Strength evaluations for treated peat with cement and polypropylene fibres using CBR tests

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Abstract

Peat or organic soils are those types of soils that contain a significant amount of organic material derived from plants or animals. Although peat deposits create obvious topographic features such as swamp and bogs, others are buried underground, having been covered with inorganic alluvial soils. These often are difficult to detect and are the source of differential settlements when subjected to loads from civil engineering projects..

This article describes a laboratory study on treating peat using ordinary Portland cement (OPC) as binding agent and polypropylene fibers as additive. Due to high initial water content of peat, the usual moist curing technique used to cure the treated peat samples is not used and air curing method is used instead. Beside routine laboratory tests on plain peat, strength evaluation test on the treated peat samples with cement and fibres used in the research was California bearing ratio (CBR). Air curing period used was 90 days for the CBR (soaked and un-soaked) test samples. Various amounts of cements (15, 30 and 50%) as well as 0.15% of fibres were used to treat plain peat samples. The result of CBR tests show significant strength improvement of stabilized peat through curing period. Also as the cement amounts increase, treated samples gain more strength, while polypropylene fibers when added to the treated peat with cement not only give more strength values, rather contribute a considerable amount of uniformity and intactness to the cement treated peat samples as well.

Key words: Cement, Polypropylene fibers, Stabilization, California Bearing Ratio, Air curing

1. Introduction

Peat is one that contains a significant amount of organic materials. Peat is well known to deform and fail under a light surcharge load, and it is characterized with low shear strength, low compressibility, and high water content (Huat, 2004) . Generally any ground that is to be subjected to additional loads which exceed its previous load condition or level, geotechnical requirements for design on that ground are to be established. These requirements include a set of standard laboratory tests and also some foundation design calculations in order to find the allowable bearing capacity.

Usually these laboratory tests including the in-situ tests identify parameters which are essential for foundation design. If these parameters indicate that the in-situ soil is not capable of carrying the design load then there are two alternatives to choose, either the limitation imposed by the in-situ soil properties should be accepted, or use the following techniques enabling the loads to lay on the site (Huat; Faisal, 2007).

i Transfer the load to a more stable soil layer without improving the properties of the in-situ soil.
ii Improve in-situ soil properties with various techniques of ground improvement.
iii Remove the soft soil and replace it, fully or partially, with better quality fill.

Sometimes it may be possible to combine different methods to provide a suitable foundation for the imposed loads. Hebib, and Farrell (2003) provide a technique of surface stabilization combined with stabilized cement columns for foundation loads support. Also, Black et al. (2007) in their study used reinforced stone column that not only transfers loads to the lower and stronger layer rather receives lateral support from the weak soil along the way.
In this study, method “ii” has been considered to strengthen the peat soil. Peat soil is stabilized with ordinary Portland cement (OPC) as binding agent , and also reinforced with polypropylene fibres as none chemically active additive. Air curing method described by Kalantari and Huat (2008) that is to strengthen the stabilized peat soil by keeping it in normal ambient air temperature and out of water intrusions during the curing period has been used as curing procedure for the stabilized peat soil samples.
Air curing method causes the high moisture content of the stabilized peat soil to gradually decrease with time and during the curing process, and as a result CBR strength values that are used in this research have increased as the curing periods become longer.

2. Test materials

Peat soil samples used for the study, were collected as disturbed and undisturbed according to AASHTO T86-70 and ASTM D42069 (Bowles 1983; Department of the army 1980)from Kampung, Jawa on the western part of Malaysia. Table 1 presents the properties of the in-situ (field) peat soil. Binding agent used for this study was Ordinary Portland Cement (Table 2), and polypropylene fibres (Figure 1) as none chemically active additive used to reinforce the stabilized peat soil (Table 3).

Table 1: Properties of the peat soil (Bowles 1983; Department of the army 1980; Kalantari and Huat 2009; British Standards Institution 1990)

Properties	**Standard Specifications****	**Values**
Depth of sampling		5 – 100 Cm.
Moisture Content	ASTM D2216	198 - 417 %
In-situ (natural) bulk density		10.23–10.4 kN/m^3
Specific gravity	BS 1337	1.22
Classification	ASTM D5715	Fibrous
Liquid Limit	BS 1337	160 %

Plastic Index	ASTM D424-59	N.P.
Organic content	ASTM D2974	80.23 %
W_{opt}	ASHTO T 180-D	130 %
$\gamma_{d(max)}$	ASHTO T 180-D	4.89 kN/m^3
Permeability (Undisturbed)	ASTM D2434-68	4.9×10^{-4} (cm/sec)
e_o (initial void ratio)	BS 1337, ASTM D2435-70	12.55
C_c (compression index)	BS 1337, ASTM D2435-70	3.64
C_r (recompression index)	BS 1337, ASTM D2435-70	0.49
UCS (Undisturbed)	ASTM 2166-6, AASHTO T208-706	28.5 kPa.
CBR (Undisturbed)	ASTM D1883-73, AASHTO T 193-63	0.782 %

Table 2: Main components and chemical compositions of ordinary Portland cement (Neville 1999; Chen and Fong 2008)

Name of Components	Oxide	Abbreviation
Tricalcium Silicate	$3CaO\ SiO_2$	C_3S
Dicalcium Silicate	$2CaO\ SiO_2$	C_2S
Tricalcium Aluminate	$3CaO\ Al_2O_3$	C_3A
TetracalciumAluminate ferrit	$4CaSO_4$, Al_2O_3, Fe2O3	C_4AF
Calsium Sulphate	$CaSO_42H_2O$ or CaSO4	Gypsum

Chemical Compositions	Content (%)
SiO_2	20.5
Al_2O_3	6.5
Fe_2O_3	3.2
CaO	62.5
MgO	0.95
SO_3	<0.01
Na_2O	<0.01
K_2O	<0.01

Table 3: Polypropylene fibres specifications (Sika Fiber 2005)

Property	Specification
Color	Natural
Specific gravity	0.91 gr/cm^3
Fiber Length	12mm
Fiber Diameter	18 micron – nominal
Tensile strength	300 – 440 MPa.
Elastic modulus	6000 – 9000 (N/mm^2)
Water absorption	None
Softening point	160^{oc}

Figure 1. Polypropylene fibres

2. Experimental program

In order to examine the effect of cement admixtures and polypropylene fibres on the CBR strength values of peat soil, index properties tests on the peat soil have been conducted. The tests include: Sieve Analysis, Water Content, Liquid Limit, Plastic Limit, Organic Content, specific gravity, Fiber Content. Strength values for the undisturbed peat soil is been examined by triaxial test and unconfined compressive strength conducted on undisturbed peat soils, also Rowe cell consolidation test has been used to evaluate undisturbed peat soil compressibility behavior. The CBR strength values of the stabilized peat soil (mixture of peat, OPC, and fibres) have been investigated by California Bearing Ratio (CBR) tests.
Peat soil used for the stabilized CBR tests were at their natural (field) moisture contents, and therefore no water was added or deducted from the peat soil during the mixing process of peat, cement, and fibres.

2.1. California Bearing Ratio (CBR)

Any CBR tests have been conducted on the undisturbed peat soil as well as stabilized peat soil with OPC and fibres**.** For the stabilized peat soil with OPC (mixture of peat soil and cement) the soil samples used were samples at their natural (field) moisture contents of about 200%. Specified dosage of OPC and polypropylene fibres were mixed well with the peat soil for their uniformity and homogeneity, before molding the samples according to the specified standard.
Stabilized peat soil samples with OPC and fibres at their CBR's mold were prepared for their following curing procedure. Curing period used for the stabilized peat soil samples was 90 days. Un-soaked and soaked CBR tests were conducted on the stabilized peat soil samples.

2.2. Curing procedure

In-order to cure the stabilized peat soil samples with OPC and fibres, Air curing technique described by Kalantari and Huat (2008) has been used. In this technique the stabilized peat soil samples for CBR tests were kept in normal air temperature of 30±2 ºC and out of reach of water intrusion during the curing period. This technique is used to strengthen the stabilized peat soil samples by gradual moisture content reduction, instead of the usual water curing technique or moist curing method which has been a common practice of past experiments for treating and stabilized peat mixed with cement described by Axelson et al. (2002); Fei et al. (2007) and Duraisamy et al . (2006).

The principle of using this type of curing for strengthening stabilized peat is that, peat soil at its natural moisture content when mixed with cement has sufficient water for curing or hydration process to take place, and does not need more water (submerging the samples in water or moist curing) during the curing process. The technique used for curing samples will cause the treated peat samples to gradually lose their moisture content through curing period and become drier and therefore gaining more strength.

2.3. Mixtures dosages

For California Bearing Ratio (un-soaked, and soaked) tests, each sample consists of peat soil having natural moisture content plus 15, 30 , and 50% of Ordinary Portland Cement (e.g.15% cement means for each 100 gr. of natural peat at its in-situ moisture content 15 gr. of cement added). Polypropylene fibres amount used in this study was a constant value and its value was found based on the results obtained from various CBR treated test samples.

2.4. Optimum Polypropylene fibres percentage determination tests

Polypropylene fibres are usually used in concrete mixes to control cracks in hardened concrete (Mullik et al. 2006). The usual dosage recommended for concrete mixes differs from 0.6 to 0.9 kg/m3 (Sika Fiber 2005).

As for soil stabilization, fibres have been used to stabilize clayey soil, and according to Nagu et al. (2008) study on the strength of stabilized clayey soil reinforced with nylon fibres, 0.4% of fibres would provide the maximum strength values when used for the unconfined compressive strength values of the stabilized clayey soil.

For this study in order to find the optimum percentage of fiber contents for the stabilized peat soil that would provide the max. strength, peat samples at their natural moisture contents mixed with OPC and various amounts (percentages) of polypropylene fibres were cured in air and then tested for their CBR values.

The samples examined for this purpose consisted of 15% of ordinary Portland cement as well as 0.1, 0.15, 0.2 and 0.25 of polypropylene fibres (e.g. 0.2% polypropylene fibres means 0.2 gr. fibres for each 100 gr. Of peat at peat's natural moisture content is added) . The sample which showed the maximum strength value for CBR tests after 180 days 0f curing was chosen as the optimum fibres mixture dosage for further strength evaluation of treated peat.

3. Results

3.1. Optimum percentage of polypropylene fibres determination tests

According to the results shown on Fig. 2, the mixture consist of peat, cement and addition of 0.15% fibres would give its maximum CBR values for soaked as well as un – soaked treated samples, when compared with the amount of 0.10 % and 0.20 and 0.5 % fibres through curing period of 180 days.

Based on the results shown in Fig. 2, it is possible to conclude that 0.15% of fibres as none chemically active additive would provide the maximum CBR values for the treated peat with cement. Also because of the obtained result of this test, 0.15% of polypropylene fibres have been chosen as an optimum amount for the treated peat samples used in this study (for each 100 gr. of peat soil with its in-situ moisture content, 0.15 gr. fibres added).

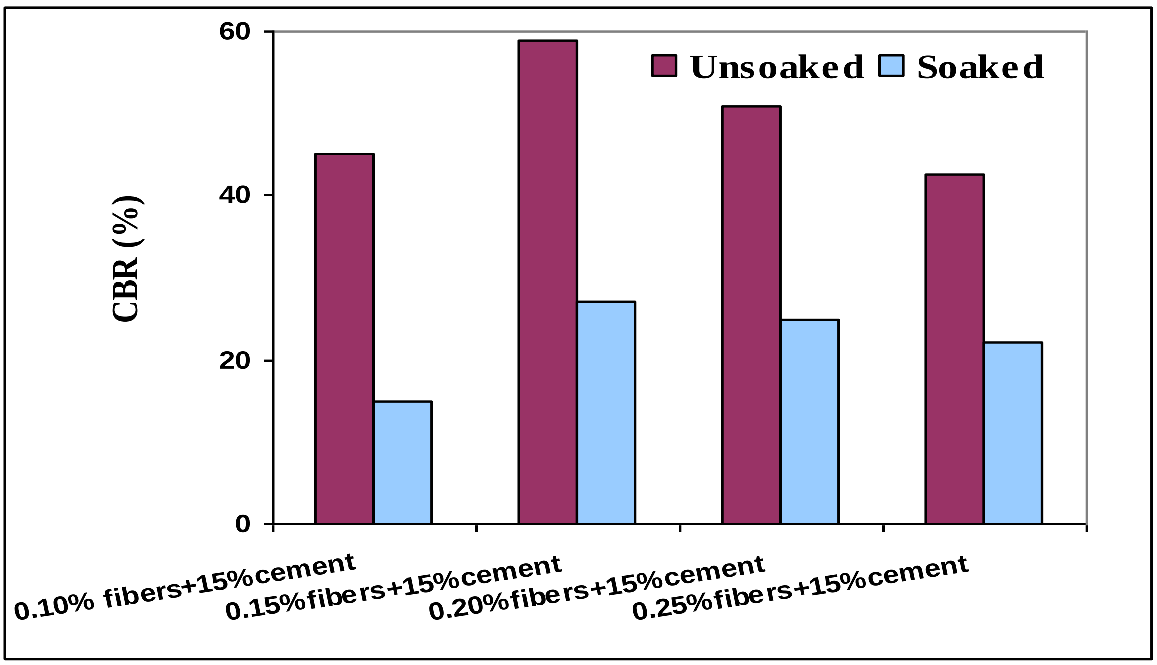

Figure 2. CBR (%) values vs. treated peat samples having different percentage of polypropylene fibres with a constant 15% of cement and cured for 180 days (soaked and un - soaked)

3.2. CBR tests on the untreated and treated peat samples with OPC and fibres

The result of CBR tests for treated peat samples with ordinary Portland cement (OPC) and polypropylene fibres after being air cured for 90 days are shown on Fig. 3. The results indicate that as cement amount in the mixture is increased, the CBR values are increased and addition of polypropylene fibres content will increase the CBR values even further. Also CBR values are decreased for soaked (saturated) samples compared with the un-soaked samples.

The curing technique as well as OPC with polypropylene fibres used for peat in this study will increase the general rating of the in-situ peat soil from very poor (CBR from 0 to 3%) to fair and good [CBR from 7 to above 20%] (Bowels 1983).

Also, visual inspection of soaked CBR samples as shown in Fig. 4 depict that, Polypropylene fibres not only increase the CBR values rather contribute a considerable amount of uniformity and intactness to the stabilized peat soil samples as well, when compared with the soaked treated peat samples having only ordinary Portland cement.

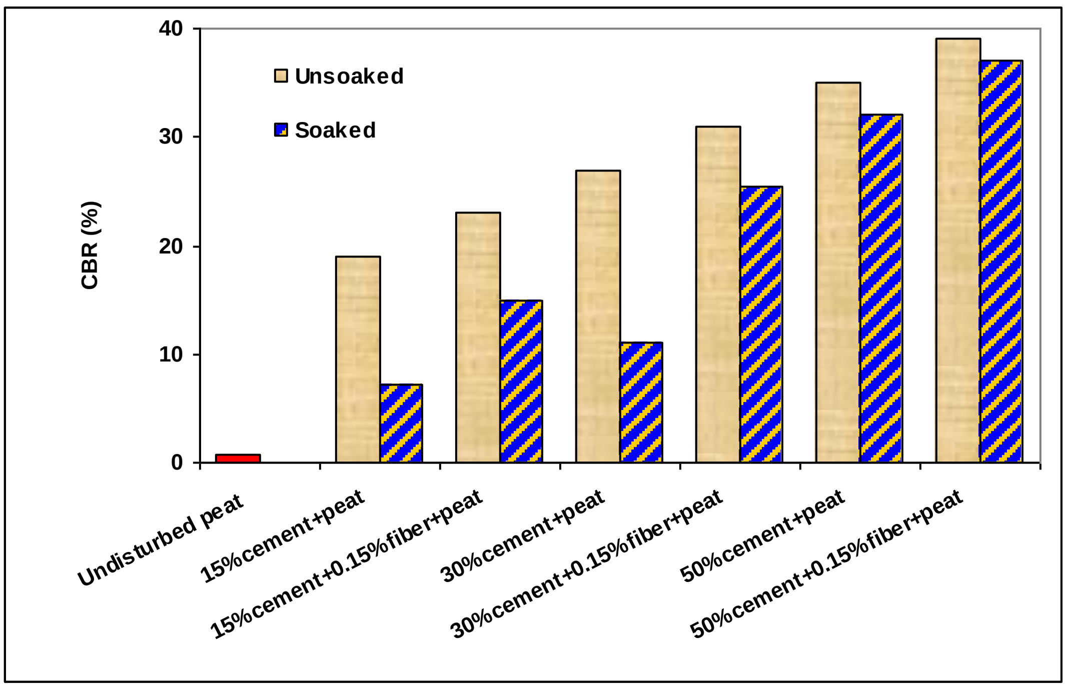

Figure 3. CBR (%) values for the undisturbed peat and different percentage of OPC and fibres for the stabilized peat soil cured for 90 days

Figure 4. Intactness and uniformity comparison between treated peat CBR samples having fibres with samples without fibres(inside dishes)

4. Conclusion

In this study a highly organic soil or peat has been treated with ordinary Portland cement (OPC) as binding agent alone, and also stabilized with, OPC, and Polypropylene fibres as none active chemical additive. Air curing technique that is to keep the treated peat with OPC in normal air temperature and out of water intrusion during the curing period is been used. The binding agent and the additive as well as the curing technique have proved to increase California bearing ratio (CBR) values of the treated peat samples after three months of curing period.

The result of CBR tests for treated peat with OPC having different percentage of polypropylene fibres show that 0.15% is the optimum percentage to provide maximum CBR values.

As the cement amount is increased, the CBR values are increased. Un - soaked CBR samples show more CBR values than soaked samples. As an example If only 15% of OPC (less than 200 kg/m3) is mixed with peat and 0.15% (less than 2 kg/m3) polypropylene fibres, the undisturbed CBR value of the peat will increase by a factor of over 22 for un - soaked, and by a factor of over 15 for the soaked samples.

References

Axelsson K., Johansson S. E., Anderson R., 2002. *Stabilization of Organic Soils by Cement and Puzzolanic Reactions-Feasibility Study*. Swedish deep stabilization Research Centre, Report 3, English translation, pp: 15-16.

Black A. J, Sivakumar V., Madhav R. M., and Hamil A. G., 2007. *Reinforced Stone Column in Weak Deposit: Laboratory Model Study. Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 1154-1161. doi: 10.1061/_ASCE_1090-0241_2007_133:9_1154.

Bowles EJ. *Engineering properties of soil and their measurements*, 2nd edition. United States, New York, McGraw-Hill, pp: 1978, 189-197, 13-14, 97-105,131-141.(ISBN 0-07-006752x)second edition.

British Standards Institution 1337, 1990. *Methods of Test for Soils for Civil Engineering purposes*. London, BS 133710.Neville. A.M, Properties of concrete-4th edition, Malaysia, Longman, 10.

Chen L, Fong DL, 2008.*Stabilization treatment of soft subgrade soil by sewage sludge ash and cement. Journal of Hazardous Materials*. 05.060. doi:10.1016.

Duraisamy Y., Huat B.B.K , Muniandy R.,and Abdul A. A., 2006. *Effect of Cement column on the Compressibility of Tropical peat Soil.,GSM-IEM Oktober forum on Engineering Geology and Geotechnical engineering*. petalang jaya, Malaysia. webed.eng.upm.edu.my/web080903/.../kawpub2006bm.pdf.

Department of the Army, *Engineering and Design Laboratory Testing, Engineer*. 1980. United States of America. No 11102-2-1906.

Department of the Environment, Building Research Establishment, 1975. *Design of Normal Concrete Mixes. Road note No. 4*. United Kingdom, Her Majesty’s, Stationary Office, pp: 5-30**.**

Fei M. C, Huat B.B.K., and Duraisamy Y., 2007. *Influence of Chemical admixtures (cement and peat) on Index and Mechanical properties of Tropical peat soil*. American Journal of Environmental Sciences, Science public.

Huat B.B.K., 2004. Organic and *Peat Soils Engineering*, University Putra Malaysia, pp: 5-(ISBN 983-2871-08-8)first edition.

Huat B. B.K., and Faisal H. A., 2007. *Ground Improvement Technology*, University Putra Malaysia, p 105.(ISBN 983-2871-08-5)first edition.

Hebib S.,and Farrell R., E., 2003. *Some experiences on the stabilization of Irish peats*. Can. Geoteh J., 40:107-120. doi: 10.1139/T02-091.

Kalantari B., and Huat B.B.K., 2008. *Stabilization of peat soil using ordinary Portland cement, polypropylene fibres, and air curing technique*. Electronic Journal of Geotechnical Engineering; Vol.13, Bund. J.

Kalantari B., and Huat B.B.K., 2009. *Precast stabilized peat columns to reinforce peat soil deposits.* Electronic Journal of Geotechnical Engineering; Vol.14, Bund. B.

Mullik K. A., Walia P., and Sharma N. S., 2006. *Application of Polypropylene Fiber Reinforced Concrete (PFRC) with Vacuum Processing. Advances in Bridge Engineering*, Walia International Machines Corp., New Delhi, India.

Nagu P.S., Chandarkaran S., Sankar N., 2008. *Behavior of lime stabilized clayey soil, reinforced with nylon fibres. National Institute of technology*. Calcutta, India.

Neville. A.M, 1999. *Properties of concrete-4th edition*, Malaysia, Longman, p: 10.

Sika Fiber, 2005. Technical data sheet, Version no. 0010 edition 3, Polypropylene Fibres, Malaysia. www.sika.co. id.