EVALUATION OF ALLAWABLE BEARING CAPACITY OF SOIL BY PLATE BEARING TEST. A CASE STUDY IN AL-DIWANIYAH CITY

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Abstract: The foundation of soil is considered safe when the factor of safety against shear failure is adequate and the settlement of the foundation should be tolerable and does not cause any unacceptable damage for the structure. The ultimate bearing capacity is defined as the maximum pressure which may be applied to the soil without causing neither a shear failure nor large settlement. In this research the bearing capacity of the soil at diesel power plant project in Al-Diwaniyah city by plate bearing test. The soil has been tested in the field in the locations of four foundations for circular tanks of diameter of 17m. The load is applied to the plate in four increments. In each increment; the load stays static for 15 minutes according to ASTM D1194-94 specification. The results showed that the plate settlements of the soil under three tanks were within the permitted settlement. The allowable bearing capacity of soils under these tanks were (117, 137 and 137) kPa respectively. While, the soil under the fourth tank was soft and the plate settled approximately 30 mm immediately after applying the first increment of load. Therefore the soil is considered improper and recommendations are suggested to improve it.

تقييم سعة تحمل التربة بواسطة فحص تحميل الصفيحة. دراسة حالة في مدينة الديوانية

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الخلاصة

يعتبر اساس التربة امين اذا كان عامل الامان ضد الفشل بالقص مناسب والهبوط ضمن النسب المقبولة ولا يسبب أي ضرر للمنشأ. وتعرف سعة التحمل القصوى للتربة بأنها أقصى ضغط ممكن ان يسلط على التربة بدون حصول أي فشل للقص أو هبوط كبير.

يهدف البحث الى حساب سعة تحمل المسموحة للتربة لمحطة كهرباء في مدينة الديوانية باستخدام طريقة تحميل الصفيحة. تم الفحص موقعيا لاربع اساسات لخزانات دائرية قطر كل واحدة ١٧ متر.تم تسليط الحمل تدريجيا على الصفيحة باربع زيادات. في كل زيادة يبقى الحمل ساكنا لمدة ١٥ دقيقة طبقا للمواصفة ASTM D1194-94. أظهرت النتائج ان الهبوط في التربة تحت ثلاث خزانات كان ضمن المسموح به. وان سعة التحمل المسموحة للتربة لهذه الخزانات هي (١١٧ ، ١٣٧، ١٣٧) كيلوباسكال على التوالي. بينما تبين ان التربة تحت الخزان الرابع ضعيفة وان الصفيحة قد هبطت بمقدار ٣٠ مم عند تسليط الزيادة الاولى من الحمل مباشرة، لذلك اعتبرت هذه المنطقة فاشلة و قد تم تقديم التوصيات الخاصة بمعالجتها.

Introduction

This test method is a semi-direct method to estimate the bearing capacity of a soil in the field be applying a load to a model footing and measure the amount of load necessary to induce a given amount of settlement [1].

Since a load test is of short duration, consolidation settlements can not be predicted. The test gives the value of immediate settlement only. If the underlying soil is sandy in nature, immediate settlement may be taken as the total settlement. If the soil is a clayey type, the immediate settlement is only a fraction of the total settlement [2].

Residual and rebound settlement may be defined as follows [3]:

Residual (plastic*) *Settlement: difference between original and final elevation of a surface due to the application of a load to the surface after removal of the load (unloading).

Rebound (elastic) Settlement: the amount of vertical rebound of a surface that occurs when a load is removed from the surface.

Plate bearing test can give bearing capacity of subsoil up to the depth about twice of plate diameter only [4]. The main advantage of the test is gain understanding behavior of the foundation which will enable the quick and easy evaluation of foundation bearing capacity and settlement under loading condition.

The scope of the work is to evaluate the bearing capacity of soil under circular four tanks of a diesel power plant in Al-Diwaniyah city by plate bearing test.

Equipments

Equipment for the plate bearing test includes a load reaction device, a hydraulic jack assembly, bearing plates and the necessary dial gauges, mounts and miscellaneous tools.

The reaction device can be a truck or another structure [3]. It is loaded with sufficient weight to produce the desired reaction on the surface under test.

The hydraulic jack capacity of 100 tons in order to provide and maintain the maximum estimated load for the specific soil conditions. The hydraulic jack assembly must includes a spherical bearing attachment and be capable of applying and releasing the load in increments.

Three circular steel bearing plates, not less than 25mm in thickness and varying in diameter from (305 to 762 mm), can be employed for the test [4].

The settlement of the plate is measured by a set of two dial gauges sensitivity 0.25 mm [4] (in this test, dial gauges sensitivity 0.01 mm were used) placed opposite to each other. The dial gauges are fixed to an independent support which remains undisturbed during the test.

Procedure of Plate Bearing Test

ASTM D1194-94 specification mentioned that the load is applied to the soil in cumulative equal increments of not more than 95 kPa, or of not more than one tenth of the estimated bearing capacity of the area being tested. Accurately measure each load, and apply it in such a manner that the entire load reaches the soil as a static load, without impact, fluctuation, or eccentricity.

After the application of each load increment, maintain the cumulative load for a selected time interval of not less than 15 minutes. Keep a continuous record of all settlement measurements as soon as possible before and after the application of each load increment, and at such equal time intervals, while load is being held constant. Continue each test until a peak load is reached or until the ratio of load increment to settlement increment reaches a minimum [4].

Load-Settlement Criteria

The load is applied to the plate in increments of the design load. The increments are applied until shear failure, the loading is 2 to 3 times the design load [5], or until a total settlement of 25 mm is obtained [1]. In another criterion, if sufficient load is available, continue the test until the total settlement reaches at least 10% of the plate diameter, unless a well defined failure load is observed. After completion of observations for the last load increments, release this applied load in equal decrements. Continue recording rebound deflections until deformation ceases or for a period not smaller than time interval of loading [4].

Field Plate Loading Test

Plate loading test provide a direct measure of compressibility and occasionally of the bearing capacity of soils which are not easily sampled. The technique adopted in this investigation for carrying out the plate loading test has been described by ASTM D1194-94 [4] and BS 1377 part 9 [6].

The plate was placed on the soil to be tested. The load was applied to the plate in successive increments and settlement was measured. Load increments are applied until the load intensity on the plate reach to (410.6) kPa for all zones in Al-Diwaniyah site as shown in the plates (1) to (4).

The load was applied to the plate via a factory calibrated hydraulic load cell and a hydraulic jack. A plate of a diameter of 0.61m and thickness of 30mm was used.

Settlement is measured using 0.01mm dial gauges. In order to measure any tilt that may occur, two gauges on the perimeter of the plate were used. These gauges supported on rigid uprights fixed firmly into the ground at a distance of more than twice the plate width from the plate center. At each pressure increment, a note was made of the load on the plate and dial gauge readings were made on a

(0.25, 0.5, 1, 3.5, 7.5, 10, 15) minutes after load application. This would ensure sufficient readings in the early stages of each load application when movement occurs most rapidly.

After completion of observations for the last load increment, release this applied load in three decrements. Continue recording rebound deflections until the deformation ceases.

The results of these measurements were plotted in two forms: a time-settlement curve and a load-settlement curve as shown in Figs. (1) to (6).

Field Results

The field results of plate bearing test for the soil at the location of four tanks are shown in Table (1). The recorded settlement, plastic settlement and elastic settlement for Zones (Tank HFO Set5, HFO Set6, DO Set7 and MDU4 Set6) are given. Table (2) shows the settlement corresponding to maximum applied stress and ultimate bearing pressures for the same zones.

The settlement of the top soil layer is predicted from the test results of plate bearing test as follows. Extrapolation of settlement for small plates to real loaded areas on granular soils is given by Tezaghi and Peck (1948) [7] as:

for square footings in granular soils:

$$S_f = S_p \left(\frac{B(b_p + 0.3)}{b_p(B + 0.3)} \right)^2 \qquad (1)$$

and in clay:

$$S_f = S_p \times \frac{B}{b_p} \qquad (2)$$

where:

S_f : Permissible settlement of foundation (mm)

S_p : Settlement of plate (mm)

B : Size of foundation (m)

b_p : Size of plate (m).

The soil in the site is a clay soil, and according to Eq. (2), the real settlement for the circular foundation of tanks (17m dia.) becomes as:

$$S_{HFO\ Set5} = 4.02 \times \frac{17}{0.61} = 112\ mm$$

$$S_{HFO\ Set6} = 3.51 \times \frac{17}{0.61} = 97.8\ mm$$

$$S_{DO\ Set7} = 3.47 \times \frac{17}{0.61} = 96.7\ mm$$

Skempton and McDonald [8] suggested the design limits for maximum settlement for raft foundation on the clay soil as 100 mm. From Table (3) it can be seen that the settlements in zones HFO Set6 and Do Set7 are within the permitted settlement, but the settlement in zone HFO Set 5 is exceed the permitted settlement. Therefore the

settlement in zone HFO Set5 to consider is 100mm and according to Eq. (2) the settlement of the plate becomes 3.59 mm, then from Fig. (1), the maximum applied stress is 350 kPa

Bowles [1] mentioned that for extrapolating the load-test results to full-size footings, the bearing capacity of clay is essentially independent of the footing size, or

$$q_{footing} = q_{plate} \quad (3)$$

The factor of safety against shear failure of the supporting soil must be adequate, a value between 2.5 and 3 normally being specified [1]. In this study 3 is used, then the allowable bearing capacity and maximum settlement for zones (HFO Set5, HFO Set6 and DO Set7) are shown in the Table 4.

Conclusions

The main conclusions that have been achieved from the test results may be summarized as follows:-

1- The increase in the elapsed time for the static applied pressure causes increase in the value of settlement for all tested zones up to 15 minutes and the settlement is faster in the first few seconds after each new load increment.

2- The allowable bearing capacity for HFO Set5, HFO Set6 and DO Set7 zones are 117, 137 and 137 kPa respectively.

3- The maximum settlement for HFO Set5, HFO Set6 and DO Set7 zones are 100, 97.8 and 96.7 respectively.

4- The soil in MDU4 Set6 zone was soft and the plate settled down immediately after applying the load.

References

[1] Bowels, J. E., **"Foundation Analysis and Design"**, McGraw-Hill Book Company, New York, Fourth Edition, 1988.

[2] Murthy, V.N.S., **"Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering"**, New York, 2000.

[3] Members of the Asphalt Institute, **"Soils Manual for the Design of Asphalt Pavement Structures"**, the Asphalt Institute, USA, 1988.

[4] ASTM D1194-94, **"Test Method for Bearing Capacity of Soil for Static Load and Spread Footing"**, Annual Book of ASTM Standards: Volume 04.08, October 2003.

[5] British Standards Institution, **"BS 5930: 1981"**, British Standards Institution, London, 1981.

[6] British Standards Institution, **"BS 1377, Part 9"**, British Standards Institution, London, 1990.

[7] Terzaghi, K. and Peck, R.B., **"Soil Mechanics in Engineering Practice"**, Wily, New York, 1948.

[8] Skempton, A., W., et al., **"Settlement Analysis of Six Structures in Chicago and London"**, PICE, part 1, vol. a, Jully, pp. 525-544, 1955.

Table (1): Recorded settlement, plastic settlement and elastic settlements for all tested zones

Zone	Recorded Settlement (mm)	Plastic Settlement (mm)	Elastic Settlement (mm)
HFO Set5	4.02	1.67	2.35
HFO Set6	3.51	2.96	0.55
DO Set7	3.47	1.15	1.32
MDU4 Set6	30*		

*: Meaning the settlement is greater than the allowable settlement.

Table (2): Recorded settlement of the plate due to maximum applied stress

Zone	Recorded Settlement (mm)	Maximum Applied Stress (kPa)	Ultimate Bearing Pressure (ton/m^2)*
HFO Set5	4.02	410.6	41.1
HFO Set6	3.51	410.6	41.1
DO Set7	3.47	410.6	41.1
MDU4 Set6	30	136.9	13.7**

*: Ultimate bearing pressure corresponding to recorded settlement of the plate.

**: Ultimate bearing pressure is smaller than the anticipated applied load, therefore the point was considered unsuccessful.

Table (3): Recorded maximum settlement for the foundations due to maximum applied stress

Zone	Recorded maximum Settlement (mm)	Maximum Applied Stress (kPa)
HFO Set5	112	410.6
HFO Set6	97.8	410.6
DO Set7	96.7	410.6

Table (4): Recorded maximum settlement and allowable bearing capacity

Zone	Recorded maximum Settlement (mm)	Allowable Bearing Capacity (kPa)
HFO Set5	112	117
HFO Set6	97.8	137
DO Set7	96.7	137

Plate (1): Plate Bearing Test for Location of Tank HFO Set 5

Plate (2): Plate Bearing Test for Location of Tank HFO Set 6

Plate (3): Plate Bearing Test for Location of Tank DO Set 7

Plate (4): Plate Bearing Test for Location of MDU 4 Set 6

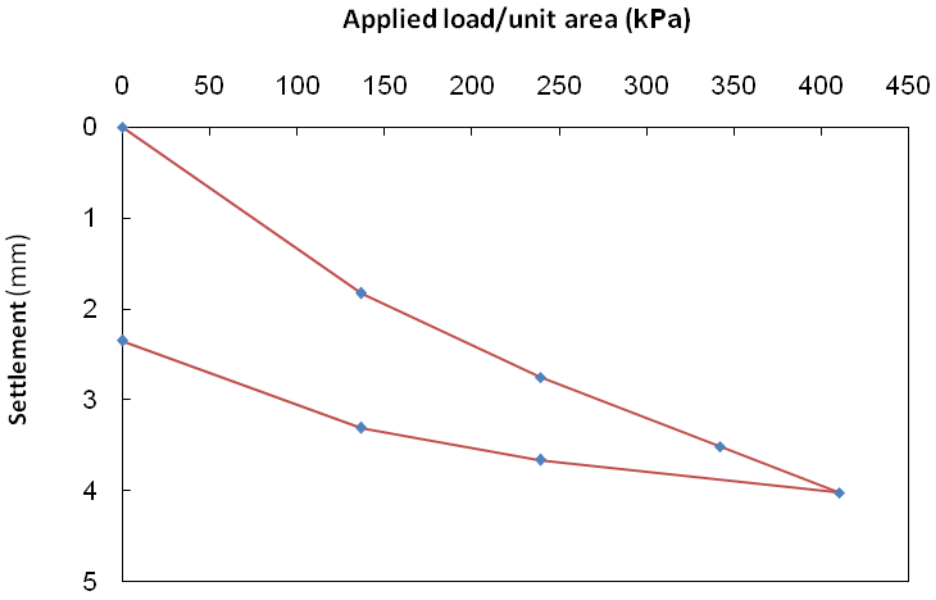

Figure (1): Load-Settlement Curve for Tank HFO. Set 5

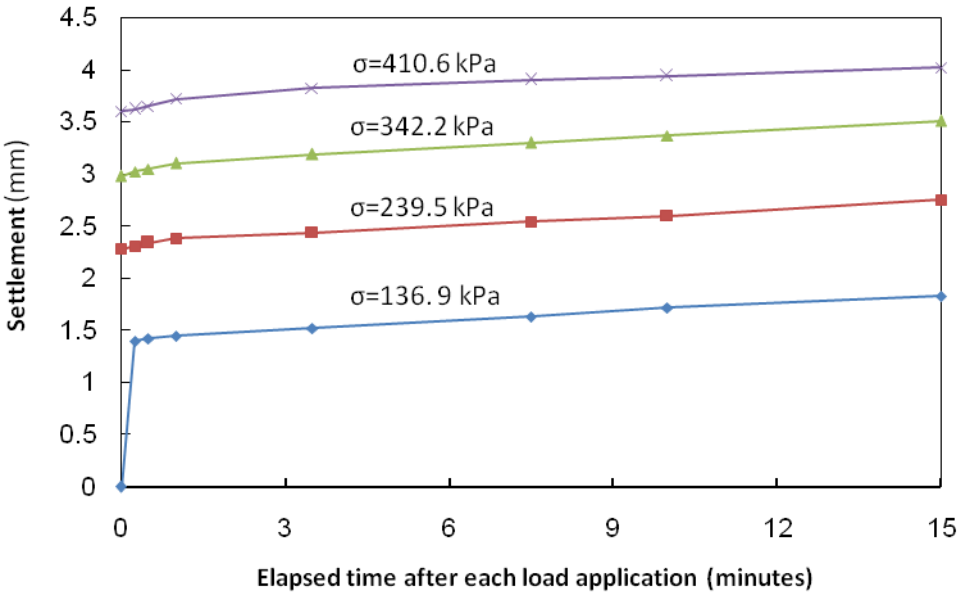

Figure (2): Time-Settlement Curves for Tank HFO. Set 5

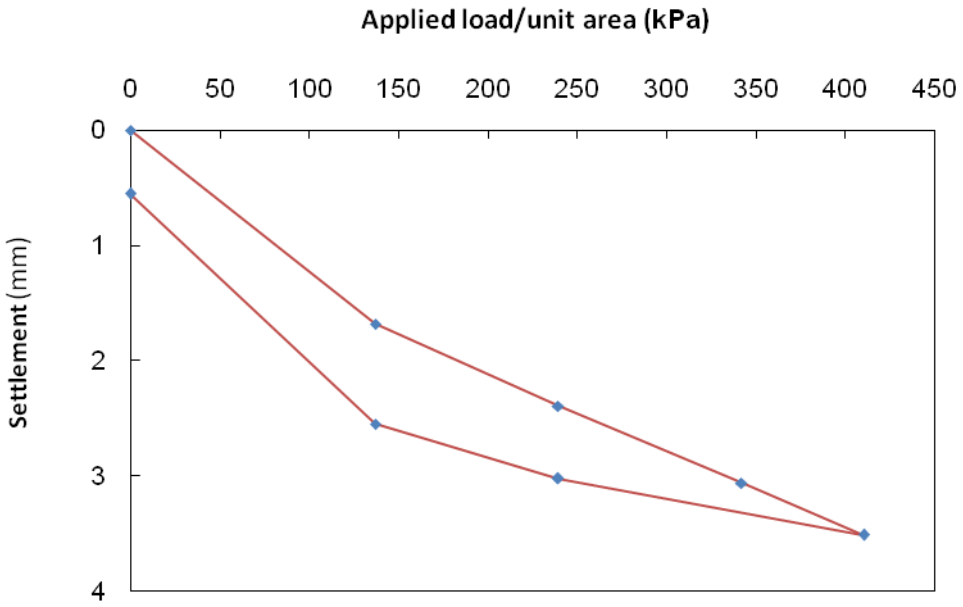

Figure (3): Load-Settlement Curve for Tank HFO. Set 6

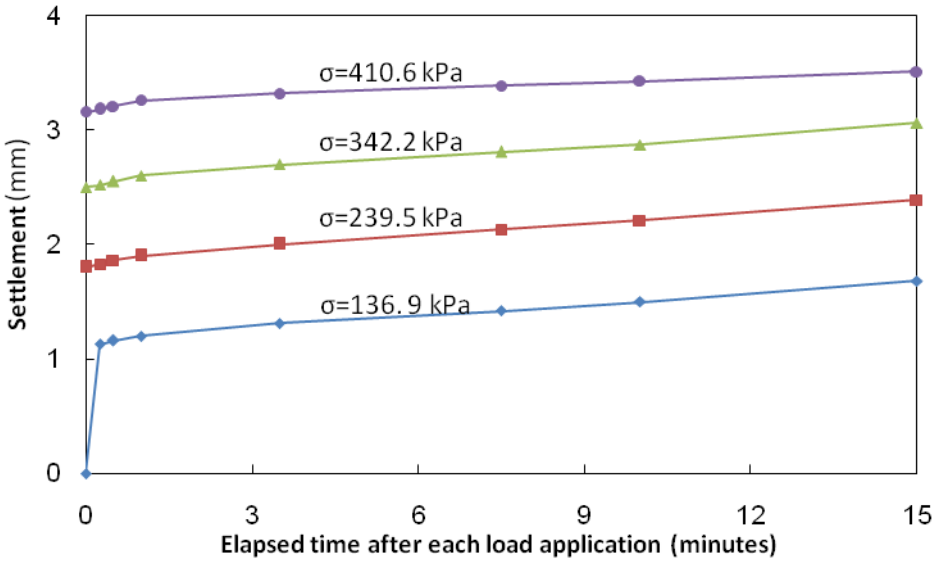

Figure (4): Time-Settlement Curves for Tank HFO. Set 6

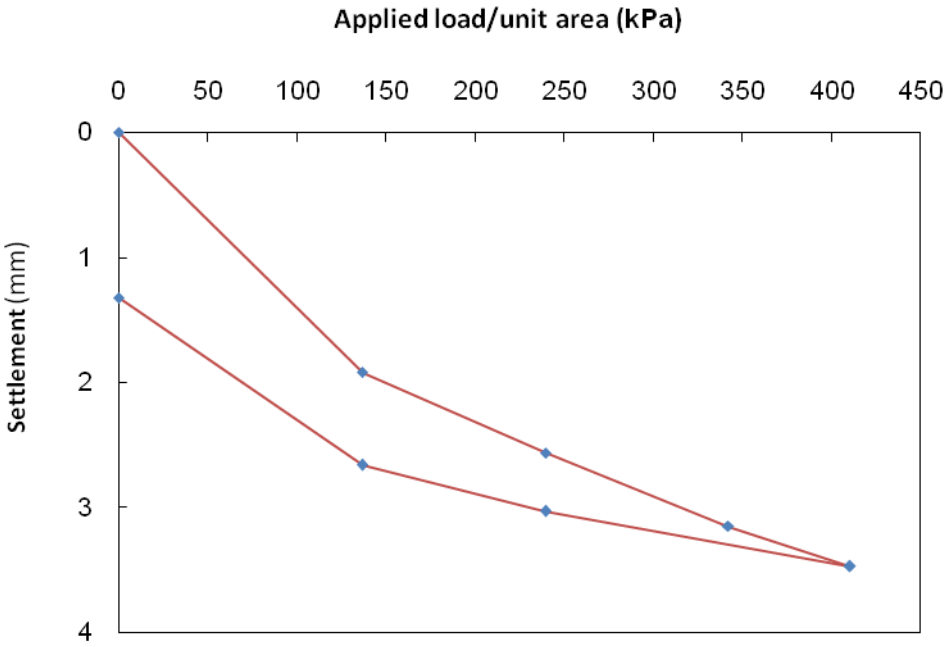

Figure (5): Load-Settlement Curve for Tank DO. Set 7

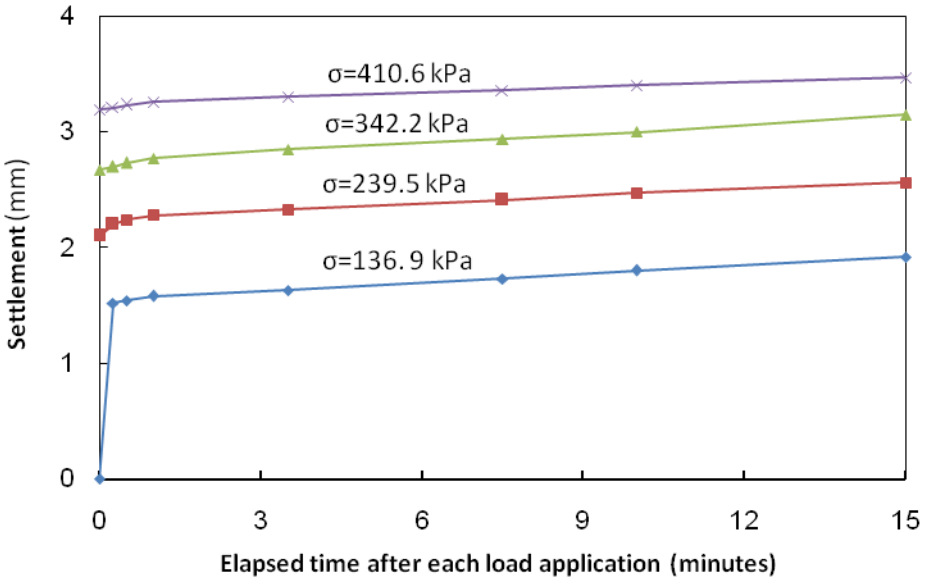

Figure (6): Time-Settlement Curves for Tank DO. Set 7