Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 1, p. 670-677, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Evaluate the impact of strength parameters on soil bearing capacity

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Article published on July 21, 2014

Key words: Bearing capacity, friction of angle, cohesion strength, modulus of elasticity.

Abstract

In this study, the role and effect of soil resistance including soil cohesion strength, internal friction angle and modulus of soil deformation have been investigated. In order to execute large structures on earth material, subsurface soils should be identified based on radius of stress effects caused by dimensions foundation. To evaluate the impact of the resistive parameters of the soil bearing capacity, Input data for this study was provided from exploratory boreholes, field researches and Laboratory results within the west of Esfahan. According to the results of review and analysis of the tests conducted on soils of the region, they can be divided into two groups. Then, according to the existing empirical criteria, safe and allowable bearing capacity is calculated and finally, the impact of strength and geometric parameters of foundation is been studied.

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Introduction

Bearing capacity is the power of foundation soil to hold the forces from the superstructure without undergoing shear failure or excessive settlement. Foundation soil is that portion of ground which is subjected to additional stresses when foundation and superstructure are constructed on the ground. The following are a few important terminologies related to bearing capacity of soil.

The purposes of foundation engineering studies are required to determine the mechanical parameters on the performance of engineering structures. This relationship must be based on geologist engineer and field survey observations, laboratory and field tests to analyze and classify the materials engineering variable pay. In this regard, the mechanical properties of soils have been subject of research of many scientists and researchers.

Today, with the advancement of human societies the needs for large underground and aboveground structures have increased rapidly. Investigation and assessment the condition of bed material from the perspective of engineering geology are the main parameters for implementation of civil projects. Despite the great progress in estimating the bearing capacity of the foundation, there are some structures which because of the problems in their foundation incurred to devastation. Many studies related to soil bearing problems have been done by scientists from around the world (e.g., Brown and Meyerhoff (1969), Yamguchi and Terashi (1971), Purushothamaraj *et al.* (1973), Meyerhoff (1973), Dembicki and Odrobinski (1973), Tejchman (1977), Meyerhoff and Hanna (1978), Oda and Koishikawa (1979), Hanna and Meyerhoff (1979, 1980), Hanna (1982), Leland and Steven (1982), Button (1993), Michalowaski and Lee (1993)).

Shallow foundations are the most commonly foundations especially for construction and civil projects. This type of foundation after excavation and passing through the fill soil layers that contain organic and unsuitable materials is executed. in order to analysis and design of foundation, the bearing capacity and the amount of soil settlement caused by loading must be determined as well as type of soil, physical parameters (density, water content, porosity, etc.), strength parameters (including cohesion strength of the internal friction angle of soil, modulus of elasticity, Poisson's ratio, etc.) and groundwater conditions must be carefully specified. In this study, the safe and allowable bearing capacity of granular soils has been investigated. For this purpose, input data for this study was provided by field studies and Laboratory results within the west of Esfahan (Fig. 1).

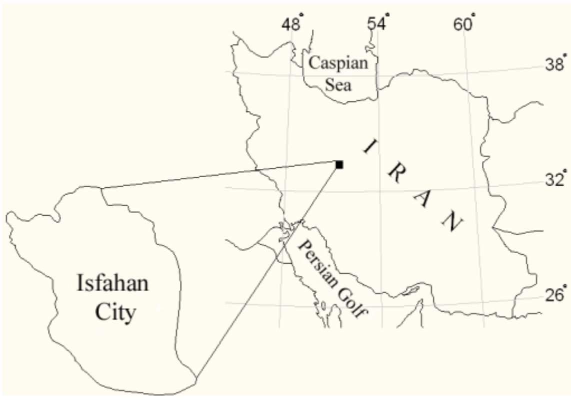

Fig. 1. Locating the study area.

Materials and methods

Research Method

Foundations are an important part of any building which transfer loads caused by the weight of the building to the ground. For durability and safety of structure which is built on soil, the soil of below it must be accurately identified and studied (Leow, 2005). Recognition physical and mechanical properties of soil are from the early stages of research and design of civil projects, so that the soil characteristics can be determined by the results of field and laboratory tests. The number of tests depends on some factors such as the importance of structure, subsurface conditions and economic conditions in each project (Sivakumar *et. al.,* 2006). Due to the natural heterogeneity, methods of measuring strength parameters and unknown deformations of soil, it is likely that the results have contradiction with natural condition (Phoon and Kulhawy, 1999a).

Research Variables

Basically, the shear strength parameters of soils depend on the type and amount of clay minerals in the soil, shape and particle size, particle arrangement, the force between clay particles and chemical composition of water content (Bojana, D., and Ludvik, T., 2007). Soil structure, water content, solid particles and air content are from the perspective of the other parameters affecting the mechanical behavior of soils (Bradley, *et. al.,* 2009). Increase the percentage of fine particles leads to increase in cohesion strength and decrease in Internal friction angle of the soil, although it should be noted that this condition depends on the type of fine particles (silt or clay) (Sunil, *et al.*, 2009).

In this regard, laboratory tests, including grading, Atterberg limits determination, determination of water content, direct shear and triaxial test have been performed on undisturbed samples obtained from exploratory trenching and drilling boreholes. it should be mentioned, the results of plate load test (PLT) were used to estimate parameters such as modulus of elasticity of soil. Table 1 shows the Mechanical and physical properties of soil in area under study.

Table 1. Mechanical and physical properties of soils.

No.	Passing Sieve			Atterberg Limited			C' Kg/cm²	'φ Degree	E Kg/cm²
	Clay & Mud	Sand	Gravel	PL	LL	PI			
1	6	40	54	N.P.	N.P.	N.P.	0.07	33	400
2	8	42	50	N.P.	N.P.	N.P.	0.05	34	380
3	9	35	56	N.P.	N.P.	N.P.	0.05	35	420
4	12	48	40	N.P.	N.P.	N.P.	0.09	32	270
5	15	40	45	15	27	12	0.02	33	310
6	15	70	15	19	28	9	0.08	34	290
7	18	35	47	22	38	16	0.16	33	310
8	23	36	41	19	29	10	0.05	32	290
9	24	41	35	16	25	9	0.06	29	280
10	25	30	45	20	35	15	0.11	30	310
11	25	38	37	21	30	9	0.04	29	270
12	29	37	34	17	24	7	0.02	27	280
13	31	27	42	24	39	15	0.19	31	250
14	32	37	31	23	41	18	0.26	29	260
15	36	39	25	19	28	9	0.12	29	195
16	38	35	27	17	25	8	0.01	28	220
17	42	37	21	26	47	21	0.22	23	180

Table 2. Mechanical and physical properties of type of soils.

Type	Passing Sieve		C' Kg/cm²	φ' Degree	E Kg/cm²
	Clay & Mud	Gravel & Sand			
A	< 25%	> 75 %	0.16 – 0.0 0.069[a]	35 – 29 32.36[a]	325[a]
B	> 25%	< 75 %	0.26 – 0.01 0.12[a]	23 – 31 29.4[a]	240[a]

[a] numerical average

Research Hypotheses

Condition of doing test such as the amount of applied stress (σ_1 and σ_3), test procedure, loading rate, temperature and also mechanical properties of device are affecting the numerical values of soil strength parameters (Su, *et. al.,* 2009).the results of tests done shows a logical relationship between the angle of internal friction and the percentage of fine soil particles while, the numerical value of cohesion strength has a weaker correlation with the percentage of fine-grained particles and it is dependent to other physical parameters such as, plasticity, water content and type of particles. Parameter of Modulus of plastic deformation moreover the particle distribution is related to other quantities such as, density, moisture content etc. however, according to Figs. 2 to 4, soils can be classified into two groups; group A(soil with less than 25% fine-grained) and group B(soil with less than 25% fine-grained).

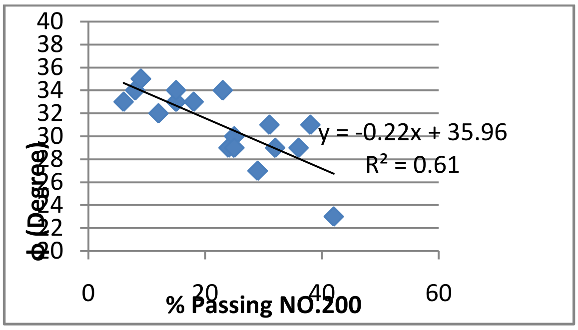

Fig. 2. The relationship between friction angel and dispersion of soil particles.

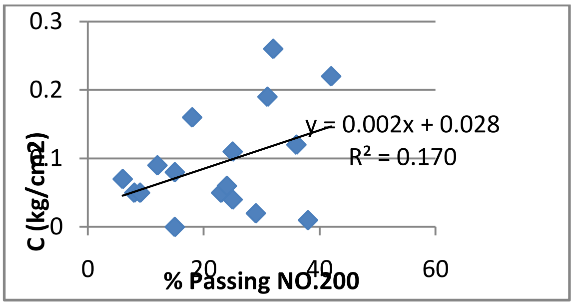

Fig. 3. The relationship between cohesion strength and dispersion of soil particles.

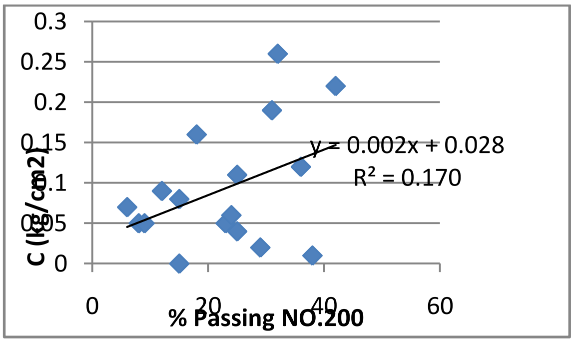

Fig. 4. The relationship between the modulus of plastic deformation and dispersion of soil particles.

Results and discussion

Determination the soil bearing capacity

In order to estimate the bearing capacity and deformability of foundation soils under static and dynamic conditions, computational and numerical methods can be used (Kumar and Khatri, (2008), Kuo, *et. al.,* (2009), Ghazi, *et. al.,* (2010), Junhwan and Eun (2009)).any foundation must be designed by applying two constraints of bearing capacity, ultimate bearing capacity and settlement bearing capacity (Padmini, *et. al.,* 2007). In effect of increasing the stress load on the soil, settlement of soil under foundation increases gradually. Resistance force against the settlement based on soil strength parameters (cohesion strength, angle of internal friction) are provided by the soil particles. Due to the conditions of depositional environment, non-uniformity mode or heterogeneous soil layers seen in nature.to determine the bearing capacity, weighted average soil mechanical parameters should be applied or soil should be considered as homogeneous and uniform (Suchomel and Mašin, 2010). By increasing tension, the amount of settlement grows so the soil is near its maximum bearing capacity and finally, failure occurs for the soil under the building. In order to design foundations based on the circumstances and needs of each project the bearing capacity of the soil can be estimated in two ways, allowable and safe. Terzaqy in 1943 to determine the bearing capacity of a rough strip foundation, presented the following equation (Amy, B., 2007).

If the ultimate capacity of the soil or maximum pressure which soil is able to tolerate and handle it, divide by reliability coefficient, safe bearing capacity (q_{safe}) is gained. Also estimate the soil bearing capacity based on project characteristics and limitation of soil settlement on below structure is the allowable bearing capacity ($q_{allowable}$).

Determination safe bearing capacity of soil

The earliest equation to determine soil bearing capacity for a rough shallow strip foundation on a homogeneous soil layer with depth of semi-infinite was suggested by Terzaqy. Equations presented by scientists were modified by in situ tests on actual foundations and laboratory simulations. It has been proven that Trzaqy studies were conservatively therefore, in the same way some scientists like (Meyerhof, 1954), (Hansen, 1970), (Vesic, 1973) considered some corrections for pervious equations by assuming the continue failure line to ground level, considering the correction factors of foundation depth (d), types of foundation shape(s), foundation gradient(b), load gradient(i) and ground(g). as a result, the general equation to determine the ultimate capacity was prepared as follows:

$$q_{ult} = \left(CN_C F_{CS} F_{Cd} + \gamma D_f N_q F_{q_s} F_{q_d} + \tfrac{1}{2}\gamma B N_\gamma F_{\gamma s} F_{\gamma d}\right)$$

Where

Nc , Nq , and Nγ = bearing capacity factors for friction angle γd

C: Cohesion strength

γ: Density

B: Foundation Width

$F_{cs} F_{qs} F_{\gamma s}$:shape factors

$F_{cd} F_{qd} F_{\gamma d}$:depth factors

Based on the above equation the numerical value of ultimate capacity of the soil is calculated. Then Safe bearing capacity of soil can be achieved by applying the reliability coefficient which is proportional to strength parameter below the foundation, regional conditions, the importance of structure and other effective parameters. The main parameter of the safe bearing capacity of soil is depth of placement of foundation.

According to the studies conducted, by raising this parameter, length of failure envelope and safe bearing capacity resulting from loading will also increase (Loukidis and Salgado, 2009). by Using field studies and laboratory test results on samples obtained from exploratory boreholes the ultimate and safe bearing capacity of soil for square foundations with different dimensions and a depth of 0.5, 1, 1.5 and 2 meters have been computed (fig. 5 and 6).

As mentioned, soils in the area based on the percentage of fine are divided into two categories which from the mean amount of their strength parameters for the calculation been used.

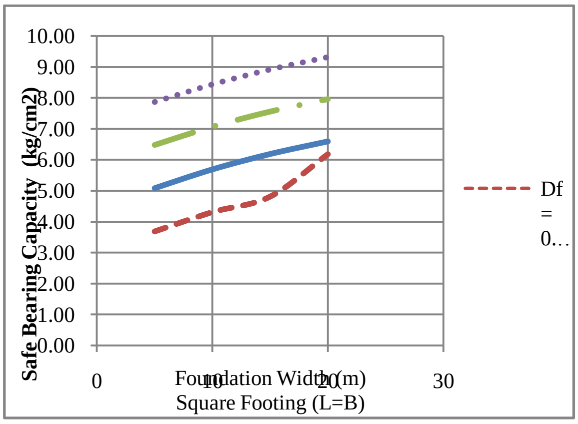

Fig. 5. Safe Bearing capacity (group A).

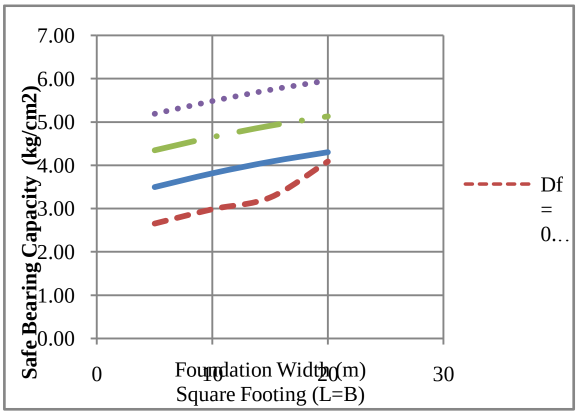

Fig. 6. Bearing capacity allowable (group B).

Determination allowable bearing capacity of soil

For designing of shallow foundations, the amount of soil settlement under the foundation is the main factor in determining and controlling allowable baring capacity. For estimating the immediate settlement of the soil by using the theory of elasticity various equations has been applied. Among these equations can be referred to the equation which was presented by Gazetaz *Et al.* (Gazetaz, *et. al.*, 1991).

$$q_{all} = \frac{S_i \times E_s}{B \times \left(1 - \nu^2\right) \mu_s . \mu_{emb} . \mu_{wall}}$$

Where

$$\mu_s = 0.45\left(\frac{A_b}{4L^2}\right)^{-0.38},$$

$$\mu_s = 1 - 0.04\frac{D_f}{B}\left[1 + \frac{4}{3}\left(\frac{A_b}{4L^2}\right)\right],$$

$$\mu_{wall} = 1 - 0.16\left(\frac{A_b}{4L^2}\right)^{0.54}$$

According to the results of field load test in the study area, deformability modulus of the soil was estimated for the different layers in natural conditions and then, considering to equation proposed the allowable bearing capacity of soil for 1 inch soil settlement for square foundations at a depth of 0.5, 1, 1.5 and 2 meters was estimated (fig. 7 and 8).

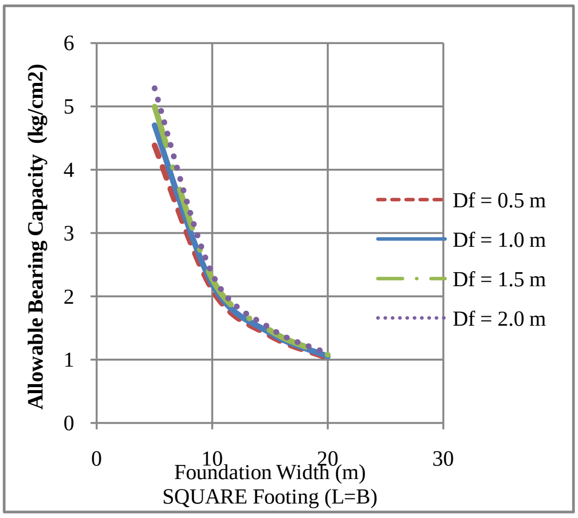

Fig. 7. Allowable Bearing capacity (group A).

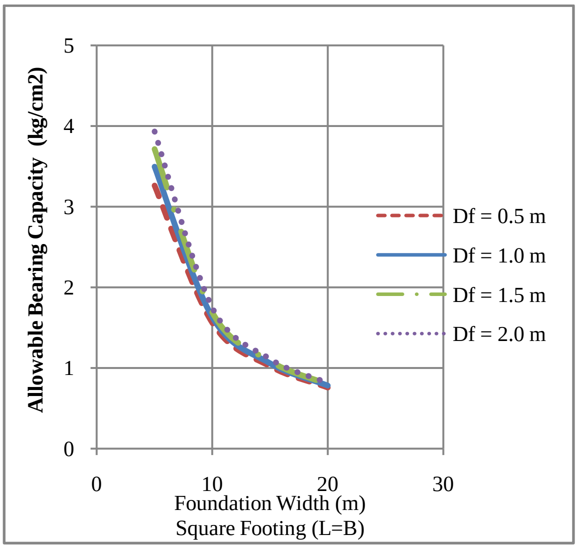

Fig. 8. Allowable Bearing capacity (group B).

Conclusions

Based on the results of tests done in relation to the determination of the strength parameters of soil it can be seen that by increasing the percentage of fine particles and increase the plasticity indices of the soil the amounts of soil cohesion will increase and soil internal friction angle values will decrease. Accordingly, due to a more effective internal friction angle of soil bearing capacity compared with the percentage of fine will be reduced.

Soil strength parameters such as cohesion strength and angle of internal friction are the main factors affecting at determining of safe bearing capacity of soil so that with the rise of these two parameters, the safe bearing capacity increases. In this regard, the role of soil internal friction angle is more significant and the bearing capacity is strongly influenced with changes of this parameter. Settlement in soil will be created proportional to the stress of the structure on the soil of below foundation. To identify the amount of settlement deformability modulus of the soil is used. The numerical amount of this parameter is reduced by increasing the percentage of fine as a result; the amount of allowable bearing capacity of the soil will be decreased. According to the results of the analysis done by increasing the depth of the foundation, soil bearing capacity increases. Considering to the equation of safe bearing capacity of soil, the item in the second sentence depth factor of foundation was applied directly. Also, typically the density and strength of the layer increased with increasing depth. The soil strength parameters such as modulus of deformation plasticity increases, which has a direct impact on the allowable bearing capacity of the soil. By increasing the width of the foundation, (B>10 m) bearing capacity Changes is reduced drastically and soil Bearing capacity curves become close to linear mode, This indicates that, in these condition, changes in soil strength parameters will not have effect on the bearing capacity of soils.

According to the results of the analyses conducted with the increasing size of foundations failure was caused by settlement Along the slip line in soil was gradually and shear strength existed for this reason decreases by increasing dimension of foundation.

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