

Comparison of Bearing Capacities for Strip, Square and Circular Shallow Foundations on Soils with Terzaghi Method by Calculating in Excel Program

Ebubekir Kilic*

Program of Geotechnics, Department of Civil, Keban Vocational School, Keban / Elazig, Turkey
* E-mail: e.kilic@firat.edu.tr

Abstract

It is important to calculate the bearing capacity on soils for foundations since the majority of building foundations build up on soils. The failed application is usually due to the miscalculation and acceptance of the bearing capacity of the soils. Using many equations and parameters to calculate bearing capacities on soils for foundations causes errors, and difficulties in calculations, thus was more useful to calculate by Excel program. In this study, it was aimed to compare the bearing capacity on soils for stripe, square circular shallow foundations by the Terzaghi method calculating the Excel program. For this, the parameters of width, length and depth of foundation, the cohesion, internal friction angle, and unit volume weight of soil, load slope angle and safety factor were used. The bearing capacity component values for the strip foundation from largest to smallest decreases as first, second and third component in bearing capacity equation. The component values in the bearing capacity equation for the square and the circular foundation decreases same as those for the strip foundation again although the amount varies. The first values in the bearing capacity equation for square and circular foundations are the same and but in strip foundations it is smaller than those in square and circular foundations. The second component in the bearing capacity equation is equal in all types of foundation. The third component value in the bearing capacity equation decreases as those in strip, square and circular foundations, respectively. Their ultimate and allowable bearing capacities increase as those in strip, circular and square foundations respectively, although the amount varies. It is more appropriate to calculate the bearing capacity on soils for shallow foundations with the Terzaghi method at the beginning as it provides the first prediction. In conclusion, except for calculation with the Terzaghi bearing capacity method, individual other methods or the average of the entire methods of bearing capacity can also use according to the aimed structure.

Keywords: Terzaghi method, strip foundation, square foundation, circular foundation, ultimate bearing capacity, allowable bearing capacity, soil.
DOI: 10.7176/JEES/15-2-03

Publication date: March 30th 2025

1. Introduction

A building system is generally defined in two parts. The upper part is called the superstructure. The intermediate area between the ground and the superstructure is also defined as the foundation. A building system consists of the superstructure, foundation and soil combination. The foundation is the intermediary structure part that is in direct contact with the soil and transfers the superstructure loads to the soil. In other words, the foundation is a system that transfers the building loads and the distribution of the load by transforming them into a form that the soil below can carry. With this feature, it is affected by both the structure and the soil. Accordingly, foundation design is a structure-soil interaction problem.

One of main foundations is shallow foundations like single foundation, continuous foundation, and raft foundation.

Foundations are largely dependent on the conditions of the soil on which they will be built. Soils make up the majority of building foundations. Some of them are hard, but some are soft. Hard soils can soften when wet, some can swell and lift the shallow foundations, some collapse and sink into the foundation. Good foundation design is a design that will fulfill the expected function under all adverse conditions and changes. Errors or incorrect applications made in the design of the foundation system of an important structure may one day come to light. If a structure and its foundation can successfully stand against various disasters, only then can it be considered a successful design and application.

The foundation should not cause excessive stress in the soil while transferring the superstructure loads to the supporting soil layers. For this reason, an appropriate safety factor should be applied in the safe foundation design. The safety factor used should provide sufficient security against shear failure of the foundation soil and excessive settlement. Terzaghi (1943) first proposed the bearing capacity equation of shallow foundations. To the failure mechanism developed by Prandtl (1920), Terzaghi (1943) expanded this equation by adding shape factors applied to some foundations based on theoretical and experimental data to the failure mechanism developed by Prandtl (1920). Skempton (1951) extended the first side of the equation by the s_c and d_c

coefficients multiplying the Terzaghi (1943) bearing capacity equation by taking into account the foundation shape and depth to determine the bearing capacity of clayey soils.
Blyth and Freitas (1984) have described the bearing capacity as the intensity of loading that causes shear failure to occur beneath a foundation. Önalp and Sert (2006) described the ultimate bearing capacity of a foundation, in kPa, indicating the highest stress that the soil can bear without visibly sinking. Waltham (2009) has also stated that the ultimate bearing capacity was the load at failure and that the allowable bearing capacity would be obtained from the ultimate bearing capacity divided by a nominal safety factor with 3 to 5.
In addition to Terzaghi (1943), Meyerhof (1951, 1953, 1956, 1963) also proposed a more expanded equation of bearing capacity for soils including the shape, depth, and inclination factors. Hansen (1963, 1970) obtained a more developed a formula that took into account such factors as the shape, depth, inclination, base of the footing, and ground slope. Although Vesic's (1963, 1973, 1975) bearing capacity formula for soils is the same as Hansen's (1970) and Vesic's (1975) formulae for inclination, base of footing, and his ground slope differ from Hansen's (1970) formulae and are more comprehensive.

2. Material and Method

In this study, given some values of parameters to the formulas was used to calculate the bearing capacity for soils according to Terzaghi (1943). The example problem was step by step calculated by Excel program, occurring 92 rows and 5 columns. It was also written using the Excel formulae and graphed as column graphs in Excel program. Results obtained were compared with each other. It was used kPa, kg/ cm^2 and ton/m^2 as units of bearing capacity equations for the soil.

3. Calculation of Terzaghi bearing capacity for the soil step by step in Excel program

Table 1: Calculation of Terzaghi bearing capacity for the soil in Excel program

Row / Column	A	B	C	D
1				
2		**TERZAGHI BEARING CAPACITY**		
3				
4	1	Foundation width	B (m)	1.00
5	2	Foundation Length	L (m)	18.00
6	3	Foundation depth	D (m)	1.00
7	4	Cohesion	c (kPa)	15.00
8	5	Internal friction angle	Ø°(degree)	30.00
9	6	Unit volume weight	γ (kN/m^3)	18.00
10	7	Load slope angle	α°(degree)	0.00
11	8	Safety factor	G_s	3.00
12		**Calculation of bearing capacity**		
13				
14		π		3.14
15		$3\pi/4$		2.36
16		Ø/2(radian)		0.26
17		tan Ø		0.58
18		(3π/4)-(Ø/2)		2.09
19		[(3π/4)-(Ø/2)]tan Ø		1.21
20		$a=[e^{[(3\pi/4)-(Ø/2)]\tan Ø}]$		3.35
21		$a^2=[e^{[(3\pi/4)-(Ø/2)]\tan Ø}]^2$	$a^2=$	11.23
22		Ø/2		15.00
23		45+Ø/2		60.00
24		Cos(45+Ø/2)		0.50
25		$\cos^2(45+Ø/2)$		0.25
26		$2\cos^2(45+Ø/2)$		0.50

27		cot Ø		1.73
28		$a^2/(2\cos^2(45+Ø/2))$		22.46
29		$[a^2/(2\cos^2(45+Ø/2))]-1$		21.46
30		$N_c=\cot Ø[a^2/(2\cos^2(45+Ø/2))]-1$	$N_c=$	37.16
31		$N_q=[a^2/(2\cos^2(45+Ø/2))]$	$N_q=$	22.46
32		$N_c=\cot Ø(N_q-1)$	$N_c=$	37.16
33		Ø+33		63.00
34		(Ø+33)/2		31.50
35		45+((Ø+33)/2)		76.50
36		tan[45+((Ø+33)/2)]		4.17
37		$\tan^2[45+((Ø+33)/2)]$		17.35
38		$K_{p\gamma}=3\tan^2[45+((Ø+33)/2)]$	$K_{p\gamma}=$	52.05
39		Cos Ø		0.87
40		$\cos^2Ø$		0.75
41		$K_{p\gamma}/\cos^2Ø$		69.40
42		$(K_{p\gamma}/\cos^2Ø)-1$		68.40
43		tan Ø		0.58
44		$\tan Ø[(K_{p\gamma}/\cos^2Ø)-1]$		39.49
45		$N_\gamma=0.5\tan Ø[(K_{p\gamma}/\cos^2Ø)-1]$	$N_\gamma=$	19.75
46				
47		**Bearing capacity**		
48	1	Cohesion component=$(c\ N_c)$	kPa	557.44
49	2	Surcharge component =$(\gamma\ D\ N_q)$	kPa	404.20
50	3	Lithology component =$(0.5\gamma BN_\gamma)$	kPa	177.71
51		**STRIP FOUNDATION (B<L)**		
52	1	$(s_c\ c\ N_c)$ for $s_c=1.0$	kPa	557.44
53	2	$(s_q\ \gamma\ D\ N_q)$ for $s_q=1.0$	kPa	404.20
54	3	$(s_\gamma\ 0.5\gamma BN_\gamma)$ for $s_\gamma=1.0$	kPa	177.71
55		**Ultimate bearing capacity (STRIP, B<L)**		
56		$q_u=(s_c c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	kPa	1139.35
57		$q_u=(s_c c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	MPa	1.14
58		$q_u=(s_c c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	kg/cm^2	11.62
59		$q_u=(s_c\ c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	ton/m^2	116.21
60		**Allowable bearing capacity (STRIP, B<L)**		
61		$q_a=(q_u/G_s)$	kPa	379.78
62		$q_a=(q_u/G_s)$	MPa	0.38
63		$q_a=(q_u/G_s)$	kg/cm^2	3.87
64		$q_a=(q_u/G_s)$	ton/m^2	38.74
65		**SQUARE FOUNDATION (B=L)**		
66	1	$(s_c c\ N_c)$ for $s_c=1.3$	kPa	724.67
67	2	$(s_q\ \gamma\ D\ N_q)$ for $s_q=1.0$	kPa	404.20
68	3	$(s_\gamma 0.5\gamma BN_\gamma)$ for $s_\gamma=0.8$	kPa	142.16
69		**Ultimate Bearing capacity (SQUARE, B=L)**		
70		$q_u=(s_c\ c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	kPa	1271.04
71		$q_u=(s_c\ c\ N_c)+(s_q\ \gamma\ D\ N_q)+(s_\gamma 0.5\gamma BN_\gamma)$	MPa	1.27

72		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kg/cm^2	12.96
73		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	ton/m^2	129.65
74		**Allowable bearing capacity (SQUARE, B=L)**		
75		$q_a=(q_u/G_s)$	kPa	423.68
76		$q_a=(q_u/G_s)$	MPa	0.42
77		$q_a=(q_u/G_s)$	kg/cm^2	4.32
78		$q_a=(q_u/G_s)$	ton/m^2	43.22
79		**CIRCULAR FOUNDATION (B=L=R)**		
80	1	$(s_c c N_c)$ for s_c=1.3	kPa	724.67
81	2	$(s_q \gamma D N_q)$ for s_q=1.0	kPa	404.20
82	3	$(s_\gamma 0.5\gamma B N_\gamma)$ for s_γ=0.6	kPa	106.62
83		**Ultimate Bearing capacity (CIRCULAR, B=L=R)**		
84		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kPa	1235.49
85		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	MPa	1.24
86		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kg/cm^2	12.60
87		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	ton/m^2	126.02
88		**Allowable bearing capacity (CIRCULAR, B=L=R)**		
89		$q_a=(q_u/G_s)$	kPa	411.83
90		$q_a=(q_u/G_s)$	MPa	0.41
91		$q_a=(q_u/G_s)$	kg/cm^2	4.20
92		$q_a=(q_u/G_s)$	ton/m^2	42.01

4. Calculation of formulae of Terzaghi bearing capacity for the soil step by step in Excel program

Table 2: Formulae and calculation of Terzaghi bearing capacity for the soil in Excel program

Row / Column	A	B	C	D
1				
2		**TERZAGHI TAŞIMA GÜCÜ**		
3				
4	1	Foundation width	B (m)	1.00
5	2	Foundation Length	L (m)	18.00
6	3	Foundation depth	D (m)	1.00
7	4	Cohesion	c (kPa)	15.00
8	5	Internal friction angle	Ø ° (degree)	30.00
9	6	Unit volume weight	γ (kN/m^3)	18.00
10	7	Load slope angle	α°(degree)	0.00
11	8	Safety factor	G_s	3.00

12		**Calculations of bearing capacity**		
13				
14		π		=Pİ()
15		3π/4		=(3*Pİ())/4
16		Ø/2(radian)		=(D8/2)*(D14/180)
17		tan Ø		=TAN(D8*Pİ()/180)
18		(3π/4)-(Ø /2)		=D15-D16
19		(3π/4)-(Ø /2)]tan Ø		=D18*D17
20		a=$\left[e^{[(3\pi/4)-(\emptyset/2)]tan\emptyset}\right]$		=ÜS(D19)
21		a^2=$\left[e^{[(3\pi/4)-(\emptyset/2)]tan\emptyset}\right]^2$	a^2=	=D20*D20
22		Ø/2		=D8/2
23		45+ Ø /2		=45+D22
24		Cos(45+ Ø /2)		=COS(D23*Pİ()/180)
25		cos^2(45+ Ø /2)		=(D24*D24)
26		2cos^2(45+ Ø /2)		=2*D25
27		cot Ø		=1/TAN(D8*Pİ()/180)
28		a^2/(2cos^2(45+Ø/2))		=D21/D26
29		[a^2/(2cos^2(45+Ø/2))]-1		=D28-1
30		N_c=cot Ø[a^2/(2cos^2(45+Ø/2))]-1	N_c=	=D27*D29
31		N_q=[a^2/(2cos^2(45+ Ø /2))]	N_q=	=D28
32		N_c=cot Ø (N_q-1)	N_c=	=D27*(D31-1)
33		Ø+33		=D8+33
34		(Ø+33)/2		=D33/2
35		45+((Ø+33)/2)		=45+D34
36		tan[45+((Ø+33)/2)]		=TAN(D35*Pİ()/180)
37		tan^2[45+((Ø+33)/2)]		=D36*D36
38		$K_{p\gamma}$=3tan^2[45+((Ø+33)/2)]	$K_{p\gamma}$=	=3*D37
39		Cos Ø		=COS(D8*Pİ()/180)
40		cos^2Ø		=D39*D39
41		[($K_{p\gamma}$/cos^2 Ø)		=D38/D40
42		[($K_{p\gamma}$/cos^2 Ø)-1		=D41-1
43		tan Ø		=TAN(D8*Pİ()/180)
44		tan Ø [($K_{p\gamma}$/cos^2 Ø)-1]		=D42*D43
45		N_γ=0.5tanØ [($K_{p\gamma}$/cos^2 Ø)-1]	N_γ=	=0.5*D44
46				
47		**Bearing Capacity**		
48	1	Cohesion component=(c N_c)	kPa	=D7*D30
49	2	Surcharge component =(γ D N_q)	kPa	=D9*D6*D31
50	3	Lithology component =(0.5γBN_γ)	kPa	=0.5*D9*D4*D45
51		**STRİP FOUNDATION (B<L)**		

52	1	$(s_c c N_c)$ for s_c=1.0	kPa	=1*D48
53	2	$(s_q \gamma D N_q)$ for s_q=1.0	kPa	=1*D49
54	3	$(s_\gamma 0.5\gamma B N_\gamma)$ for s_γ=1.0	kPa	=1*D50
55		**Ultimate bearing capacity (STRIP,B<L)**		
56		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kPa	=D52+D53+D54
57		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	MPa	=D56/1000
58		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kg/cm^2	=D56*0.0102
59		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	ton/m^2	=D56*0.102
60		**Allowable bearing capacity (STRIP, B<L)**		
61		$q_a=(q_u/G_s)$	kPa	=D56/D11
62		$q_a=(q_u/G_s)$	MPa	=D57/D11
63		$q_a=(q_u/G_s)$	kg/cm^2	=D58/D11
64		$q_a=(q_u/G_s)$	ton/m^2	=D59/D11
65		**SQUARE FOUNDATION (B=L)**		
66	1	$(s_c c N_c)$ for s_c=1.3	kPa	=1.3*D48
67	2	$(s_q \gamma D N_q)$ for s_q=1.0	kPa	=1*D49
68	3	$(s_\gamma 0.5\gamma B N_\gamma)$ for s_γ=0.8	kPa	=0.8*D50
69		**Ultimate bearing capacity (SQUARE, B=L)**		
70		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kPa	=D66+D67+D68
71		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	MPa	=D70/1000
72		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kg/cm^2	=D70*0.0102
73		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	ton/m^2	=D70*0.102
74		**Allowable bearing capacity (SQUARE, B=L)**		
75		$q_a=(q_u/G_s)$	kPa	=D70/D11
76		$q_a=(q_u/G_s)$	MPa	=D71/D11
77		$q_a=(q_u/G_s)$	kg/cm^2	=D72/D11
78		$q_a=(q_u/G_s)$	ton/m^2	=D73/D11
79		**DAİRE TEMEL (B=L=R)**		
80	1	$(s_c c N_c)$ for s_c=1.3	kPa	=1.3*D48
81	2	$(s_q \gamma D N_q)$ for s_q=1.0	kPa	=1*D49
82	3	$(s_\gamma 0.5\gamma B N_\gamma)$ for s_γ=0.6	kPa	=0.6*D50
83		**Ultimate bearing capacity (CIRCULAR, B=L=R)**		
84		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kPa	=D80+D81+D82
85		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	MPa	=D84/1000
86		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	kg/cm^2	=D84*0.0102
87		$q_u=(s_c c N_c)+(s_q \gamma D N_q)+(s_\gamma 0.5\gamma B N_\gamma)$	ton/m^2	=D84*0.102
88		**Allowable bearing capacity (CIRCULAR, B=L=R)**		
89		$q_a=(q_u/G_s)$	kPa	=D84/D11
90		$q_a=(q_u/G_s)$	MPa	=D85/D11
91		$q_a=(q_u/G_s)$	kg/cm^2	=D86/D11
92		$q_a=(q_u/G_s)$	ton/m^2	=D87/D11

5. Results and Discussion

Parameters such as width, length, and depth of foundation and cohesion, internal friction angle, and unit weight of soil, load slope angle and safety factors were entered in each row in Table 1. Formulas were entered in column B, units in column C and values in column D. By entering the values in Table 2, Excel formulas related to Terzaghi (1943) bearing capacity method were written in column D. As a result, in Figure 1, component values of the bearing capacity for the strip foundation which cohesion component (557.44), surcharge component (404.20) and lithology component (177.71kPa) were obtained. In Figure 2, component values of the bearing capacity for the square foundation which was calculated values of cohesion component (724.67), surcharge component (404.20) and lithology component (142.16 kPa). For the circular foundation, from Figure 3 values of cohesion component (724.67), surcharge component (404.20), and lithology component (106.62kPa) were obtained. The total graphs of the component values of the bearing capacities in the strip, square and circular foundation is seen in Figure 4. Accordingly, the first values in the bearing capacity equation in square and circular foundations are 724.67 kPa and in strip foundations they are 557.44 kPa, which are smaller than the other two values. The second component in the bearing capacity equation is equal in all and is 404.20 kPa. The third component values in the bearing capacity equation decreases as 177.71, 142.16 and 106.62 kPa in strip, square and circular foundations, respectively. It is pictured in Figure 5 that the ultimate bearing capacity values on the soil for strip, square and circular foundations are 1139.35 kPa in strip foundation, 1271.04 kPa in square one and 1235.49 kPa in circular one. The ultimate bearing capacity values on the soil for given foundations are from largest to smallest those in strip, circular and square foundations. The allowable bearing capacity values proportionally decreases with the ultimate bearing capacity, that is, bearing capacity of the strip foundation is 379.78 kPa, that of the square one is 428.68 kPa and that of the circular one is 411.83 kPa, as seen in Figure 6.

Terzaghi's (1943) bearing capacity method is much easier to apply than the other methods to calculate the ultimate bearing capacity of soils because it includes the least number of formulae compared to others. This method is useful to compare with other methods and can be considered as a basis for developing bearing capacity equations due to its simplicity. Other bearing capacity methods are, on other hand, more complex, involve more parameters, and become more and more difficult to solve relative to the Terzaghi (1943) method.

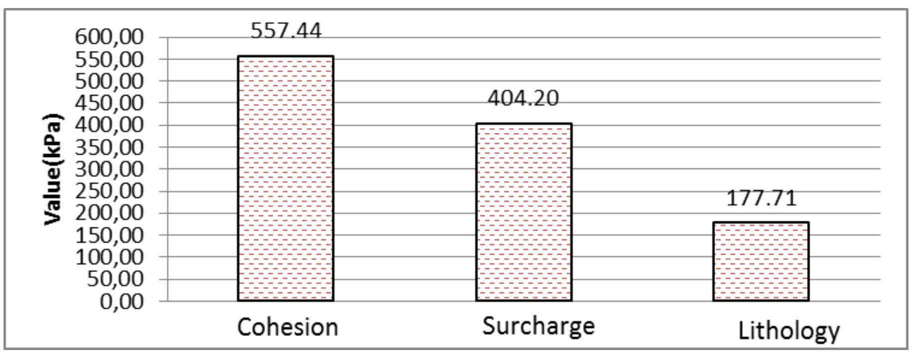

Figure 1: Graphs of component values of bearing capacity for the soil in the strip foundation:

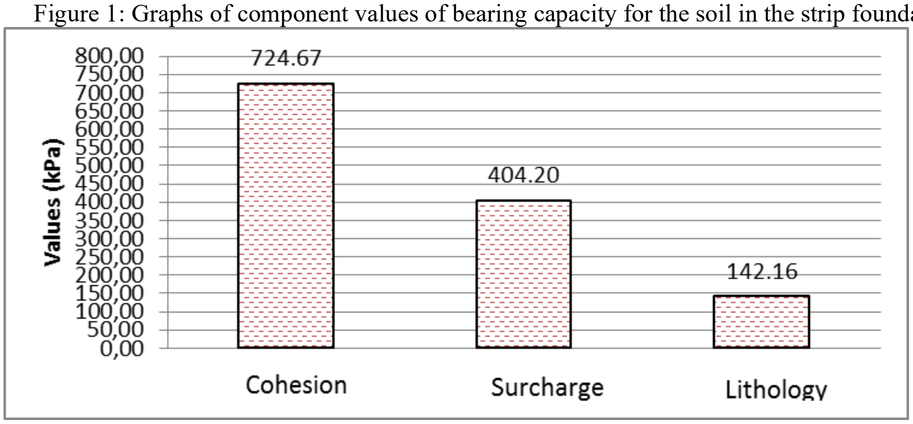

Figure 2: Graphs of component values of bearing capacity for the soil in the square foundation

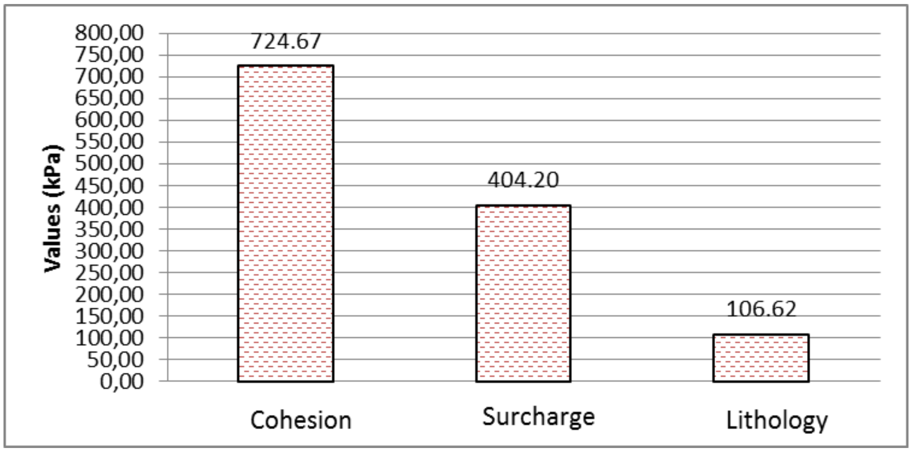

Figure 3: Graphs of component values of bearing capacity for the soil in the circular foundation

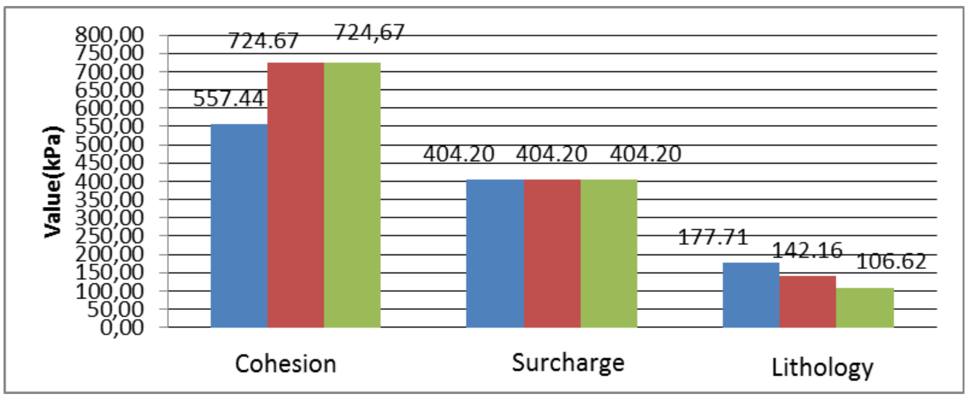

Figure 4: Totally graphs of component values of bearing capacity for the soil in the stripe, square, and circular foundations. Blue: strip foundation, red: square foundation and green: circular foundation

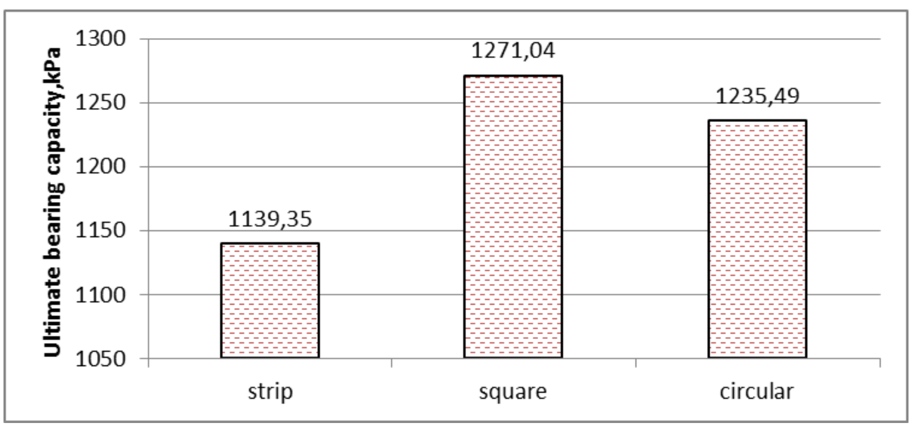

Figure 5: Ultimate bearing capacity for the soil in strip, square, and circular foundations

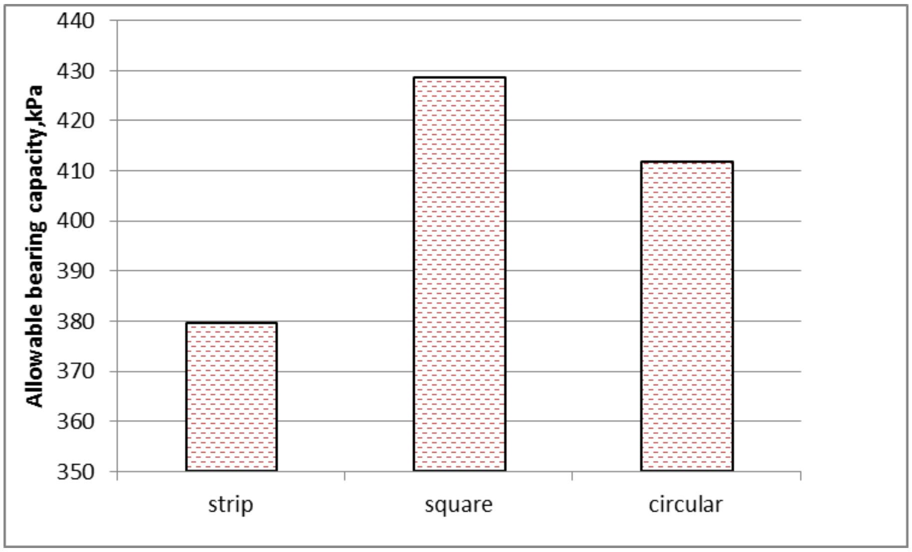

Figure 6: Allowable bearing capacity for the soil in strip, square, and circular foundations

6. Conclusions

The component values of bearing capacity for the strip foundation from largest to smallest decreases as values of cohesion, surcharge and lithology components. Those for the square foundation and the circular foundation decrease same as those for the strip foundation although the amount varies. The cohesion component values in square and circular foundations are the same and but in strip foundations it is smaller than those in square and circular foundations. The second component of the bearing capacity, being surcharge component, is equal in all of foundations. The third component value of the bearing capacity for the soil, lithology component, decreases as in strip, square and circular foundations, respectively. Their ultimate and allowable bearing capacities increase as those of strip, circular and square foundations respectively, although the amount varies.

Terzaghi's method is much easier to apply than the other methods to calculate the ultimate and allowable bearing capacity for foundations on soils because it includes the least number of formulae. This method is useful to compare with other methods and can be considered as a basis for developing bearing capacity equations. Other bearing capacity methods are, on other hand, more complex, involve more parameters, and become more and more difficult to solve compared to the Terzaghi method. However, performing calculations on computers reduces errors, difficulties and complexities.

References

Blyth, F. G. H. & Freitas, M. H. De. (1984). A Geology for Engineers, Elsevier, ISBN 0 7131 2882 8, London

Hansen, B.J. (1963). A general formula for bearing capacity, Danish Geotechnical Institute. Bulletin No 11: 38–46

Hansen, B.J. (1970). A revised and extended formula for bearing capacity, Copenhagen. Danish Geotechnical Institute. Bul. No 28. (Successor to Bul. No. 11): 21 p.

Meyerhof, G.G. (1951). The ultimate bearing capacity of foundations, London-England. Geotechnique. Vol 2. No 4: 301-331.

Meyerhof, G.G. (1953). The bearing capacity of foundations under eccentric and inclined loads, Third ICSMFE. Vol 1: 440-445.

Meyerhof, G.G. (1956). Penetration tests and bearing capacity of cohesionless soils, JSMFD, ASCE. Vol 82. SM l: 1-19.

Meyerhof, G.G. (1963) Some recent research on the bearing capacity of foundations, CGJ. Vol 1. No 1:16-26.

Önalp, A. & Sert, S. 2006 Geotecnics Information 3. Building Foundations, Türkiye: Birsen Publication (in Turkish).

Prandtl, L. (1921). Über die Eindringungsfestigkeit (Harte) plastischer Baustoffe und die Festigkeit von Schneiden, Z angev. Math. Mech.1, No 1: 15-20.

Skempton, A.W. (1951). The bearing capacity of clays, Building Research Congress. Vol.1:180- 189.

Terzaghi, K.V. (1943). Theoretical Soil Mechanics, New York : John Wiley & Sons.

Vesic, A.S. (1963). Bearing capacity of deep foundations in sands, Highway Research Record No 39. National Academy of Sciences: 112–153.

Vesic, A.S. (1973). Analysis of ultimate loads of shallow foundations, JSMFD. ASCE Vol. 99. SM 1: 45-73.

Vesic, A.S. (1975) Foundation Engineering Handbook, Chapter3. First edition: ed Winterkorn and Fang. Van Nostrand Reinhold.

Waltham, T. (2009). Foundations of Engineering Geology, Third Edition. New York: Taylor & Francis.