Using the SPT value to compare with theoretical methods for calculating the ultimate Bearing capacity of shallow foundations

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Abstract: Estimation of the ultimate bearinga capacity of the soil supporting foundation is one of the important requirements to develop safe design of foundations. There are many methods used to estimate bearing capacity of soil such as theoretical, empirical and field tests. There are different methods proposed to estimate the theoretical ultimate bearing capacity. In this work, we will carry out to compare the obtained results using theoretical equations with the results of standard penetration test (field Test). To achieve the goal of study, Terzaghi (1943), Meyerhof (1963), Hansen (1970), Vesic (1973) was chosen.

Results SPT for 10 sites from the geotechnical report collected from projects to construct communication towers in the cities of Sirte, Misurata, Gharyan, Tarhuna and Tripoli. Were used to conduct this analysis. the calculations showed that the obtained results, they were found that the values from the Ultimate Bearing capacity calculated using standard penetration test are far from the theoretical methods and it is not possible to compare them.

Geotechnical investigation of the subsoil strata from several sites are based on the data collected from trial pits and from laboratory results. The conclusion presented in this paper is limited to allowable bearing capacity in these sites to these soils. However, it can be for any soils.

Keywords: Ultimate Bearing Capacity, Standard Penetration Test (SPT), Allowable Bearing Capacity, Factors of Safety.

1. Introduction:

Foundation is a part of the structure which is used to transmit the structural loads to the soil layer(s). Foundations are classified mainly based on the depth to width ratio into two categories: shallow foundations and deep foundations.

A deep foundation is a type of foundation which is placed at a greater depth below the ground surface and transfers structure loads to the earth at depth. The depth to width ratio of such a foundation is usually greater than 4 to 5m. Shallow foundation is a type of foundation unit that provides support of a structure by transferring loads to soil or rock at shallow depths. Usually, the depth to width ratio of foundation is less than unity and the depth of foundation is within 3m from the surface. The most prevalent type of foundation utilized in traditional structures is shallow foundations.

The safe bearing capacity of soil is required for the design of the plan dimensions of the footing for the structure. To compute bearing capacity of soil there are different field tests are available. Field tests like Plate bearing test, Standard penetration test, Pressuremeter test and Field vane shear test are generally used to determine bearing capacity of soil.

The first function is satisfied by applying a total pressure not more than the allowable soil capacity. the determination of the ultimate soil capacity is a very important mission of the geotechnical engineers (Parry, 1977). Prandtl in 1921 and Reissner in 1924 were the pioneers who considered a rigid loaded strip. . There are several methods proposed to determine the ultimate soil capacity. These methods can be categorized as: theoretical methods based on the

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soil properties and empirical methods based on the data of field tests such as SPT, CPT and PLT.

This method uses a single N value which must be representative of the soil. The zone of soil affected by the foundation is typically taken as between 0.5 x the foundation width above the foundation base to a depth of 2 x the foundation width below the base. The N value used can be an average value over this depth, with care taken if there are any large deviations. The choice of N value may need to be iterative if the foundation width is adjusted as this will also adjust the influence zone of the foundation.

Care must also be taken where there are areas of significantly lower N value below the foundation influence zone as this can lead to higher than expected settlements. In this case the N value used in the calculations should be adjusted.

2. METHODOLOGY:

2.1. Collecting Data:

The data used for comparison were collected from Reports for 10 sites are shown in table 1. These data include SPT test data, footing geometry {width of footing (B), footing shape (L/B) and footing depth (D), and finally the corresponding ultimate soil capacity (q_u).

Table1: Details of Different soils Collected

	Soil									
No. of soil	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Location	Misurata	Gharian	Misurata	Misurata	Sirt	Misurata	Misurata	Gharian	Gergarish	Sidi Al-Sid
Depth,m	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Width,m	2	2	2	2	2	2	2	2	2	2
Length,m	2	2	2	2	2	2	2	2	2	2
N_{60}(corr)	17	29	26	7	11	12	20	30	7	26
q_{all} , KPa	200	331	400	100	210	200	235	410	215	130

2.2. Calculations:

The study carried out in these steps:

1- The SPT test is carried out at these proposed sites.

2- The value of N Field and N corrected (N60) was taken from the reports

3- Then the value of Φ was calculated using:

$$Ø = \sqrt{20\ x\ (N60)} + 20 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots.(1)$$

Some of these reports have no a (corrected N value). But it has N value data per meter which was collected by the geotechnical engineer. The data in the borehole log was then used to find the values of the field N and correct N using the equation below:

$$N60 = \frac{N\ n1\ n2\ n3\ n4}{60} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Where:

N_{60} = Corrected SPT N-value for field procedures.

n_1 = Hummer correction.

n_2 = Rod Length correction.

n_3 = Sampler correction.

n_4 = Borehole correction.

And $N\ corr = CN\ X\ N60$ ……………………………… (3)

Where: Ncorr: corrected N-value to a standard value.

N: SPT blows value obtained from the field

CN: adjustment for effective overburden pressure

$n_{1, 2, 3, 4}$ adjustment factors computed

Table 2: Correction Factor for N-Values

n_i	Description	Correction Value
n_1	Hummer correction	0.857
n_2	Rod Length correction	Length > 10 = 1 m 6-10=0.95 4-6=0.85 0-4=0.75
n_3	Sampler correction	Without liner= 1.00
n_4	Borehole correction	Hole diameter (60-120) =1

$$CN = 9.78\sqrt{\frac{1}{\sigma v}}.\sigma v' \quad \ldots\ldots\ldots\ldots\ldots\ldots .(4)$$

σ_v : effective overburden pressure.

$\sigma_v = \gamma.h.$ γ = average unites weight.

γ = 07.5 KN/m^3

h=depth.

The average was then taken for both N field and N corrected in order to get the Φ value.

• Partial factors for soil parameter (γ_M)

For the verification of the structural (STR) and geotechnical (GEO) limit states, the values of the partial factors on soil parameters should be taken from table below.

Table3: Partial factors for soil parameters (γ_M) for the STR and GEO limit state

Soil Parameter	Symbol	Set	
		M1	M2
Angles of shearing resistance[A]	$\gamma_{\phi'}$	1.0	1.25
Effective cohesion	γ_c	1.0	1.25
Undrained shear strength	γ_{cu}	1.0	1.4
Unconfined strength	γ_{qu}	1.0	1.4

Applied to tan Φ’ and tan Φ’$_{cv}$ although it might be more appropriate to determine the design value of Φ’$_{cv}$ directly.

NOTE: The value of the partial factor should be taken as the reciprocal of the specified value if such a reciprocal value produces a more onerous effect than the specified value. [3]

Following the value of Φ, bearing capacity factors (N_c, N_q, N_γ) are found, in addition Φ and N field are used to find the value of γ from the table below:

Table 4: Penetration Resistance and Soil Properties on the Basis of SPT (Cohesionless Soil: Fairly reliable) (Peck et. al. 1974; Bowles, 1977; BNBC 2015

Penetration Resistance and Soil Properties on the Basis of SPT (Cohesionless Soil: Fairly reliable)						
SPT N-value		0 to 4	4 to 10	10 to 30	30 to 50	>50
Compactness		very loose	Loose	medium	Dense	very dense
Relative Density, Dr (%)		0 to 15	15 to 35	35 to 65	65 to 85	85 to 100
Angle of Internal Friction,ϕ(°)		<28	28 to 30	30 to 36	36 to 41	>41
Unit Weight (moist)	pcf	<100	95 to 125	110 to 130	110 to140	>130
	kN/m3	<15.7	14.9 to 19.6	17.3 to 20.4	17.3 to 22.0	>20.4
Submerged unit weight	pcf	<60	55 to 65	60 to 70	65 to 85	>75
	kN/m3	<9.4	8.6-10.2	9.4 to 11.0	10.5 to 13.4	>11.8

3. Results:

The results of Standared Pentration Test obtain from different sites in Misurata, Gharian, Sirt cities, Gergarish, and Sidi A- Said area used to calculate the value of bearing capacity.The soil bearing capacity calculation performed by Excel sheet.

4. Discussion

It is seen from Figures1-10 below, that the ultimate bearing capacities of Φ soil for all methods increase with increase of angle of friction. At lower value of angle of friction. The ultimate bearing capacities are very far apart with the spt test by parry equation values.

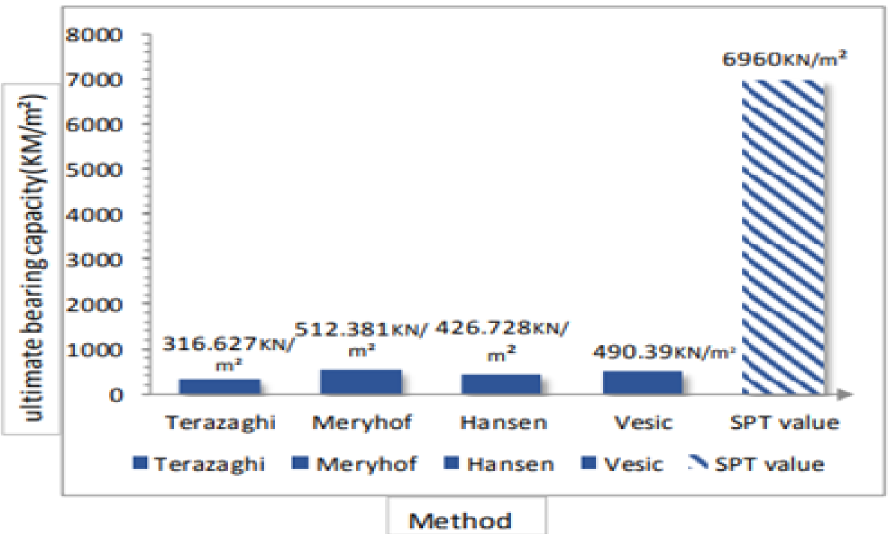

Figure 1: Effect of methods on ultimate bearing capacity of soil 1.

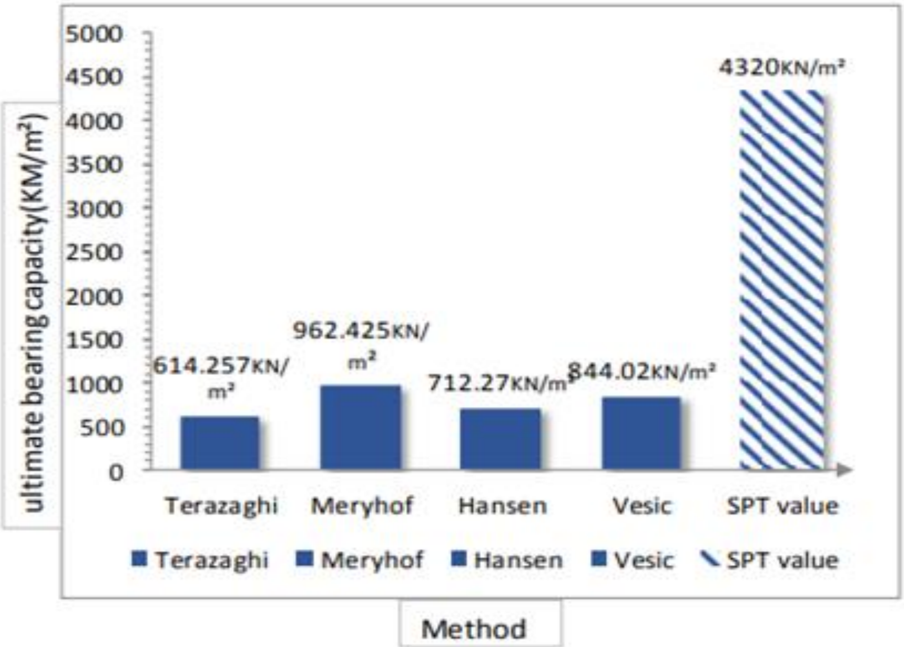

Figure 2: Effect of methods on ultimate bearing capacity of soil 2.

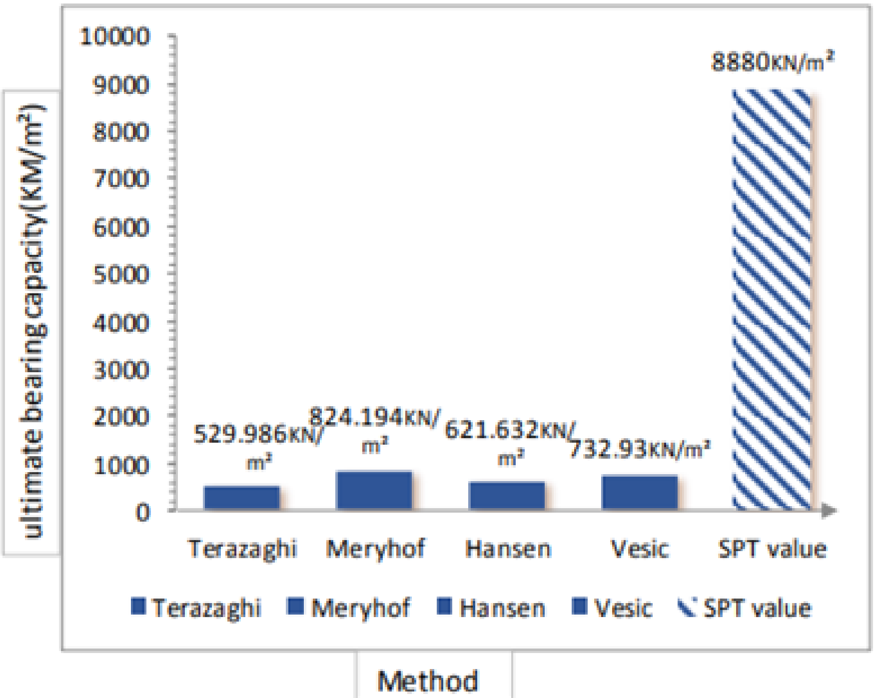

Figure 3: Effect of methods on ultimate bearing capacity of soil 3.

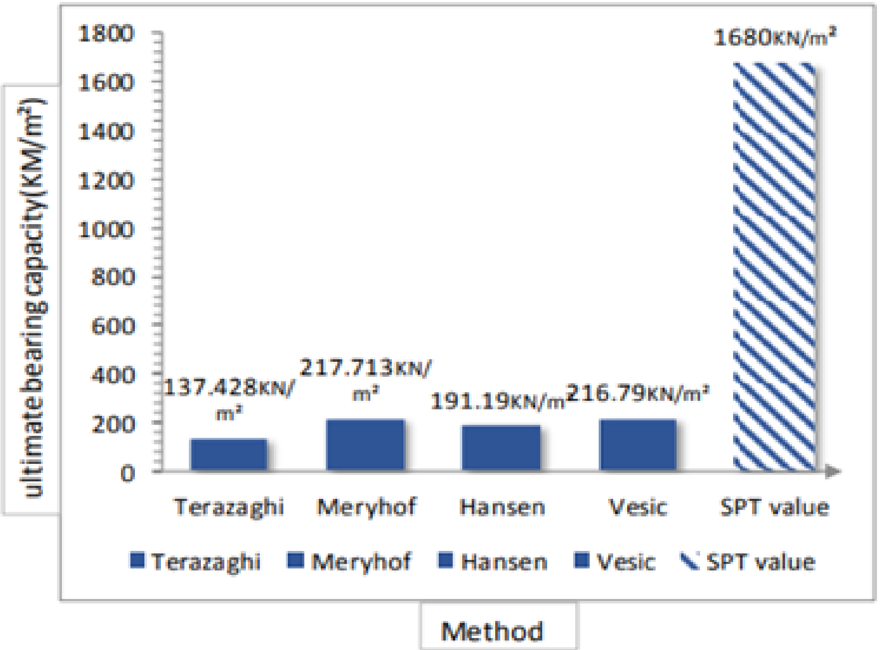

Figure 4: Effect of methods on ultimate bearing capacity of soil 4.

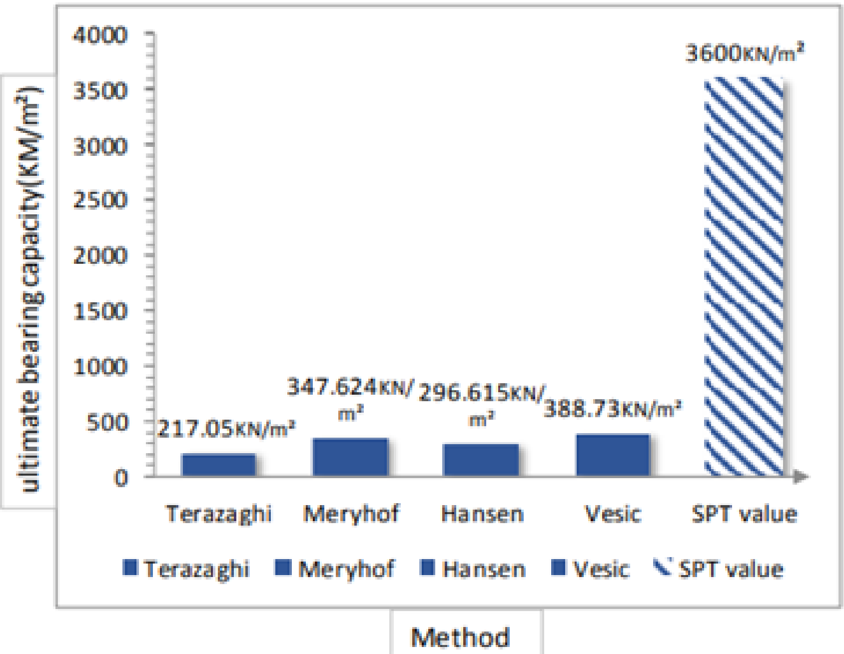

Figure 5: Effect of methods on ultimate bearing capacity of soil 5.

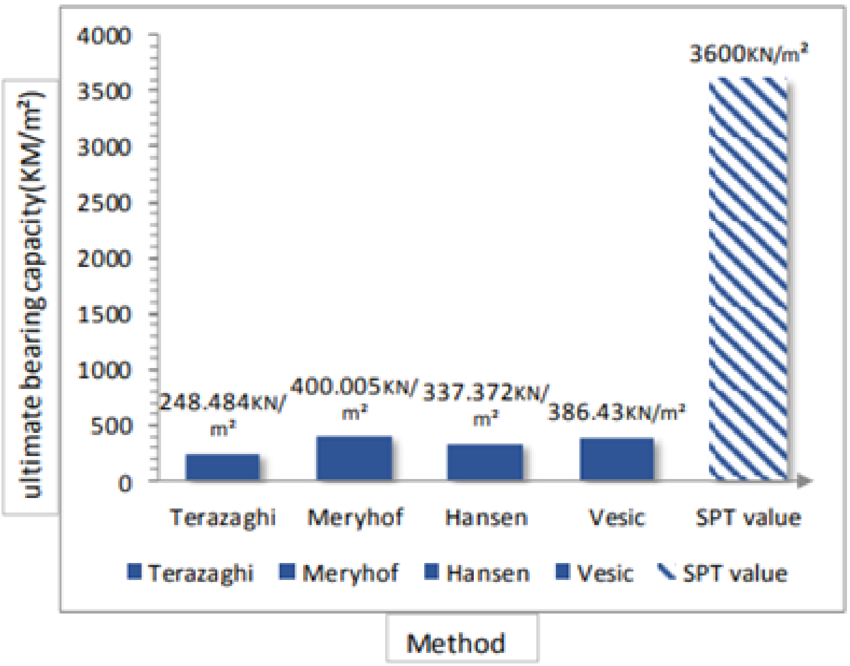

Figure 6: Effect of methods on ultimate bearing capacity of soil 6.

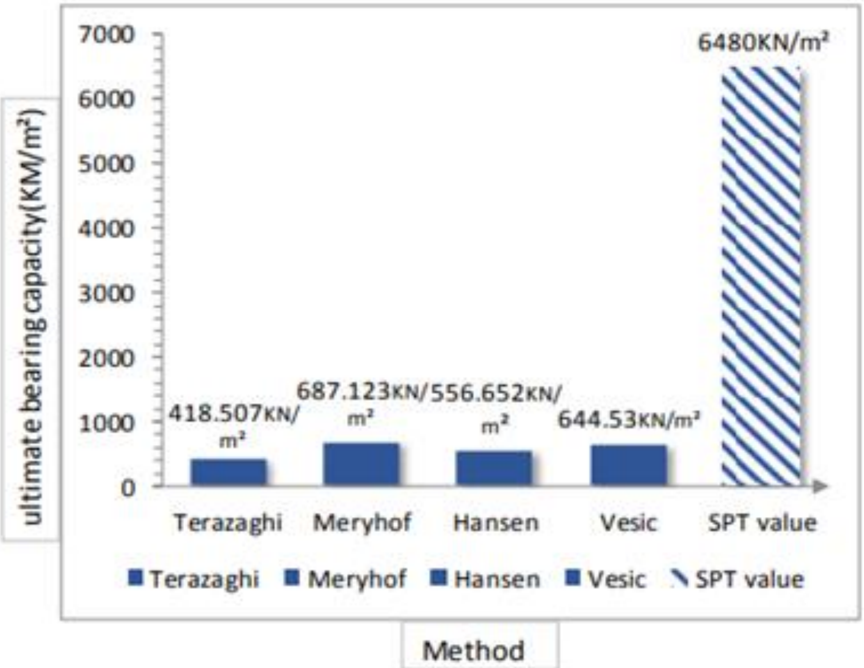

Figure 7: Effect of methods on ultimate bearing capacity of soil 7.

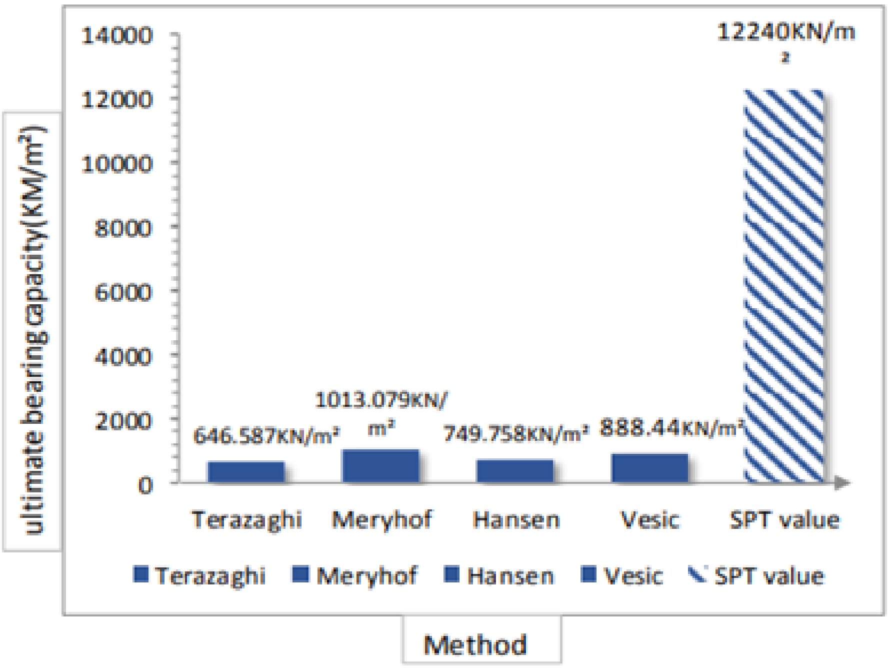

Figure 8: Effect of methods on ultimate bearing capacity of soil 8.

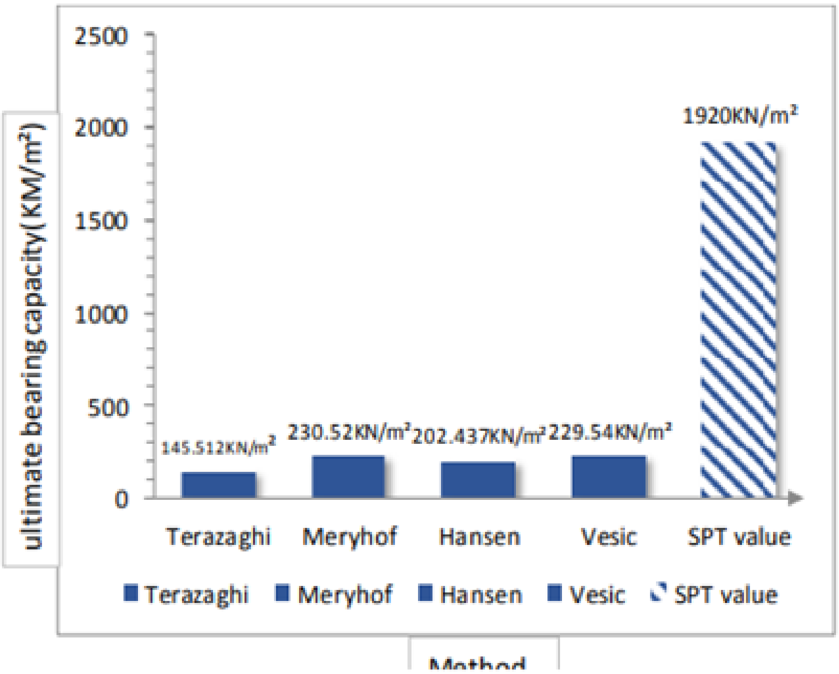

Figure 9: Effect of methods on ultimate bearing capacity of soil 9.

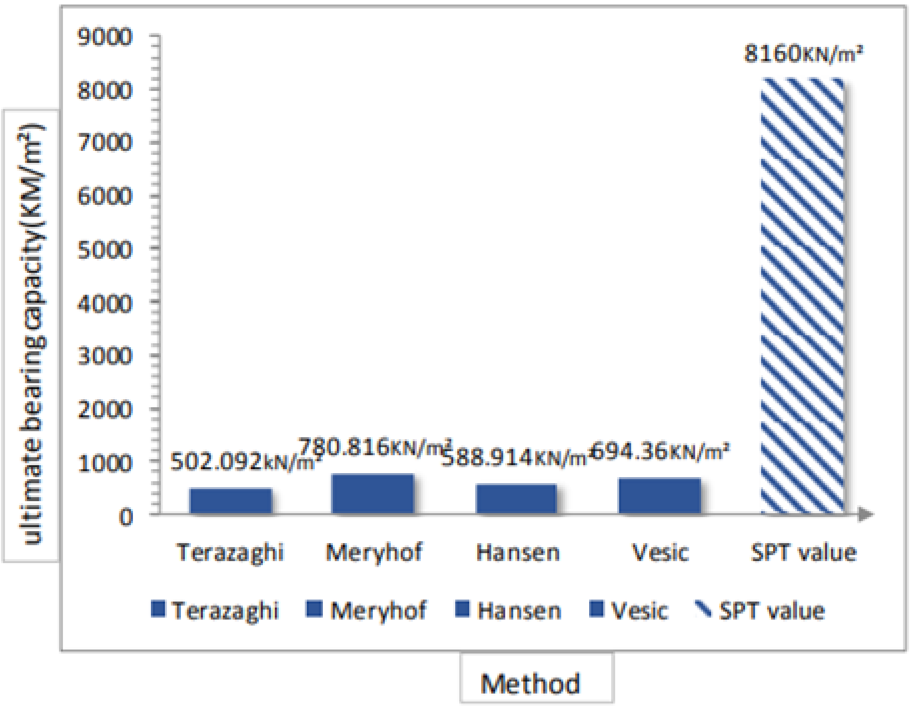

Figure 10: Effect of methods on ultimate bearing capacity of soil 10.

To understand the differences obtained with all these methods, see table 5 of the bearing capacity calculation methods for square footing which illustrate the effect of angle of friction and method of bearing capacity on the ultimate bearing capacity of soil for c=0.

Table 5: Comparison of Methods for Calculating the Bearing Capacity of soil

Bearing – capacity method	Soil									
	1	2	3	4	5	6	7	8	9	10
	D = 1.5m	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	B = 2m	2	2	2	2	2	2	2	2	2
	L = 2m	2	2	2	2	2	2	2	2	2
	γ = 20	19	19	17	18	18	20	20	18	18
	Φ = 38° (30°)	44° (35°)	43° (34°)	32° (25°)	35° (28°)	36° (29°)	40° (32°)	44° (35°)	32° (25°)	43° (34°)
	C = 0	0	0	0	0	0	0	0	0	0
Parry (1977)	q_{all} = 6960	4320	8880	1680	3600	3600	6480	12240	1920	8160
Terzaghi	q_{all} = 316.627	614.257	529.986	137.428	217.050	248.484	418.507	646.587	145.512	502.092
Meyerhof	512.381	962.425	824.194	217.713	347.624	400.005	687.123	1013.079	230.520	780.816
Hansen	426.728	712.27	621.632	191.19	296.615	337.372	556.652	749.758	202.437	588.914
Vesic	490.39	844.02	732.93	216.79	338.73	386.43	644.53	888.44	229.54	694.36

Notes:

1) Φ design= Φ / 1.25

2) γ values on the Basis of SPT.

3) All values computed using Microsoft Excel with subroutines for each method. Values all use for L/B = 1.

4) The value of the methods were far away to the parry value.

5. Conclusions:

1. The value of theoretical bearing capacity it was more less than suggested values from Standard penetration test and not practicable value.

2. The Ultimate Bearing capacity calculated using standard penetration test takes into account the SPT value from the field.

3. The four methods used to calculate the ultimate bearing capacity of the soil for comparison have similar values , and the slight difference is due to the different factors of each method.

4. Through the obtained results, it was found that the values from the Ultimate Bearing capacity calculated using standard penetration test are far from the theoretical methods and it is not possible to compare them. It is considered an unreliable method at the present time. Alternative methods are used to obtain the best results.

استخدام قيمة SPT للمقارنة مع الطرق النظرية لحساب سعة التحمل القصوى للأساسات الضحلة

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المستخلص: يعد تقدير السعة التحملية القصوى للأساس الداعم للتربة أحد المتطلبات المهمة لتطوير التصميم الآمن للأساسات. هناك العديد من الطرق المستخدمة لتقدير سعة تحمل التربة مثل الاختبارات النظرية والتجريبية والميدانية. هناك طرق مختلفة مقترحة لتقدير سعة التحمل القصوى النظرية. في هذا العمل ، سنقوم بمقارنة النتائج التي تم الحصول عليها باستخدام المعادلات النظرية مع نتائج اختبار الاختراق القياسي (الاختبار الميداني). لتحقيق هدف الدراسة ، تم اختيار طريقة Terzaghi (1943)، Meyerhof (1963)، Hansen (1970)، Vesic (1973) .

نتائج SPT لـ 10 مواقع من التقرير الجيوتقني الذي تم جمعه من مشاريع إنشاء أبراج اتصالات في مدن سرت ومصراتة وغريان وترهونة وطرابلس تم استخدامها لإجراء هذا التحليل. أظهرت الحسابات أن النتائج التي تم الحصول عليها تبين أن القيم لسعة التحمل القصوى المحسوبة باستخدام اختبار الاختراق القياسي بعيدة عن الطرق النظرية ولايمكن مقارنتها.

يعتمد الاستقصاء الجيوتقني لطبقات باطن الأرض من عدة مواقع على البيانات التي تم جمعها من الحفر التجريبية ومن النتائج المختبرية..الاستنتاج المقدم في هده الورقة يقتصر على سعة التحمل المسموح بها في هذه المواقع لهذه التربة ومع ذلك يمكن ان يكون لاي تربة.

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