July 2001 and numbered 4708) was approved in the parliament. The construction supervising regulation is especially valid for metropolitans and is at the beginning stage in small or newly developed cities such as Bartın that grew to be a city in 1991.

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Since Bartın, located in the western part of the Black Sea region, is in the first-degree seismic zone and its residential area only occupies 7% of the total acreage that is expected to expand with newly flourishing urbanization, the bearing capacity of soils in the city center of Bartın are examined. In this research, the general characteristics of Bartın and the geology of new residential areas are introduced. Samples from different formations in the area were collected and were subjected to some experiments in the soil mechanics laboratories. Allowable bearing capacities of the soils for different foundation types and sizes determined via laboratory experiments and the results were also interpreted.

2. Study Area

2.1 General Characteristics

Bartın is located in Western Black Sea Region, between 41° 53' northern latitude and 32° 45' eastern longitude; and between E-28, E-29 and F-28 and F-29 map section and has 2143 km² acreage. The city is surrounded by Zonguldak on the west, Kastamonu on the east and Karabük on the south; Bartın has a Black Sea shore line of 59 km on the north coast. The border coordinates of Bartın city are given in Table 1 [1]. The average elevation is 25 m in Bartın. The sea-cliffs along to shore line have higher elevation (higher than 25 m) compare to the elevation of interior region (less than 25 m) and it also demonstrates the characteristics of mild pen plane topography towards the interior region.. Throughout the region the mountains are parallel to the sea. In Bartın, which is surrounded by mountains on the east and west, the mountains are steep and the shores are stiff and rugged. A site location map of the investigation area is in Figure 1 [1].

Table 1. Bartın city border coordinates [1]

Border Points	North Latitude	East Longitude
East: Ulus-Kerpiçli Village	41º 44'	32º 54'
West: Büyük Kızılkum-Kapan Cape	41º 35'	32º 06'
North: Kurucaşile-Kapısuyu Village	41º 53'	32º 45'
South: Center-Günye Gerişli Village	41º 20'	32º 23'

In Bartın (total population 182311), there are 4 districts including the Center, Amasra, Kurucaşile, Ulus, and 268 villages. The population of Bartın's Center district--where the study area is located--is 47082, the urban population of all districts is 58788 and the total rural population is 123523 [2]. In Bartın, the widest agriculture products are fodder crops and grain, which are followed by fruits and vegetables [1]. Amasra Coal Mine is the only mine producing company within Bartın city center. Besides, in Tarlaağzı, there is a fire-clay mine and quartz sand is processed in the Başköy region of Kurucaşile. In addition, there are numerous operating sand-gravel quarries [2]. In Bartın, the typical Black sea climate can be seen. It has a mild winter and a fairly warm summer.

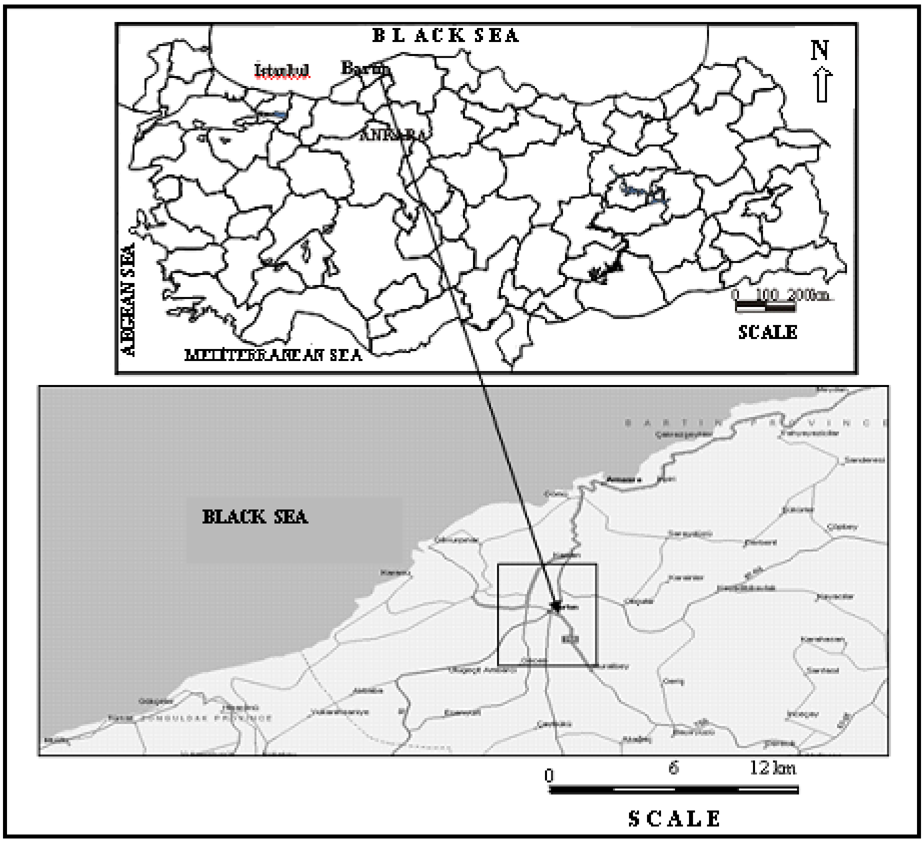

Figure 1. Location map of study area [1]

Its location near the sea and the low mountain ranges, parallel to shore, result in minimizing temperature variations on the shore, rising humidity and the influence of air masses from the Balkans. Bartin city gets twice as much precipitation as the annual average of Turkey. The annual precipitation of Bartin is 1000 mm^3 in the center area and 1200 mm^3 in the higher regions. Relative humidity is 80%. Winds blow from southeast and northwest with an average speed of 2.4 m/s [1]. In Bartın, the hottest month is July with an average of 21.9 °C, the coldest month is January with an average of 4.2°C. The number of total clear, sunny days is 225, the number of rainy days is 125 and the number of snowy days is 15 [3]. Out of a total acreage of 2143 km^2, forests cover 46%, agricultural areas cover 35%, meadows and pastures cover 7%, uncultivated areas and settlements cover 12% [4] (Figure 2). The existing settlement area which constitutes 7% of total acreage is enlarging and new constructions are seen.

2.2 Geology

The following are the lithological units in the area from bottom to top: Yemişliçay, Akveren and Çaycuma Formations with alluvium (Figure 3, Figure 4). Yemişliçay Formation is generally represented with a thin to medium layered volcanogenic sandstone, grayish green, thin to medium layered shale and sandstone intercalation, tuff, tuffite at lower layers, beige and a red-pinkish thin mid layered pelagic and semi pelagic clayey limestone at medium layers and brown and dark gray agglomerates at upper layers. The age of the unit is Upper Cretaceous. Akveren Formation is in the garb of white and beige, sometimes a red-pinkish, thin to medium layered (pelagic, semi pelagic) clayey limestone and grayish green shale intercalation at lower layers [6].

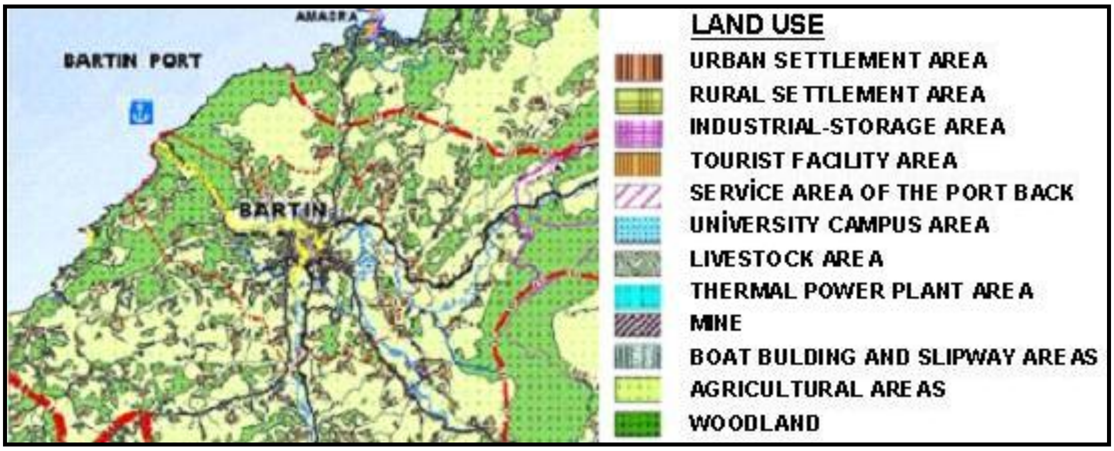

Figure 2. The existing land use in Bartın and surrounding area [5]

This layer comprises of turbid limestone, sandstone and shale intercalation. Towards upper layers it transforms into grayish green, in some parts pink, thin mid layered shale with sandstone in mid level, marl, and sandstone. The unit is made up of sandy carbonate at the bottom, clayey limestone, mudstone, marl, turbidity and ebonite towards the top. The age of the unit is Upper Campanian–Lower Eocene. Çaycuma Formation comprises of sandstone with volcanic intermediate level, siltstone, claystone, shale intercalation. Sandstone is yellowish, with a light green, thin mid layer; in some convolute layered levels it is observed to have intermediate thick layers. The age of Çaycuma Formation is Lower-Middle Eocene. Quarternary aged alluvium formations are gravel, sand, mud sediments in plain areas that are shaped on streambeds, old grabens. Different materials like clay, alluvion, silt, sand, gravel and blocks are laid on streambeds depending on stream current [6].

THEM	System	Series	Formation	Unit	Thickness(m)	Symbol	Lithology	Explanation
Cenozoic	Quaternary					Qal		Alluvium Sand, gravel
Cenozoic	Tertiary – Paleogene – Eocene	Middle Lower	Çaycuma	Kaynarca Unit	350	Teç, Teçk	Teçk	Teç: Sandstone, shale, conglomerate Teçk: Limestone, marl
Cenozoic / Mesozoic	Tertiary – Paleogene – Paleocene / Cretaceous	Upper	Akveren	Çangaza Volcanic Unit	350-400	KTa, KTaç	KTaç	KTa: Semi pelagic limestone, shale, sandstone, conglomerate KTaç: Basalt, andesite
Mesozoic	Cretaceous	Upper	Yemişliçay	Kapanboğazı Unit	100–200	Ky, Kyk	Kyk	Ky: Sandstone, tuff, agglomerate, andesite, basalt Kyk: Pelagic-semi pelagic limestone

Figure 3. Stratigraphic columnar section of the study area (not to scale) [6]

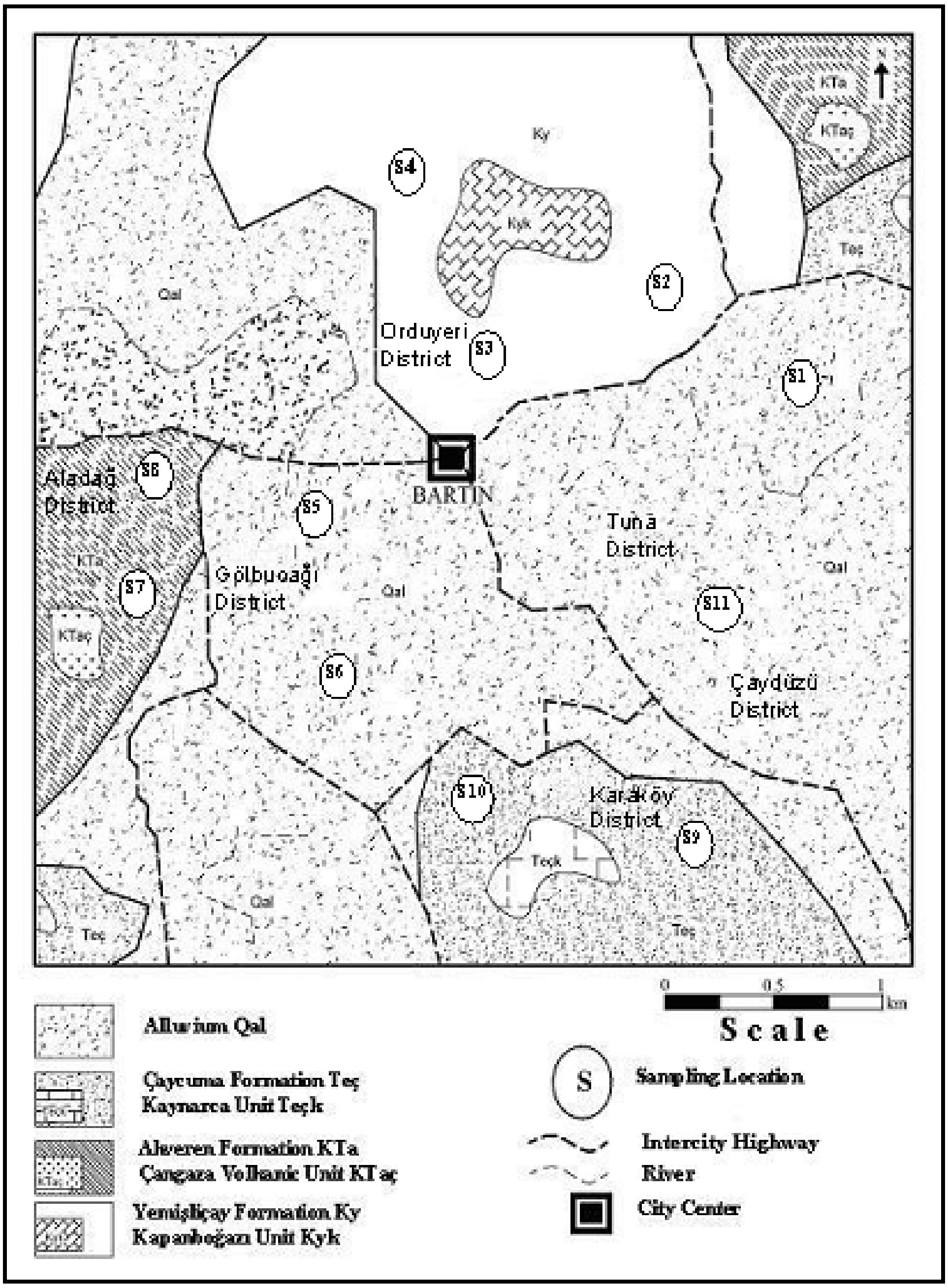

Figure 4. The geological map [6] and sampling location of study area

There are small scale normal fault lines having net slip between 40-50 cm at claystone and sandy claystone levels in Çaycuma Formation. At Akveren Formation border, a vertical fault line lies on NE-SW direction in Boğazköy and surrounding area; and in Kirsinler and surrounding area there are fault lines lying on W-E direction in the area surrounding Keçideresi; and lying on SW-NE direction with vertical discharge in Körler and its surrounding area and within Akveren Formation [4].

Bartın is 132 km away at air line distance from North Anatolia Fault. Most of the seismic activities that occurred during the last half a century in North Anatolia are related with the North Anatolia Fault and this fault is described as an active strike-slip and right directed. Bartın is in a First Degree Seismic Zone on Turkey's earthquake map [7]. The most devastating earthquake that occurred in the region was the 6.1 magnitude one in 1968 but there is no satisfactory information about recurrence interval.

Research has been conducted in order to reveal the basic geological characteristics and to designate the direction towards which the city can develop without being exposed to natural disasters and without harming the environment [8]. According to this research, the geological formations in and around Bartın are divided into two groups for settlement. The first group is all of the lithological units except for alluvium. The second group is alluvium that covers huge areas in Bartın and its surrounding area. The lithological units are divided into two groups. Akveren, Atbaşı and Kusuri Formations are generally known to provide a firm foundation because of their high bearing capacity but due to their clayish structure they are prone to mass movements and they have problems such as swelling and heaving. In the units other than these formations no natural instability or mass movement occurred. These units have a high bearing capacity and they serve as flawless foundations. Alluvium is made up of loose gravel, sand, silt and clay. It contains high levels of ground water. Therefore it forms a soil type with a low bearing capacity and high liquefaction risk. The only unit in Bartın and the surrounding area which is problematic in terms of ground water is alluvium. Sometimes groundwater level in alluvium reaches surface level and it generally is a few meters above the surface. Bartın city is to a large extent built on the alluvium formed by Bartın River and its tributaries. The bearing capacity of alluvium, which is in itself low, decreased because of high groundwater levels and consequently it became risky ground. The geological factors that limit settlement are the physical and mechanic conditions of the rock or the soil on which settlement areas are built, groundwater level, mass movements, stability, seismicity, and the soil reaction to earthquake. Bartın has a limited and risky area for settlement in terms of seismicity, flood, topography, and forest [8].

3. Sampling and Laboratory Experiments

A total of 11 soil samples were taken from Yemişliçay, Akveren, Çaycuma Formations and alluvium according to TS 1900 Standard so as to represent the soil characteristics of the study area. Samples were put in plastic bags, labeled and their locations (S1-S11) on a geology map are marked (Figure 4). The physical properties of soil samples were obtained at Zonguldak Karaelmas University Geology Engineering Laboratory. The soil samples are classified by using the Unified Soil Classification System (USCS). It was observed that there are four different geologic formations surfacing in this study area. Because of that, all 11 soil sample locations were reduced to 4 groups as follows: Yemişliçay (S3), Akveren (S7), and Çaycuma (S10) Formations taking the surfacing areas of formations into consideration; and alluvium (S5 and S11). However, alluvium units have larger surface area and they are considered as a risky soil for foundations stability therefore the units are divided into 2 individual groups. Eventually, five soil groups were subjected to the compaction, direct shear test, and consolidation tests in the soil mechanics laboratory of the Civil Engineering Department at Middle East Technical University. The tests were conducted according to TS 1900 Standards [9, 10] and the soil parameters necessary for allowable bearing capacity calculations were detected (Table 2).

Table 2. Index and strength parameters of investigation soils

Sample No	Formation	USCS	w_{opt} (%)	γ_d (kN/m^3)	γ_n (kN/m^3)	c' (kPa)	ϕ' (°)	m_v m^2/kN	E≈1/m_v kPa	μ
S1	Alluvium	SP-SM	-							
S2	Yemişliçay	SP-SM	-							
S3	Yemişliçay	SP-SM	21.0	16.26	19.81	85	23	2.68E-04	3730.04	0.3
S4	Yemişliçay	SW-SM	-							
S5	Alluvium	SW-SM	18.0	16.50	19.46	99	20	4.69E-04	2132.61	0.3
S6	Alluvium	SW-SM	-							
S7	Akveren	SP-SM	20.2	16.31	19.62	78	32	2.74E-04	3646.84	0.3
S8	Akveren	SP-SM	-							
S9	Çaycuma	SW-SM	-							
S10	Çaycuma	SP-SM	26.5	14.88	18.82	56	38	2.49E-04	4020.49	0.3
S11	Alluvium	SP-SM	21.9	15.70	19.15	128	19	3.88E-04	2574.80	0.3

As seen in Table 2, all soil samples are sand and silty sand. According to USCS, soil samples fall into well graded silty sand (SW-SM) to poorly graded silty sand (SP-SM). Soil samples were reconstituted in the laboratory according to compaction tests because of their low cohesions and granular structures. Obtained three individually samples from each soil formation were tested in direct shear test under 100, 150, 200 kPa normal pressures. The cohesion (c') and internal friction angles (ϕ') which are dislocation endurance parameters of samples were investigated. Later, one dimensional consolidation (odometer) tests were conducted on the reconstituted soil samples having unit weight. In consolidation experiments, samples were loaded under 25, 50, 100, 200, 400, 800, 1600 kPa and the compressibility (m_v) parameters were determined.

In this study, the foundation depth is accepted to be 1.0 m. As a result, pressures under foundation system are between 0-25 kPa so m_v values within this range were used. The elastic module (E) values of the soil samples which were necessary for compressibility coefficient used for calculating bearing capacity of foundation are derived from m_v values. Taking previous studies into consideration, Poisson ratios (μ) of soil samples are assumed as 0.3 for silty sand soils [11, 12, 13].

4. Bearing Capacity

In this study, the bearing capacity values for foundation types which are classified as shallow foundations; square (B=L), rectangle (L>B) and continuous type (L>>B) shallow foundation systems were considered. According to the shallow foundation definition the ratio (D_f/B) of foundation system width (B) and foundation depth (D_f) must be more than 0 and less than 2 [12, 13, 14, 15, 16] as seen in Figure 5. An ultimate bearing capacity (q_u) of a shallow foundation system is given in Equation (1) by Meyerhof [17].

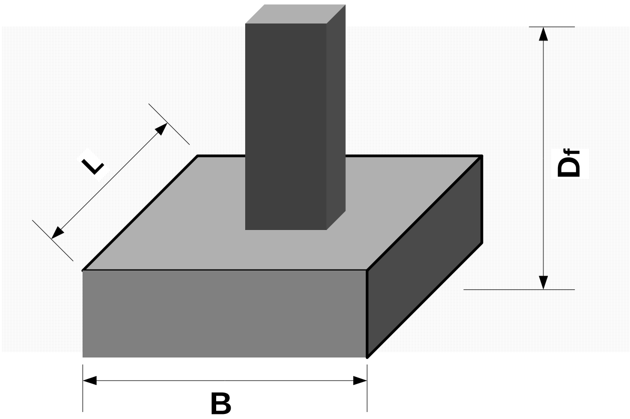

Figure 5. Single dimensioning of shallow foundation

$$q_u = c' N_c F_{cs} F_{cd} F_{ci} F_{cc} + q N_q F_{qs} F_{qd} F_{qi} F_{qc} + \frac{1}{2}\gamma B N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i} F_{\gamma c} \quad (1)$$

If c' is the cohesion of foundation soil, q (γ D_f) is surcharge load, γ is the unit volume weight of the soil beneath the foundation, here Nc, Nq, Ny are bearing strength coefficients defined by Vesic (1973). As seen in Equation (2) they are functions of ϕ' which is internal friction angle [18].

$$\left.\begin{cases} N_q = \tan^2(45 + \frac{\phi'}{2}) e^{\pi \tan\phi'} \\ N_c = (N_q - 1)\cot\phi' \\ N_\gamma = 2(N_q + 1)\tan\phi' \end{cases}\right\} \text{Bearing Capacity Factors} \quad (2)$$

The influence of foundation size on the bearing capacity of a foundation is proven by many researchers. As a result, shape factors are added to general bearing capacity. In this study, the shape factors offered by De Beer (1970) and given in Equation (3) are used [19]. L given in the equation is the length of long edge of the foundation (Figure 5). F_{cs}, F_{qs}, $F_{\gamma s}$ are foundation shape factors that vary according to foundation type. They are valid for square and rectangle foundation shapes. These values are taken as $F_{cs}=F_{qs}=F_{\gamma s}=1$ for continuous foundations or strip foundations classified as retaining wall foundation systems.

$$\left\{\begin{array}{l} F_{cs} = 1 + (\frac{B}{L})(\frac{N_q}{N_c}) \\ F_{qs} = 1 + (\frac{B}{L})\tan\phi' \\ F_{\gamma s} = 1 - 0,4(\frac{B}{L}) \end{array}\right\} \text{Shape Factors} \quad (3)$$

The depth of a shallow foundation system (D_f) must be at least 75cm-1m taking frost action depth into consideration. The deeper the foundation system is located the higher the bearing capacity values to be achieved. In this study, the bearing capacities of foundation systems are calculated for varying foundation sizes; with a minimum 1.0 m foundation depth (B) and 1.25, 1.5, 1.75, 2.0, 2.25, 2.5 and 3.0 m. The aim of calculating allowable bearing capacities for different B values is to give standard to foundations of structures to be built in the future. Construction companies that work for designing in the region can select a suitable foundation system (square, rectangle or continuous sectioned) and size; then they can chose an appropriate allowable bearing capacity from the graphics visualized from the bearing capacity calculations.

Consequently B/L ratio is used as 1, 0.8, 0.6, 0.5 for each B value and as 0 for continuous foundation. F_{cs}, F_{qs}, $F_{\gamma s}$ values given in Equation (1) are depth factors that determine bearing capacity. Depth factors are defined differently $D_f/B \leq 1$ and $D_f/B>1$ by Hansen (1970) [20]. In this study D_f=1 m is stable and B varies between 1 and 3, so D_f/B is less than 1. Equation (4) are equations that are derived for situations when D_f/B is less than or equal to 1 [12, 13, 15].

$$\left\{\begin{array}{l} F_{cd} = 1 + 0,4\frac{D_f}{B} \\ F_{qd} = 1 + 2\tan\phi'(1-\sin\phi')^2\, 0,4\frac{D_f}{B} \\ F_{\gamma d} = 1 \end{array}\right\} \rightarrow \quad D_f \,/\, B \leq 1 \text{ Depth Factors} \quad (4)$$

In the study conducted by Meyerhof (1963) it is advised that inclined load factors in Equation (5) can be used when the load on the foundation has an inclined angle [17].

$$\left\{\begin{array}{l} F_{ci} = F_{qi} = (1 - \frac{\beta^\circ}{90^\circ})^2 \\ F_{\gamma i} = (1 - \frac{\beta}{\phi'})^2 \end{array}\right\} \text{Inclined Load Factors} \quad (5)$$

Where β angle shows the angular value of load vector that stands upon a foundation system in an inclined angle with vertical axis. In this study, it is thought that the vertical load of the structure will not have an oblique angle. In this case β=0°and the value of inclined load factors in Equation (5) is 1.

The ultimate bearing capacities of foundations systems were calculated numerically by assuming surface under the foundation has general shear failure. If foundation soil is loose coarse granular or soft cohesion fine, local shear failure under foundation system should be expected. So it is proposed in previous studies that some corrections must be made in calculations taking failure types into consideration [12, 13]. The effect of failure type on the compressibility of loose surface is given by Vesic (1973) in Equation (6) [18].

$$I_r = \frac{E_s}{2(1+\mu_s)(c' + q' \tan\phi')}, \quad q' = \gamma\,(D_f + \frac{B}{2})$$

$$I_{r(cr)} = \frac{1}{2}\exp\left(\left(3{,}3 - 0{,}45\frac{B}{L}\right)\cot\left(45 - \frac{\phi'}{2}\right)\right)$$

$$F_{\gamma c} = F_{qc} = \exp\left(\left(-4{,}4 + 0{,}6\frac{B}{L}\right)\tan\phi' + \left(\frac{(3{,}07\sin\phi')\,\mathrm{Log}(2I_r)}{1+\sin\phi'}\right)\right) \tag{6}$$

$$F_{cc} = F_{qc} - \frac{1 - F_{qc}}{N_q \tan\phi'} \leftrightarrow \phi' \rangle\ 0$$

Here, E_s and μ_s are elastic module and poisson ratio of soil beneath the foundation system. I_r is the stiffness index of the soil, and I_{cr} is critical rigidity index. If I_{cr} value is higher than I_r, F_{cc}, F_{qc} and $F_{\gamma c}$, compressibility factors, are calculated as in Equation (6) and they should be used in the ultimate bearing capacity Equation (1). If I_r value is higher than I_{cr}, then F_{cc}, F_{qc} and $F_{\gamma c}$ factors take the value 1 which means there are no effects from the failure types.

Lastly, from the ultimate bearing capacity (q_u), obtained from Equation (1), the surcharge load (q) is deducted, and this value is divided by the factor of safety (G_s) as in Equation (7); so an allowable bearing capacity value is obtained. Factor of safety may take values between 1-5. This factor of safety is affected by the importance of the structure factor, seismicity of the soil, proximity to the surface of the ground water table or highly changeable potential of ground water table according to the seasons. Considering Bartın being in the first degree earthquake zone and ground water level can be seasonally changeable especially in alluvium parts, the factor of safety value was chosen as 4.

$$q_a = \frac{q_u - q}{G_s} \tag{7}$$

In Table 3, for Yemişliçay Formation (S3) using Equation (1-7) the calculation of allowable bearing capacity values are given. The general expectation for ultimate bearing capacity of soils increases when the width of the foundation (B) increases. As seen in the Table 3, when B values increase ultimate bearing capacity (q_u) and allowable bearing capacity (q_a) decreases. Form factors, F_{cs}, F_{qd} values, are in direct proportion with B/L values, and in inverse proportion with $F_{\gamma s}$. Depth factors, F_{cd} and F_{qd}, as seen in Equation (4) are in inverse direction with B value. As base depth D_f is stable, when B values are increased F_{cd} and F_{qd} numerically decrease and bearing capacity values decrease. As $F_{\gamma d}$ factor is $D_f/B \leq 1$, is stable and has no effects on bearing capacity values.

As understood from Table 3, critical stiffness index of the soil (I_{cr}) is higher than its natural stiffness index so the soil of S3 has the possibility of fracture and stapling. Because of that, compressibility coefficients and general bearing capacity equation should be corrected. In this situation, although B values increase, depending B/L ratio, while basic system moving from square to strip, the values of $F_{\gamma c}$, F_{qc} and F_{cc} decrease as percentage. In this study, though the I_r values of examined grounds vary between 6.85 and 19.81, the I_{cr} values are calculated as 27.18–433.92.

For Yemişliçay Formation (S3), Akveren Formation (S7), Çaycuma Formation (S10) and Alluvium (S5, S11), numerical values and the width of allowable bearing capacity are given in Table 4-8, as graphic Figure 6-10.

The ratios of with to length of the foundations (B/L) were chosen zero to one. Observing Table 4 and Figure 6, the highest and the lowest allowable bearing capacities of S3 soil were calculated 559.04 (B/L= 1& B=1 m) kPa and 228.20 (Continues Foundation, B=3 m) kPa, respectively. For S5 soil sample, highest and lowest allowable bearing capacity values are calculated 380.70 (B/L ratio is 1 and B=1 m) kPa and 147.31 (continuous foundation, B=3 m) (Table 5 and Figure 7). For S7 soil, highest and lowest allowable bearing capacity values were determined 764.0 (B/L ratio is 1 and B=1 m) and 279.94 (continuous foundation, B=2.5 m) kPa (Table 6 and Figure 8), respectively. When the values for S10 soil are examined, the highest allowable value is found as 882.19 kPa and B=1 m and B/L ratio =1 square foundation. The lowest values is found as 302.79 kPa for B=1.75 in continuous foundation (Table 7 and Fig. 9). For the S11 soil sample, the highest and lowest allowable bearing capacity values are calculated as 446.53 (B/L ratio 1 and B=1 m) kPa and 168.28 (continuous foundation, B=3 m) kPa (Table 8 and Fig. 10).

Table 3. Allowable bearing capacity calculation steps of Yemişliçay Formation (S3)

B m	L m	D_f m	B/L	D_f/B	F_{cs}	F_{qs}	$F_{\gamma s}$	F_{cd}	F_{qd}	$F_{\gamma d}$	I_r	I_{cr}	$F_{\gamma c}$	F_{qc}	F_{cc}	q_u kPa	G_s	q_a kPa	Foundation Type
	1.00		1.00		1.48	1.42	0.60					37.07	0.71	0.71	0.63	2255.98		559.04	Square
	1.25		0.80		1.38	1.34	0.68					42.47	0.67	0.67	0.58	1972.39		488.14	Rectangular
1.00	1.67	1.00	0.60	1.00	1.29	1.25	0.76	1.40	1.32	1.00	14.70	48.65	0.64	0.64	0.54	1714.84	4.00	423.76	Rectangular
	2.00		0.50		1.24	1.21	0.80					52.07	0.62	0.62	0.52	1595.28		393.87	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.55	0.55	0.43	1081.48		265.42	Continuous
	1.25		1.00		1.48	1.42	0.60					37.07	0.70	0.70	0.62	2127.91		527.02	Square
	1.56		0.80		1.38	1.34	0.68					42.47	0.67	0.67	0.58	1862.40		460.65	Rectangular
1.25	2.08	1.00	0.60	0.80	1.29	1.25	0.76	1.32	1.25	1.00	14.54	48.65	0.64	0.64	0.54	1621.25	4.00	400.36	Rectangular
	2.50		0.50		1.24	1.21	0.80					52.07	0.62	0.62	0.52	1509.30		372.37	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.55	0.55	0.42	1028.15		252.08	Continuous
	1.50		1.00		1.48	1.42	0.60					37.07	0.70	0.70	0.62	2042.49		505.67	Square
	1.88		0.80		1.38	1.34	0.68					42.47	0.67	0.67	0.58	1789.55		442.43	Rectangular
1.50	2.50	1.00	0.60	0.67	1.29	1.25	0.76	1.27	1.21	1.00	14.39	48.65	0.63	0.63	0.53	1559.81	4.00	385.00	Rectangular
	3.00		0.50		1.24	1.21	0.80					52.07	0.62	0.62	0.51	1453.15		358.33	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.54	0.54	0.42	994.68		243.72	Continuous
	1.75		1.00		1.48	1.42	0.60					37.07	0.70	0.70	0.62	1981.46		490.41	Square
	2.19		0.80		1.38	1.34	0.68					42.47	0.66	0.66	0.57	1737.94		429.53	Rectangular
1.75	2.92	1.00	0.60	0.57	1.29	1.25	0.76	1.23	1.18	1.00	14.24	48.65	0.63	0.63	0.53	1516.74	4.00	374.23	Rectangular
	3.50		0.50		1.24	1.21	0.80					52.07	0.62	0.62	0.51	1414.04		348.56	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.54	0.54	0.42	972.55		238.18	Continuous
	2.00		1.00		1.48	1.42	0.60					37.07	0.70	0.70	0.61	1935.70		478.97	Square
	2.50		0.80		1.38	1.34	0.68					42.47	0.66	0.66	0.57	1699.62		419.95	Rectangular
2.00	3.33	1.00	0.60	0.50	1.29	1.25	0.76	1.20	1.16	1.00	14.09	48.65	0.63	0.63	0.53	1485.17	4.00	366.34	Rectangular
	4.00		0.50		1.24	1.21	0.80					52.07	0.61	0.61	0.51	1385.59		341.44	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.54	0.54	0.41	957.50		234.42	Continuous
	2.25		1.00		1.48	1.42	0.60					37.07	0.69	0.69	0.61	1900.13		470.08	Square
	2.81		0.80		1.38	1.34	0.68					42.47	0.66	0.66	0.57	1670.17		412.59	Rectangular
2.25	3.75	1.00	0.60	0.44	1.29	1.25	0.76	1.18	1.14	1.00	13.95	48.65	0.63	0.63	0.52	1461.26	4.00	360.36	Rectangular
	4.50		0.50		1.24	1.21	0.80					52.07	0.61	0.61	0.50	1364.26		336.11	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.54	0.54	0.41	947.17		231.84	Continuous
	2.50		1.00		1.48	1.42	0.60					37.07	0.69	0.69	0.61	1871.71		462.97	Square
	3.13		0.80		1.38	1.34	0.68					42.47	0.66	0.66	0.56	1646.94		406.78	Rectangular
2.50	4.17	1.00	0.60	0.40	1.29	1.25	0.76	1.16	1.13	1.00	13.80	48.65	0.62	0.62	0.52	1442.73	4.00	355.73	Rectangular
	5.00		0.50		1.24	1.21	0.80					52.07	0.61	0.61	0.50	1347.90		332.02	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.54	0.54	0.41	940.13		230.08	Continuous
	2.75		1.00		1.48	1.42	0.60					37.07	0.69	0.69	0.60	1848.50		457.17	Square
	3.44		0.80		1.38	1.34	0.68					42.47	0.65	0.65	0.56	1628.24		402.11	Rectangular
2.75	4.58	1.00	0.60	0.36	1.29	1.25	0.76	1.15	1.11	1.00	13.67	48.65	0.62	0.62	0.52	1428.11	4.00	352.07	Rectangular
	5.50		0.50		1.24	1.21	0.80					52.07	0.61	0.61	0.50	1335.17		328.84	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.53	0.53	0.41	935.49		228.92	Continuous
	3.00		1.00		1.48	1.42	0.60					37.07	0.69	0.69	0.60	1829.22		452.35	Square
	3.75		0.80		1.38	1.34	0.68					42.47	0.65	0.65	0.56	1612.95		398.28	Rectangular
3.00	5.00	1.00	0.60	0.33	1.29	1.25	0.76	1.13	1.11	1.00	13.53	48.65	0.62	0.62	0.52	1416.44	4.00	349.15	Rectangular
	6.00		0.50		1.24	1.21	0.80					52.07	0.60	0.60	0.50	1325.17		326.34	Rectangular
	0.00		0.00		1.00	1.00	1.00					73.16	0.53	0.53	0.40	932.63		228.20	Continuous

Table 4. The values of allowable bearing capacity according to foundation system and foundation width for Yemişliçay Formation (S3)

S3	q_a (kN/m^2)				
B	B/L	B/L	B/L	B/L	Continuous
m	1	0.8	0.6	0.5	0
1.00	559.04	488.14	423.76	393.87	265.42
1.25	527.02	460.65	400.36	372.37	252.08
1.50	505.67	442.43	385.00	358.33	243.72
1.75	490.41	429.53	374.23	348.56	238.18
2.00	478.97	419.95	366.34	341.44	234.42
2.25	470.08	412.59	360.36	336.11	231.84
2.50	462.97	406.78	355.73	332.02	230.08
2.75	457.17	402.11	352.07	328.84	228.92
3.00	452.35	398.28	349.15	326.34	228.20

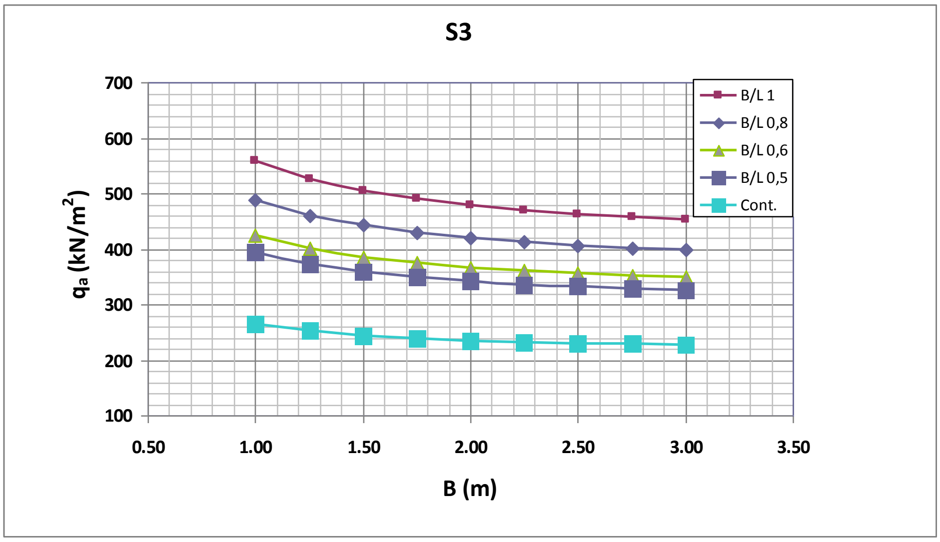

Figure 6. Allowable bearing capacity values for Yemişliçay Formation (S3)

Table 5. The values of allowable bearing capacity according to foundation system and foundation width for alluvium (S5)

S5	q_a (kN/m^2)				
B	B/L	B/L	B/L	B/L	Continuous
m	1	0.8	0.6	0.5	0
1.00	380.70	330.43	284.81	263.66	173.18
1.25	358.70	311.58	268.82	249.00	164.20
1.50	344.00	299.06	258.28	239.37	158.50
1.75	333.47	290.15	250.84	232.62	154.69
2.00	325.55	283.51	245.35	227.67	152.04
2.25	319.38	278.37	241.16	223.91	150.17
2.50	314.42	274.30	237.88	221.00	148.85
2.75	310.36	270.99	235.27	218.71	147.93
3.00	306.97	268.27	233.15	216.87	147.31

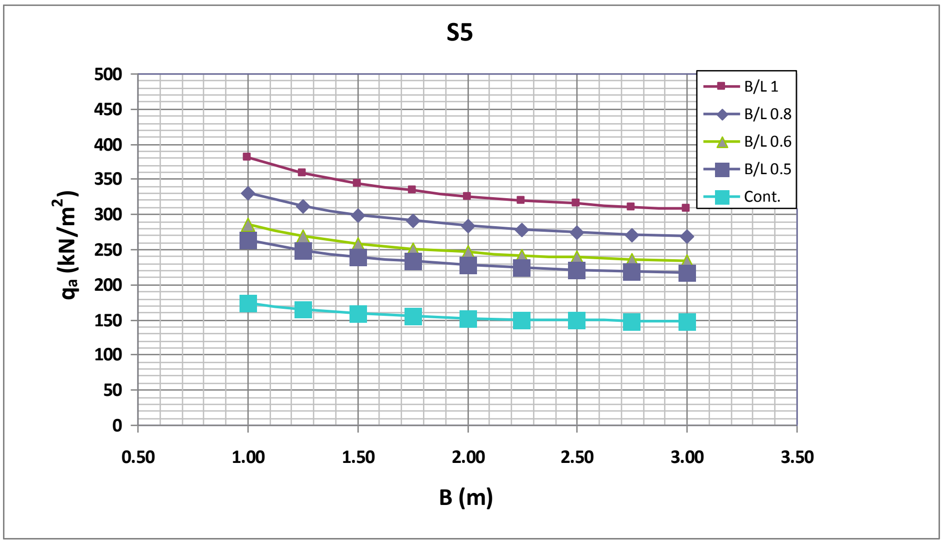

Figure 7. The allowable bearing capacity values for alluvium (S5)

Table 6. The values of allowable bearing capacity according to foundation system and foundation width for Akveren Formation (S7)

S7	q_a (kN/m^2)				
B	B/L	B/L	B/L	B/L	Continuous
m	1	0.8	0.6	0.5	0
1.00	764.00	648.80	546.91	500.56	308.95
1.25	721.46	613.79	518.54	475.19	295.88
1.50	693.24	590.87	500.27	459.02	288.31
1.75	673.21	574.85	487.77	448.12	283.89
2.00	658.30	563.16	478.89	440.50	281.42
2.25	646.83	554.35	472.41	435.07	280.23
2.50	637.77	547.57	467.62	431.17	279.94
2.75	630.46	542.26	464.04	428.38	280.29
3.00	624.48	538.06	461.39	426.43	281.12

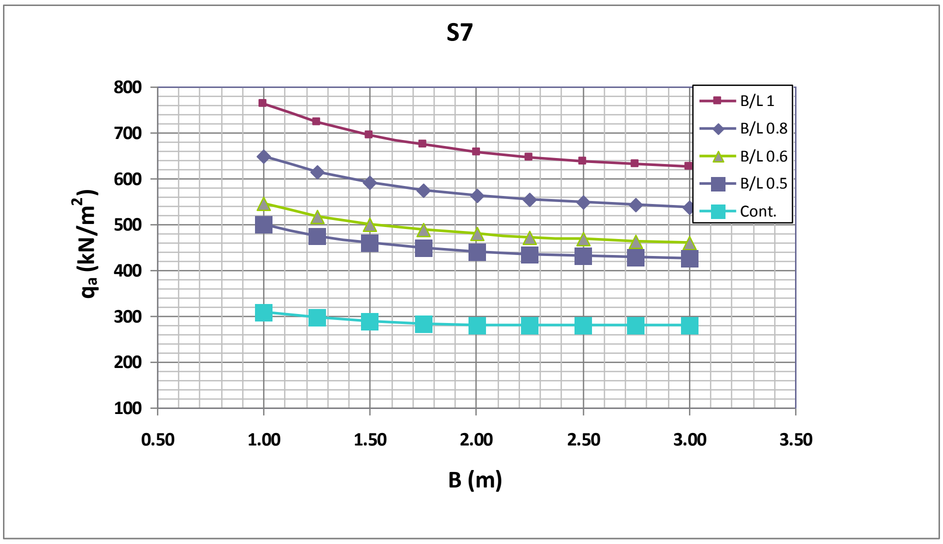

Figure 8. The allowable bearing capacity values for Akveren Formation (S7)

Table 7. The values of allowable bearing capacity according to foundation system and foundation width for Çaycuma Formation (S10)

S10	**q_a (kN/m^2)**				
B	B/L	B/L	B/L	B/L	Continuous
m	1	0.8	0.6	0.5	0
1.00	882.19	734.12	605.90	548.49	318.30
1.25	835.45	697.35	577.65	524.02	308.67
1.50	804.70	673.71	560.08	509.14	304.26
1.75	783.12	657.59	548.61	499.72	302.79
2.00	767.27	646.17	540.94	493.70	303.12
2.25	755.28	637.88	535.79	489.92	304.61
2.50	745.98	631.80	532.40	487.72	306.91
2.75	738.66	627.30	530.29	486.64	309.75
3.00	732.83	624.01	529.12	486.40	313.00

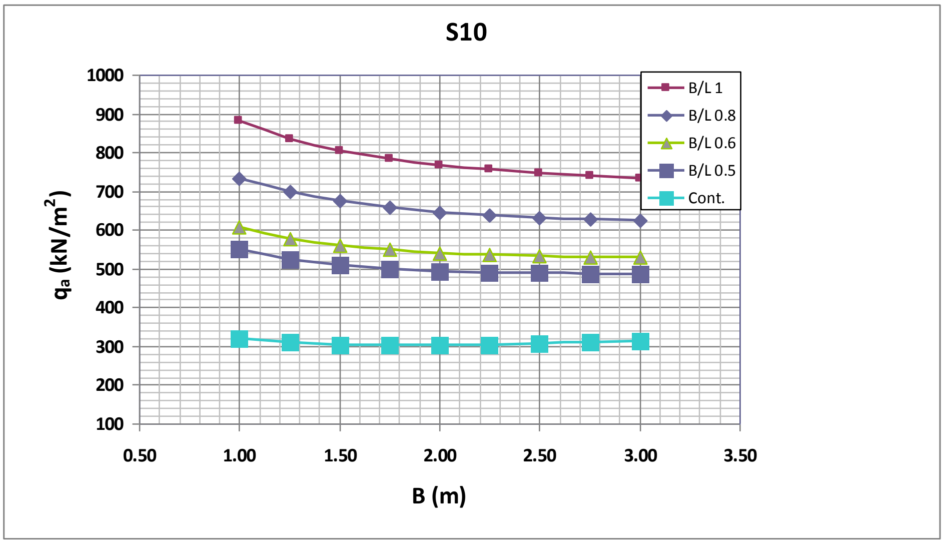

Figure 9. The allowable bearing capacity values for Çaycuma Formation (S10)

Table 8**.** The The values of allowable bearing capacity according to foundation system and foundation width for alluvium (S11)

S11	**q_a (kN/m^2)**				
B	B/L	B/L	B/L	B/L	Continuous
m	1	0.8	0.6	0.5	0
1.00	446.53	386.97	332.88	307.78	200.43
1.25	420.73	364.82	314.04	290.49	189.74
1.50	403.48	350.08	301.58	279.08	182.86
1.75	391.12	339.57	292.75	271.03	178.16
2.00	381.82	331.70	286.19	265.08	174.82
2.25	374.56	325.61	281.15	260.54	172.39
2.50	368.73	320.75	277.18	256.97	170.60
2.75	363.95	316.79	273.98	254.13	169.27
3.00	359.94	313.51	271.36	251.81	168.28

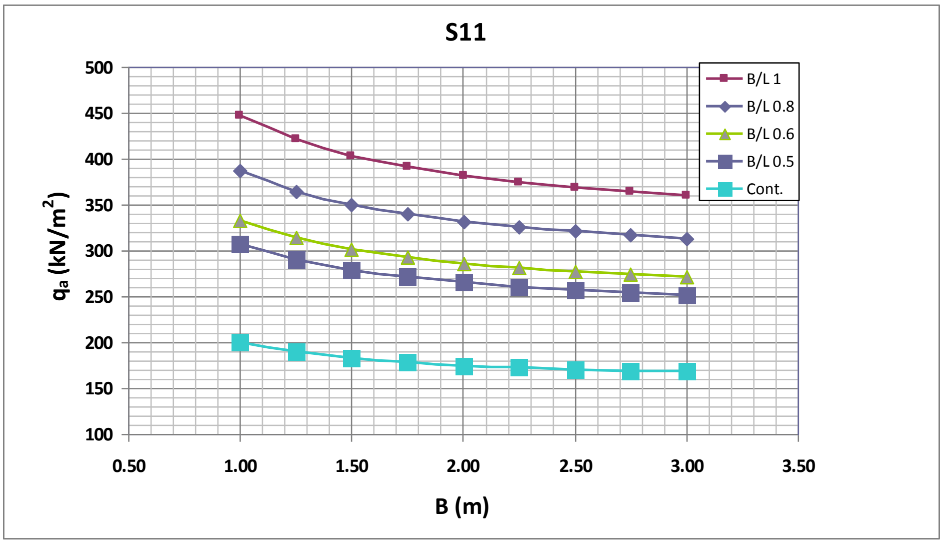

Figure 10. The allowable bearing capacity values for alluvium (S11)

5. Conclusion

In this study, study areas were analyzed and geological formations have been ascertained with the help of previous studies on Bartın, which became a province in 1991 and is supposed to increase its settlements with new urbanization. Intended for Bartın's residential areas, 11 soil samples from the city district were obtained and classified. Similar soil types were grouped into 5 categories. These groups were tested in laboratories and Engineering properties of the soil samples were acquired, so using these results, allowable bearing capacities of soils were calculated for shallow foundation desing . The results of the study are submitted below.

- Total area of Bartın (2143 km^2) is covered by forests (46%), agricultural areas (35%), meadows and pastures (7%) and the land unsuitable for agriculture and settlement places (12%). In these rates, total settlement places compose 7%.

- These are participated from old to young: Yemişliçay Formation consisted of volcanogenic sandstone, tuff, tuffite, clayey limestone and agglomerate intercalation; Akveren Formation consisted of clayey limestone, sandstone, shale, marl and mudstone intercalation; Çaycuma Formation consisted of sandstone, siltstone, claystone, shale intercalation; and Quaternary aged alluvium consisted of loosely connected sediments like gravel, sand, mud, clay, alluvion, silt. The province of Bartın is mainly established on the alluviums of Bartın River and its branches; so is a risky ground because of already low level bearing capacity and high level groundwater.

- It has been found out that these 11 soil samples correspond to the groups of well graded silty sand and poor graded silty sand according to Unified Soil Classification System (USCS). These soil categories reserve 5-12% thin material(<0.075mm).

- Allowable bearing capacity values for Bartın city district; considering foundation depth constant as (D_f) 1 m; are calculated for square, rectangular and strip foundation systems. In the calculation of allowable bearing capacity, correction factors were used taking into the effects of the foundation systems, depth and compressibility potential. The allowable bearing capacity values of these soils vary between 882 and 147 kPa.

- The aim of calculating allowable bearing capacity values for different B values is to propose information about the foundation designs of the buildings supposed to be constructed in the future. After choosing the convenient foundation system for buildings, Engineering companies which make building designs in the area, can obtain allowable bearing capacity from Tables 4-8 depending on soil type. In addition, if the material parameters from the experimental results are different from Table 2, they can comprise Tables convenient to their soil classification using Equations (1-7).

- According to geotechnical and foundation investigation regulations approved by Ministry of Public Works, allowable bearing capacity value must be unique for foundation soils. In practical applications, allowable bearing capacity is calculated for B value as 1 m, and this value is thought as the allowable bearing capacity value for that soil. But as seen in the calculations, when B value increases, bearing capacity value decreases. The main reasons of this are shape, depth and compressibility values. For this reason, if the compressibility potential of the soil is high, allowable bearing capacity values must be recalculated considering the basic width of considered manufacture of the building.

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