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The use of CPT to predict the load carrying capacity of piles in expansive soils of Sudan

L'utilisation des données de CPT pour prédire la capacité de pression de bornes pieux dans les sols expansifs du Soudan

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ABSTRACT
The determination of load carrying capacity of bored piles generally uses the conventional semi-empirical static methods. For piles in expansive soils, more concern was given to the uplift forces. Few researches dealt with the prediction of the load carrying capacity of bored piles in expansive soils. In this paper some published CPT based methods are used to predict the ultimate capacity of bored piles and the change in capacity due to increase of moisture from semi-dry to excessive wetting. The results show that the CPT based design methods are promising when used to predict the capacity of small diameter short bored piles.

RÉSUMÉ
La détermination de la capacité de pression apportée aux bornes des pieux utilise généralement les méthodes statistiques de la convention semi- empirique. Pour les pieux dans les sols expansifs; une grande attention est donnée aux forces du levage. Peu de recherches ont été attribuées à la capacité de la pression apportée aux bornes des pieux dans les sols expansifs. Cet article applique quelque CPT méthode basée pour prédire l'ultime capacité des bornes de pieux et le changement dans la capacité due à l'augmentation de moisissure de semi-aride à la saturation excessive, Les résultats montrent que les méthodes de calcul du CPT ont été promues quant elles sont utilisées pour prediction la capacité du petit diamètre de courts bornes pieux

1 INTRODUCTION

Expansive soils are considered by foundation engineers as problem soils. They have the characteristic of changing volume upon wetting and drying. They therefore cause considerable damage to structures as is the case in Sudan. The use of bored concrete piles to support lightly and moderately loaded structures has been found efficient in combating foundation heave.

The use of Cone Penetration Test, CPT, in geotechnical investigations appeared in Sudan in the early seventies of the 20th century. The test has been routinely used for classification of soils and for design of foundations (Osman and Ahmed 2003). Local experience has been gained in using the CPT data for soil classification and for the prediction of strength parameters (Zein, 2004). The use of CPT is encouraged by the difficulties usually encountered in sampling the very stiff to hard expansive clay soils. World-wide the test is most preferred for assessing foundation performance as compared with other in-situ test methods such as Standard Penetration Test, pressuremeter, and dilatometer tests (Mayne et al 1995).

This paper evaluates some published CPT based design methods to predict the allowable bearing capacity of two bored piles fully embedded in expansive soils. The predictions were weighed against load test results of two piles. One of the piles was load tested under field moisture conditions while the other was load tested following prolonged wetting of the surrounding soil. CPT tests were performed for natural and wetted conditions.

2 THE CPT-BASED DESIGN METHODS

The CPT-based methods for determination of pile capacity may be grouped into direct and indirect methods. The direct methods use the CPT data as direct input in empirical formulae to provide estimate for pile capacity. As for the indirect methods the CPT data is used to estimate soil parameters that are utilized in theoretical models for prediction of the static pile capacity.

Titi and Abu Farsakh (1999) reviewed several known direct CPT-based methods used for the prediction of pile capacities of which are: Schmertsmann method (1978); de Ruiter and Beringer method (1979); Bustamante and Gianeselli method (LCPC/LCP) (1982); Tummy and Fakhroo method (1982); Akoi and de Alendar method (1975); Price and Wardle method (1980); Philliponnat method (1980)

Shmertsmann method related the pile skin friction to the sleeve friction of the cone by applying a safety factor of 0.25 to 1.25 to the sleeve friction values of clay soils. The unit base resistance is calculated as a function of the average minimum over a length of 4 to 8 times the pile diameter.

De Ruiter and Beringer method is based on experience in Europe. It expresses the skin friction as a ratio (maximum 0.1) of the un-drained shear strength of the soil around the pile shaft which is also a function of cone resistance. The pile base resistance is a function of the undrained shear strength which is obtained based on the cone resistance divided by a factor of 9.

Bustamante and Gianselli method related the pile base resistance to the equivalent average cone tip resistance around the pile tip using a factor of 0.15 to 0.6. They did not give any concise relationship for the shaft resistance.

Tummy and Fakhroo method calculated the unit skin friction as a function of average local sleeve friction multiplied by an adhesion factor, while the pile unit base resistance is calculated using the average maximum and the average minimum of the cone resistance over a distance of 4 times the pile diameter above and below the tip.

Akoi and de Alendar method related the unit skin friction to the average cone resistance multiplied by an adhesion factor and divided by an empirical factor (3.5 for bored piles) giving a limiting value of 120 kN/m^2 for unit skin resistance. The unit base resistance is to be calculated as the average cone resistance around the pile tip divided by an empirical factor (1.75 for bored piles) giving a limiting value o 1500 kN/m^2 for unit base resistance.

Price and Wardle method related the unit skin friction to the local sleeve friction along the pile shaft multiplied by 0.49 (for bored piles) given a limiting value of 120 kN/m^2 for unit skin friction. The unit base resistance is calculated by multiplying the cone resistance by a factor of safety of 0.3 for jacked and bored piles given a limiting value of 15000 kN/m^2 for unit base resistance.

Philipponat method related the unit skin resistance to the cone resistance multiplied by an adhesion factor (less than unity) and divided by a factor that depends on soil type (50 for clay) while the unit base resistance is calculated by multiplying the average cone resistance over a distance of 3 times the pile diameter by a factor of 0.5 for clays.

3 DESCRIPTION OF FIELD TESTS

The test site was selected in an area dominated by expansive soil of high potential in the eastern part of Khartoum. The program of field tests was arranged and executed as follows: Five piles were casted, three anchor piles 0.7 m diameter and 8.0 m in length and two small diameter test piles, each 0.35m diameter and 3.0 m in length.

The tests were performed in the following sequence: two CPT soundings were performed in the test area close to the locations of the test piles to 5.0m depth. Load test was conducted to failure on the first test pile. The pile offered an ultimate bearing capacity of 53.0 tons. Then the area around the two test piles was subjected to intensive artificial wetting (flooding) continuously for about two months. Pile load tests were then conducted on the two test piles. They gave ultimate capacity values of 21.07 ton and 21.0 ton for the first and second test piles, respectively. CPT tests were performed close to the test piles after the artificial wetting. The test points were made as close as possible to the piles to minimize the errors when using the CPT data to estimate the bearing capacity of such piles. The test results were presented in Fig. 2, and Fig. 3. Line qc1 corresponds to the qc values before wetting while line qc2 corresponds to qc values after wetting.

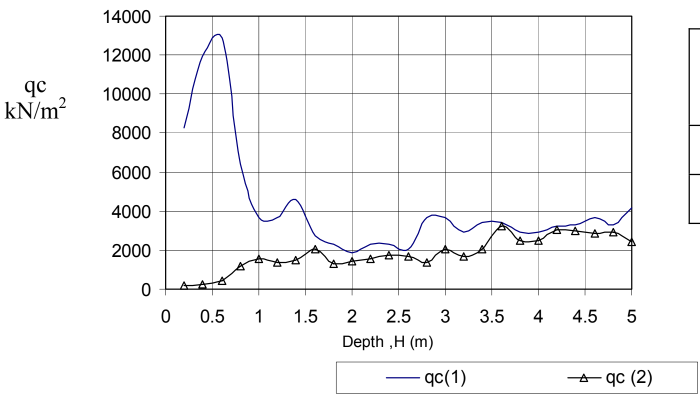

Figure 1: CPT Results Close to the First Test Pile

4 ANALYSIS AND DISCUSSION OF RESULTS

Figure 1 and Figure 2 show remarkable reduction in cone resistance due to wetting of the surrounding soil. This reduction justifies the large drop in bearing capacity due to wetting. A large reduction in cone resistance value occurred in the top one meter mainly due to loss of strength due to the excessive wetting of the upper 1.0 m, followed by a moderate reduction in the upper half of the second meter, and followed by non homogeneous reduction values in the third meter. The reduction of cone resistance could easily reflect the reduction in unconfined shear strength since they are well related.

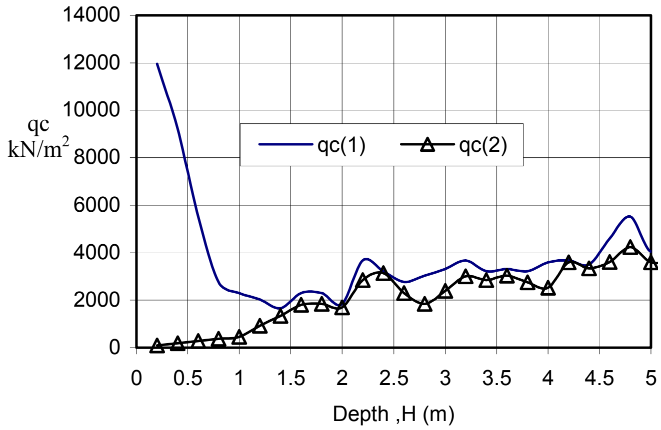

Figure 2: CPT Results Close to the Second Test Pile

The CPT data before and after wetting were used as inputs for the purpose of estimating the bearing capacity of piles based on the design methods presented here-above. The estimated values were compared with the load test values before and after wetting. Table 1 presents the results of estimated bearing capacity using the CPT design methods before wetting, and Table 2 presents the results of estimated bearing capacity using CPT design method after wetting.

Table 1: Predicted Capacities Before Wetting

Method	Schmert-mann	De Ruiter	Akoi and de Alendar	Price and Wardle	Philipon-nent
Qu (ton)	57.7	52.64	57.74	45.3	28.97
Error %	+8.86	-0.68	+3.28	-14.53	-45.34

Table 2: Predicted Capacities After Wetting

Method	Schmert-mann	De Ruiter	Akoi and de Alen-dar	Price and Wardle	Philipon-nent
Qu (ton)	23.93	18.12	17.61	22.24	13.69
Error %	+9.907	-16.78	-19.12	+2.14	-37.2

Before wetting the estimation of bearing capacity using different methods suggest that De Ruiter method is rated the best in estimating the ultimate capacity (error=.068%), followed by Aoki & de Alendar method (error=+3.28%), Schmertmann method (error=+8.86%) and Price & Wardle (error = 14.53%). Phillipponnet and Pen pile showed great variability, error of -45.3% and -56.55 were reported respectively for the two methods.

After wetting the estimation of bearing capacity using different methods suggest that Price and Wardle method is the first (error=+2.14%), followed by Schmertmann method, (error=+9.907%), De Ruiter method (error=+16.78%), and Aoki & De Alenedr method (error =+19.16%). Phillipponnet and Pen Pile methods showed the highest errors (–37.2% and –40.75%).

5 CONCLUSIONS

The CPT is a useful tool for geotechnical investigation in very stiff to hard expansive soil deposits. The study showed that some CPT methods could be successful in estimating the ultimate bearing capacity of bored concrete piles in expansive clays of high potential. The methods, as expected, vary in their success in the estimation. When the clay is dry to semidry De

Ruiter method followed by Aoki & De Alendar method were the best. However for wetted conditions Price and Wardle method is the best followed by Schmertsmann method.

The wetting conditions of the soils affected the predictions. This variability when estimating the bearing capacity reflect the fact that more researches is needed in this area.

REFERENCES

Mayne (1995), "The Cone Penetration Testing", CPT 95.

Osman M.A. and Ahmed O. El Fatih (2003), "Evaluation of Some CPT Classification Methods for Some Local Soils", Building and Road Research Journal, Vol. 5, 2003.

Titi and Abu Farsakh (1999), "Evaluation of Bearing capacity of piles from cone penetration test data", Louisiana Department of Transportation and development, Louisiana Transportation Research Center, No. 1999.

Zein A. M. (2004) "Use of Static Cone Penetration Test for Classification of Local Soils" Building and Road Research Journal, Vol. 5, pp. 23-29, Building and Road Research Institute, University of Khartoum.