Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 9 (10): 1968-1973, 2009
ISSN 1812-5654

Bearing Capacity of Stabilized Peat Column Using Hand Operated Cone Penetrometer

Md. Shahidul Islam and R. Hashim
Department of Civil Engineering, Faculty of Engineering,
University of Malaya, 50603 Kuala Lumpur, Malaysia

Abstract: The main objective of this study is to stabilize peat soil by deep mixing method using cement, sand, bentonite and calcium chloride as binder and to determine the effect on bearing capacity using proving ring hand operated cone penetrometer. Eight soil-binder columns have been constructed by mixing auger and prebored and premixing method using two different combination of binder. Bearing capacity of the columns has been evaluated by hand operated cone penetrometer after 1, 3, 7, 14 and 28 days of curing time. From the test results it was observed that bearing capacity of peat column increased considerably after stabilization.

Key words: Deep mixing method, binder, mixing auger, prebored premixed, curing time

INTRODUCTION

Problematic peat soil poses serious problem in construction due to its low bearing capacity, low shearing strength and high compressibility. Ground improvements are being often required before undertaking any construction work over this type of soft soil. Conventional methods of peat soil stabilization are soil replacement, soil displacement, RCC pile, stone pile, sand drains, preload etc. But all these methods are not economical and prolong construction time. Deep Mixing Methods (DMM) is now a day's very much suitable for stabilization of peat soil considering cost and time. The essential feature of deep soil stabilisation is that columns of stabilised material are formed by mixing the soil in place with a binder and the interaction of the binder with the soft soil leads to a material which has better engineering properties than the original soil (Hebib and Farrell, 2003).

One of the main steps for the safe and economic design of foundations is determination of ultimate bearing capacity. The maximum load that can be applied to subgrade soil from the foundation without occurrence of shear or punching failure, keeping settlement to a limited range and avoiding serviceability damage to super structures (Eslami and Gholami, 2006). The Cone Penetration Test (CPT) is regarded as an effective tool for pile design, since it resembles the penetration process of a pile. However, CPT resistance is significantly higher than the equivalent pile base resistance (Borghi *et al*., 2001).

Hashim and Islam (2008) conducted an experiment to stabilize peat soil by soil-cement column method using various types of binder using prebored and premixed method. Hand operated cone penetrometer has been used in that experiment to determine undrained shear strength after 14 days of stabilization. Nevertheless, Prebored and premixed method is not suitable method for actual construction works and soil is stabilized by soil-cement column using mixing auger. So, the present study is aimed to use mixing tools instead hand mixing and to observe increase in bearing capacity with increment of curing time. The objective of this study is to stabilize problematic soil by deep mixing method using binders and determine effect on bearing capacity by hand operated cone penetrometer. The purpose of this study is to find a suitable method to determine bearing capacity of stabilized soil and to compare bearing capacity of stabilized peat by hand mixing and using mixing auger.

HAND OPERATED PROVING RING CONE PENETROMETER

The axial capacity of a single pile has to be predicted for the design of a piled foundation. This requires the knowledge of appropriate soil parameters and their influence on both base and shaft resistance of a pile. The complexity of the penetration mechanism as well as the diversity of the governing parameters justifies the use of an empirical method based on *in situ* measurements. Design methods based on the Cone Penetration Test (CPT) allow the unit base resistance q_b of a pile to be correlated directly to the unit cone penetration resistance q_c. Since, the CPT resembles the geometry and vertical penetration process of a pile, a one-to-one correlation of q_b and q_c seems intuitive. Several researchers in recent design guidelines (Biddle, 1997; Tomlinson, 1998; Bowles, 1997; Fleming *et al*., 1992) recommend that pile base resistance q_b should be taken to be equal to the cone resistance q_c.

Corresponding Author: Md. Shahidul Islam, Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603, Kuala Lumpur, Malaysia Tel: +60162362378 Fax: +603-7967-5318

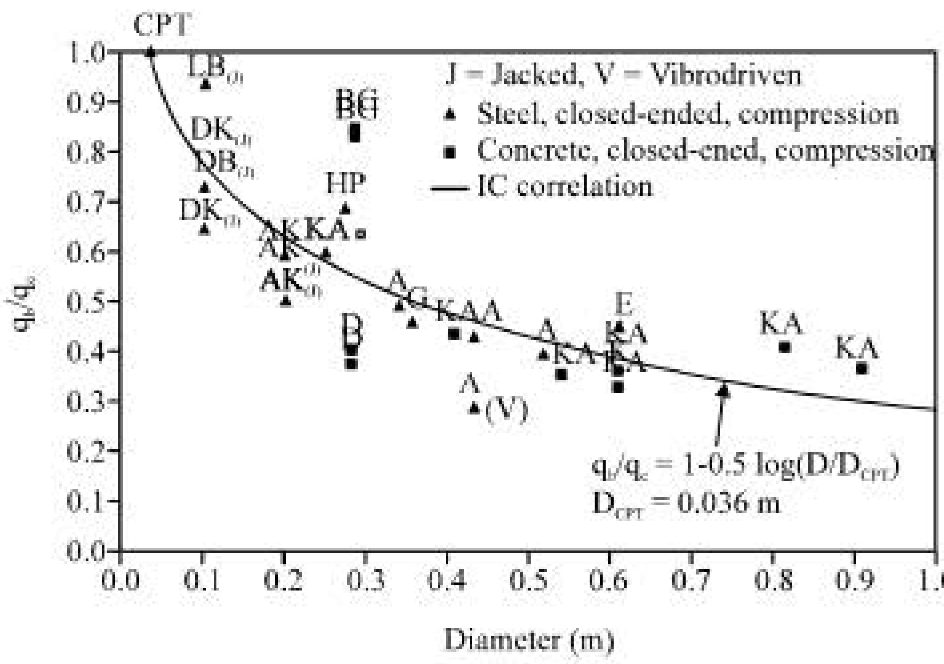

Fig. 1: The base resistance scale effect (Chow, 1996)

This, however, has been shown to be inconsistent with field and laboratory observations. Indeed, the unit base resistance of a pile appears to decrease markedly as its diameter increases, so that a penetrometer (D = 36 mm) has a much greater unit base resistance than the unit base capacity of a pile in the same soil. This trend is referred to as the base resistance scale effect. It has been demonstrated experimentally by Kerisel (1961), Tejchman and Gwizdala (1979), Meyerhof (1983) and more recently by Chow (1996) (Fig. 1). Her database of load tests reveals that the ratio of the pile to the penetrometer base resistance q_b/q_c may be as little as 0.4 for close-ended pile of diameter 600 mm. Hence, designing a pile with the oversimplified assumption that $q_b = q_c$ may lead to a dangerous over prediction of the pile capacity.

The cone penetration test consists of advancing a cylindrical rod with a conical tip into the soil and measuring the forces required to push this rod. A proving ring hand operated cone penetrometer (Fig. 2) has been used in this experiment which consists of a T handle, penetration rod, proving ring of 1 kN capacity with dial indicator and a removable cone point. The penetrometer is pressed into the soil manually and relates the force required to drive the probe a certain distance through a soil in order to determine the relative density, stiffness, strength or bearing capacity. Unit cone tip (q_c) resistance is obtained from this test by following equation:

$$q_c = \frac{\text{Required force to penetrate the cone}}{\text{Base area of the cone}} \quad (1)$$

Bustamante and Gianeselli (1982) proposed an equation to determine the bearing capacity (q_t) from the cone tip resistance. The equation is as follows:

$$q_t = K_b\, q_c \quad (2)$$

Fig. 2: Hand operated proving ring cone penetrometer

Table 1: Bearing capacity factor (K_b)

Soil type	Bored piles	Driven piles
Clay-silt	0.375	0.600
Sand-gravel	0.150	0.375
Chalk	0.200	0.400

(Bustamante and Gianeselli, 1982)

where, K_b is an empirical bearing capacity factor that varies from 0.15 to 0.60 depending on the soil type and pile installation procedure (Table 1).

The proving hand operated cone penetrometer has been calibrated for peat soil by comparing with laboratory vane shear test data. It was found that the bearing capacity factor for peat soil is 0.5. We have used the value for present experiment.

MATERIALS AND METHODS

The test was conducted in Klang, Selengor Darul Ehsan in Malaysia from September 2008 to December 2008. Both disturbed and undisturbed sample were collected to characterise peat soil by performing moisture content, organic content, fibre content, ash content, specific gravity and pH test in laboratory. All this tests were performed following BS 1377:1990 standard. Test peat was excavated to find out the water table and Mackintosh test was performed to determine the bearing capacity of in situ peat soil in different layers.

Binder: Ordinary portland cement, high setting cement, bentonite, calcium chloride and well graded silica sand were used for field experimentation. Short description of these binders is as follows.

Cement: Two types of cement such ordinary portland cement and high setting cement was used in this experiment. Both of these cements were collected from

Table 2: Mixing proportion of binder

Mix No.	Dosage rate (kg m^{-3})	Ordinary portland cement	High setting cement	Bentonite	Calcium chloride	Sand
1	300	85% of total binder		15% of total binder		25% of total in volume basis
2	300		100% of total binder		4% of total binder	25% of total in volume basis

Malaysian local market. YTL brand cement was used as ordinary portland cement which is using in normal construction works. On the other hand MASCRETE brand cement is produced by Lafarge (Malaysia) was used as high setting cement.

Sodium bentonite: Sodium bentonite was used which is highly swelling material imported from America. CETCO (Colloid Environmental Technologies Company), Arlington Height, USA supplies the bentonite material.

Calcium chloride ($CaCl_2$): Dehydrate calcium chloride ($CaCl_2.2H_2O$) has been used as admixture in this experiment. Minimum assay content of this substance was 74%. Maximum impurities were free alkali iron (Fe) 0.005% and magnesium and alkalies (sulphate) 0.5%.

Sand: Sand plays a vital role in enhancing the bond in cementation reactions of soil mixing. It is found that grain size distribution provides a satisfactory skeleton and the voids are filled with fine-sand, giving a compact and high load-bearing capacity. The type of sand used in the laboratory was from Kuala Selangor, Selangor in Malaysia.

Preparation binder: Binders have been used in this experiment in two different mixing proportions. Binder has been applied at a dosage rate of 300 kg m^{-3} of the total volume of column. Mixing proportions of binder are showing in Table 2. Binders have been prepared in laboratory using a mixture machine.

Mixing tools: From laboratory model study, a set of mixing tools have been selected for field column installation. The tools consist of a 200 mm diameter mixing auger, a 50 mm diameter wooden tamping tools and a 50 mm piston. Figure 3 shows the mixing tools.

Installation of column: A 50 mm diameter and 1000 mm borehole has been made by penetrating drilling piston (Fig. 4a) and pulled out. Binder has been inserted into the borehole to form binder column and tamping simultaneously to ensure that there is no cavity inside the binder and binder to reach upto the bottom (Fig. 4b). Three numbers of boreholes have been made for each column in such a way that the binder can be mixed uniformly. The mixing tool was rotated along the binder columns and is penetrated downward upto the desire depth (Fig. 4c). Then it is rotated opposite direction and pulls the mixture upward. The rotation of mixing tool

Fig. 3: Mixing tools for field column installation

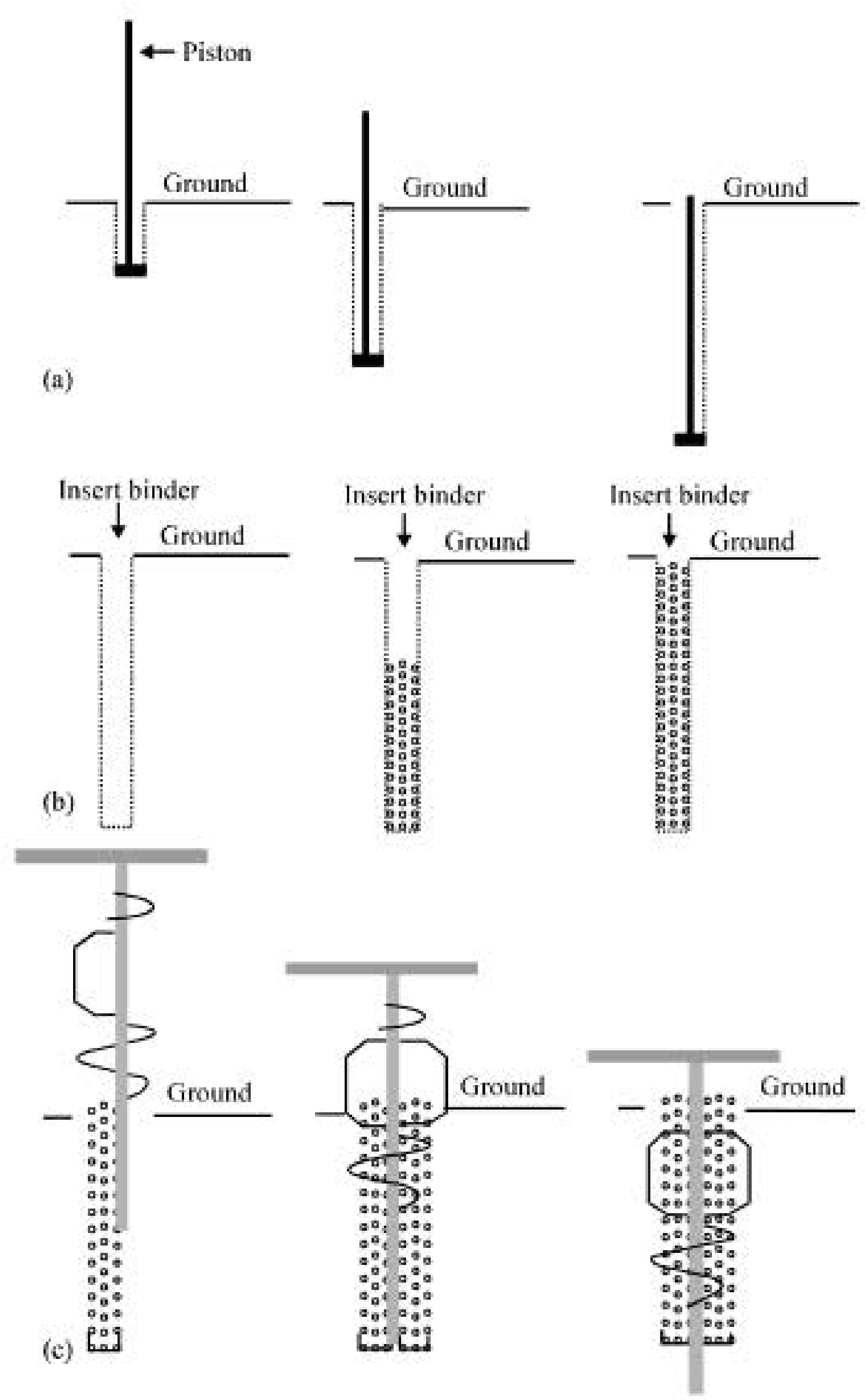

Fig. 4: Procedure of column installation (a) penetration of piston (b) insert binder and (c) mixing by auger

Table 3: Detail programme for installation of single columns

Column No.	Binder	Column diameter (mm)	Column height (mm)	Method	Test (3, 7, 14 and 28 days)
1 and 2	Binder 1	200	1000	Mixing by tools	Hand operated cone penetrometer test
3 and 4	Binder 1	200	1000	Prebored and premixed	Hand operated cone penetrometer test
5 and 6	Binder 2	200	1000	Mixing by tools	Hand operated cone penetrometer test
7 and 8	Binder 2	200	1000	Prebored and premixed	Hand operated cone penetrometer test

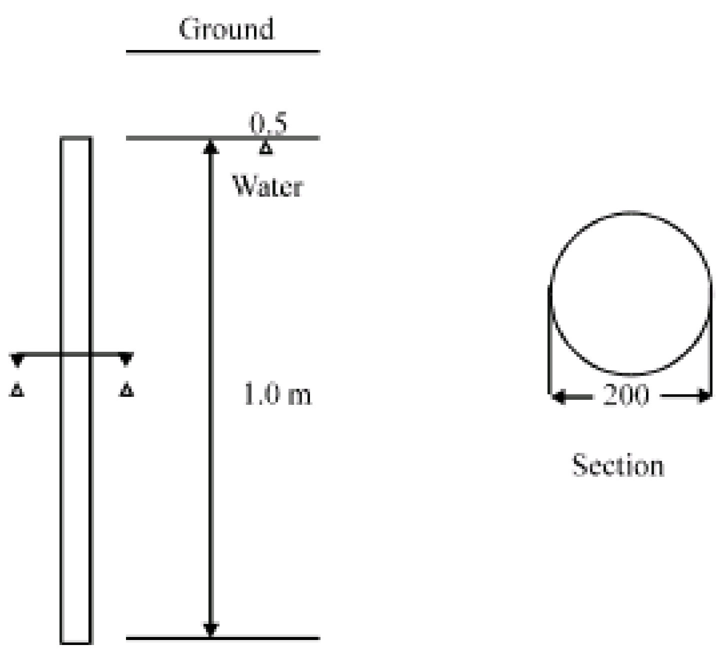

Fig. 5: Detail of column (not in scale)

upward and downward is done several times until binder and peat soil mix properly.

Total eight numbers of single columns have been constructed to investigate the bearing capacity of column after stabilization. Both prebored and premixed and mixing tools have been used for column installation. Binder combinations of 1 and 2 (Table 2) have been used for constructing single columns. Hand operated cone penetrometer was used to determine bearing capacity of stabilized columns after 3, 7, 14 and 28 days curing periods. Figure 5 and Table 3 show detail programme for single column.

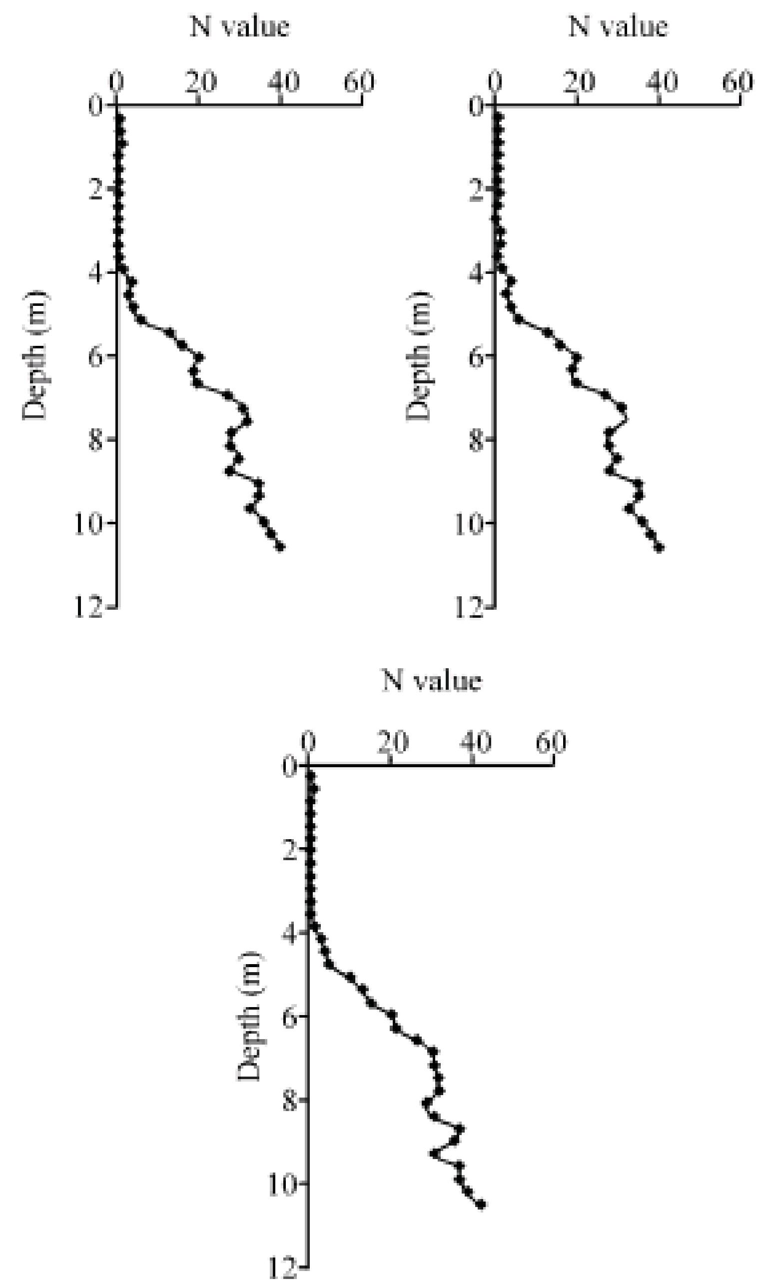

Fig. 6: Result of Mackintosh probe test, N value vs. depth (Hashim and Islam, 2008)

RESULTS AND DISCUSSION

Close examination of each trial pit indicated that the ground water table was below 0.3 m from the ground surface. Based on the visual observation, the soil can be classified as fibrous peat mixed with vegetal fibre, wooden chips inside and roots appear top layer. According to Von Post (1992) classification system based on its degree of humification the peat can be classified as H_4. The basic properties of the peat soil are shown in Table 4.

From the result of Mackintosh Probe test it was found that N value varies from 0 to 2 in peat and organic layer. Then N value gradually increases upto 10 m depth and reaches at 40 after 10 m depth. This means bearing capacity of peat soil is very low. Figure 6 shows the mackintosh probe result for three different points.

Form the test result it was observed that highest result obtained for Prebored and premixed method when we used high setting cement, calcium chloride and sand

Table 4: Basic properties of Klang peat

Index properties	Range	Average
Natural moisture content (%)	414.0-674.00	555.00
Specific gravity	00.95-1.34	1.24
Fibre content (%)	90.25-90.49	90.39
Organic content (%)	88.61-99.06	96.45
Ash content (%)	00.94-11.39	3.55
pH of peat	-	3.51

(Hashim and Islam, 2008)

as binder. Figure 8 show that bearing capacity reached upto 151 kPa after 28 days. But for using mixing tools and same binder the bearing capacity was lower than that of using prebored and premixed method. Figure 7 shows that bearing capacity was 132 kPa for using mixing tools. On the other hand when we used ordinary portland cement, bentonite and sand as binder it was obtained lower bearing capacity than that of others binder combination. From Fig. 7 and 8 it was found that the bearing capacity reached upto 125 kPa for prebored and premixed method and for other method it was 106 kPa. From literature review

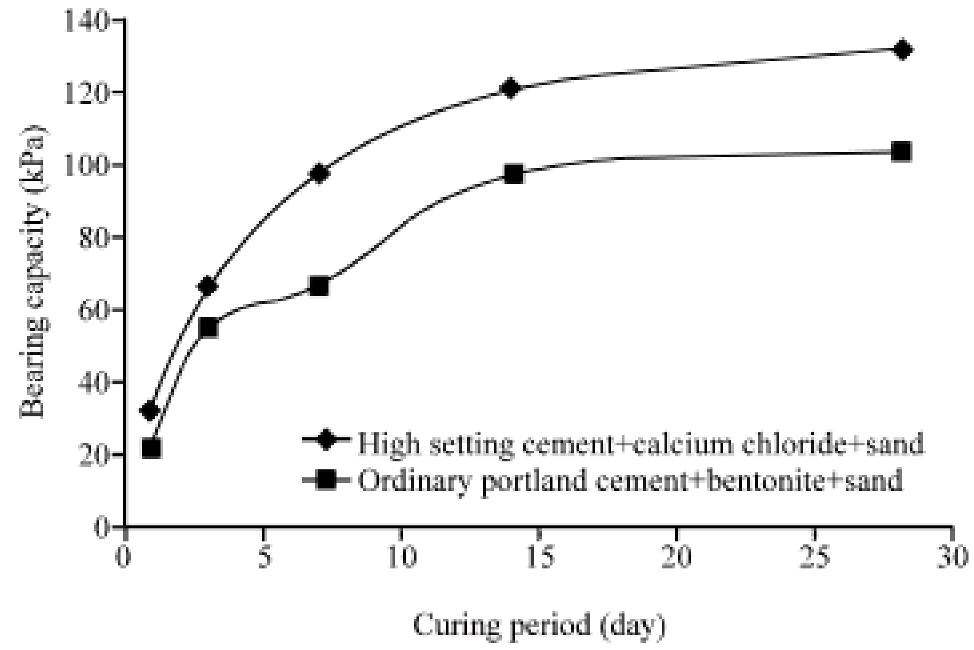

Fig. 7: Bearing capacity of stabilized column for different curing periods (using mixing tools)

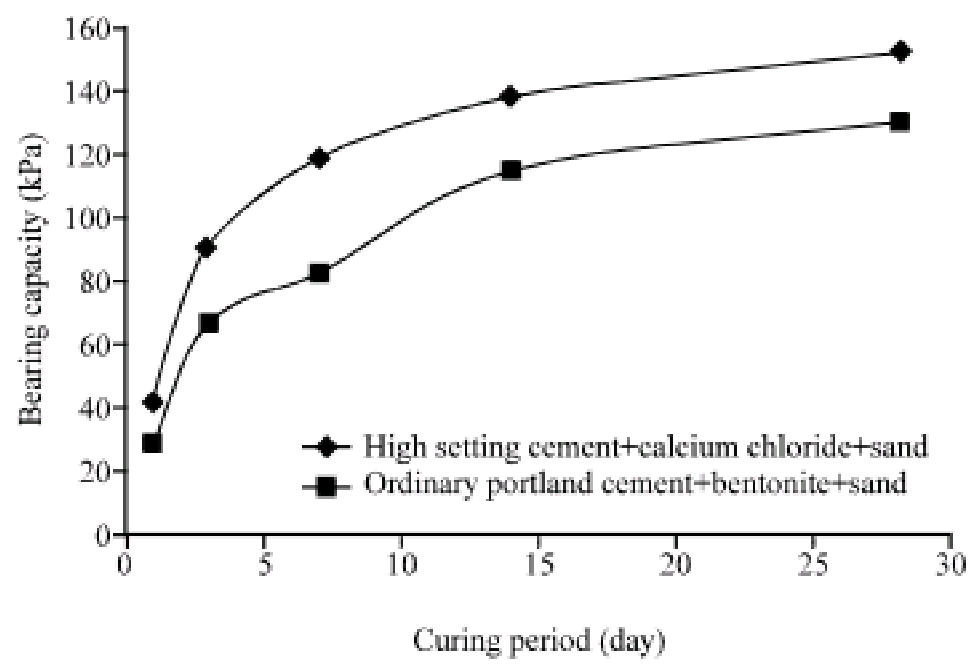

Fig. 8: Bearing capacity of stabilized column for different curing periods (prebored and premixed)

we found that 28 days strength is higher 1.5 times higher than 7 days strength. From present experiment we found that for binder 1 and prebored and premixed method bearing capacity was 151 kPa which was 115 kPa at 7 days curing time and the ratio is 1.30. On the other hand for binder 2 the ratio is 1.39. For mixing tools and binder 1 and 2 the ratio is 1.47 and 1.54, respectively. These results are almost closer to the theoretical concepts. In addition mixing by hand give good result than that of mixing with tools. Hashim and Islam (2008) have found undrained shear strength of 150 kPa after 14 days of curing by prebored and premixed method using high setting cement, calcium chloride and sand. Present result is also very closer to that finding. So, in order to high bearing capacity the quality of mixing should be good.

CONCLUSION

The following conclusion can be drawn on the basis of test result obtained from peat soil stabilisation by deep mixing method using various types of binder:

- Bearing capacity of peat soil increased considerably after stabilization by deep mixing method using various binders. Mixing of high setting cement, calcium chloride and sand as binder has better effect on bearing capacity than ordinary Portland cement, bentonite and sand
- Prebored and premixed method has given higher bearing capacity than stabilization with mixing auger. This means that homogeneous mixing is important for achieving better result
- Bearing capacity increases with the increase of curing time. 60-70% bearing capacity that of 28 days achieved after 7 days curing time and about 90% bearing capacity that of 28 days has achieved after 14 days curing time
- Hand operated cone penetrometer can be used for bearing capacity measurement but an adjustment is required to get appropriate result from this test

ACKNOWLEDGMENTS

The authors are wish to gratefully acknowledge for financial support provided by the Postgraduate Research Fund (PPP) under University of Malaya Research University Grant PS012-2007C and Science Fund under the Ministry of Science and Technology, Malaysia, Project No. 13-02-03-3003.

REFERENCES

Biddle, A.R., 1997. The Steel Bearing Piles Guide. 5th Edn., Steel Construction Institute, Ascot, UK.

Borghi, X., D.J. White, M.D. Bolton and S. Springman, 2001. Empirical pile design based on cone penetrometer data: An explanation for the reduction of unit base resistance between CPT s and piles. Proceedings of the 5th International Conference on Deep Foundation Practice, Apr. 2001, Singapore, pp: 125-132.

Bowles, J.E., 1997. Foundation Analysis and Design. 5th Edn., McGraw-Hill, New York.

Bustamante, M. and L. Gianeeselli, 1982. Pile bearing capacity predictions by means of static penetrometer CPT. Proceedings of the 2nd European Symposium on Penetration Testing, ESOPT-II, May 24-27, Amsterdam, pp: 493-500.

Chow, F.C., 1996. Investigations into the behaviour of displacement piles for offshore foundations. Ph.D. Thesis, Imperial College, UK.

Eslami, A. and M. Gholami, 2006. Analytical model for the ultimate bearing capacity of foundations from cone resistance. Scientia Iranica, 13: 223-233.

Fleming, W.G.K., A.J. Weltman, M.F. Randolph and W.K. Elson, 1992. Piling Engineering. 2nd Edn., Blackie Academic and Professional, Glasgow, UK., ISBN: 0751401943.

Hashim, R. and S. Islam, 2008. Engineering properties of peat soils in Peninsular, Malaysia. J. Applied Sci., 8: 4215-4219.

Hebib, S. and E.R. Farrell, 2003. Some experiences on the stabilisation of Irish peats. Can. Geotech. J., 40: 107-112.

Kerisel, J., 1961. Fondations profondes en milieux sablonneux: Variation de la force portante limite en fonction de la densité, de la profondeur, du diamètre et de la vitesse d'enfoncement. Proceedings of the 5th International Conference on Soil Mechanics and Foundation Engineering, Jul. 17-22, Paris, pp: 73-83.

Meyerhof, G.G., 1983. Scale effect of ultimate pile capacity. J. Geotech. Eng. Div. ASCE, 109: 797-806.

Tejchman, J. and K. Gwizdala, 1979. Analysis of safety factors of bearing capacity for large diameter piles. Proceedings of the 7th European Conference on Soil Mechanics and Foundation Engineering, Sept. 1979, Brighton, UK., pp: 293-296.

Tomlinson, M.J., 1998. Foundation Design and Construction. 6th Edn., Pitman, London.

Von Post, L., 1992. Sveriges geologiska undersoknings torvinventering och nagre av dess hittills vunna resultat, Sr. Mosskulturfor. Tidskr, 1: 1-27.