PERFORMANCE OF EMBANKMENT ON BAMBOO-GEOTEXTILE COMPOSITE REINFORCED SOFT CLAY

BAKHTIAR AFFANDY BIN OTHMAN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Geotechnics)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

APRIL 2012

Special dedication to my family especially to my dad Othman bin Abdul Karim, my mum Katirah binti Slamat and all my brother and sisters and also to a special person, my wife Nilidawati binti Buhari for her patience and support all the times. Also special thanks to all my colleagues who had given the guidance and encouragements until the end of this research

ACKNOWLEDGEMENTS

Alhamdulillah, thanks to the Almighty with his permission this thesis had been completed successfully. In this opportunity, I take to express my sincere appreciation to all individuals who had involved directly or indirectly in completing this thesis. Various barriers and obstacles along the completion of this thesis had to be handled with the help of prayer and effort of the partners involved, whether from Universiti Teknologi Malaysia (UTM) or friends from other university.

Appreciations are also addressed to my supervisor, Prof. Dr. Aminaton Marto for patiently help, teach and encourage me on how to write and produce a good thesis and independence in pursuit of knowledge. I will not forget the contribution and dedication of Prof. Dr. Aminaton Marto and also her husband, Assoc. Prof. Dr Ahmad Mahir Makhtar for providing the opportunity and space for me to improve and expand the existing knowledge for my future career. To Mrs. Fauziah Kasim and Dr. Hisham Mohamed who had given constructive comments on the simulation modeling, special thanks are offered to them.

Thanks to all members especially for Geotechnical Engineering Laboratory staff, RECESS (UTHM) staff and also my friends in the same research group for assistance, guidance and friendship. The National Science Fellowship (NSF) scholarship from the Ministry of Science, Technology and Innovations (MOSTI) and the research grants from MOSTI (Project Number 03-01-06-SF0236) and UTM Research University Grant (Vote Number 00J22), are gratefully acknowledged.

Finally, I would like to express exceptional appreciations to my parents and wife for their supports and loves throughout the challenging journey in doing this research. Thank you to all.

ABSTRACT

Road embankments and other constructions on deposits of natural soft clay are still a challenge in geotechnical engineering work. The used of various soil improvement methods to stabilise the soft clay need to be carried out in order to increase the bearing capacity and reduce the settlement. Most methods are costly while the time taken to complete the improvement works takes a long period. The Soft Soil Research Group of Universiti Teknologi Malaysia had proposed the combined used of bamboo as a green technology and a layer of low strength geotextile to become a reinforcement system called the "Bamboo-Geotextile Composite" (BGC). Full-scale embankments on BGC system reinforced soft clay (BGC embankment) together with an embankment on unreinforced soft clay (UR embankment) and also an embankment on high strength geotextile reinforced on soft clay (HSG embankment) had been constructed. Each embankment measured 10 m long, 16 m wide and about 3 m height. Semantan Bamboo of about 8 cm outer diameter with 48-94 MPa tensile strength and 43-49 MPa bending strength, and TS 40 Geotextile of 13.5 kN/m length tensile strength were selected as the materials for the system. In BGC system, the bamboo poles arranged in 1 m x 1 m square pattern were laid at the top of soft clay layer and the geotextile was then laid on top of bamboo. The objectives of this research are to determine the performance of BGC embankment and to develop a representative method of modelling the BGC embankment through the evaluation of field data using finite element (FE) model from PLAXIS 2D computer software. The embankments were monitored since the start of the construction until Day 418. Field monitoring data showed that the used of BGC system reduced more than 20% of immediate settlement and 57% of lateral movement during construction compared to UR embankment. The confinement of the soft clay in square pattern arrangement of bamboo increased the bamboo stiffness while the tensile resistance of horizontal ribs and compressive resistance of vertical ribs of bamboo prevented excessive settlement. The BGC system retained the surcharge load and distributed only small load to the underlain soft clay soil resulting in smaller consolidation settlement compared to UR and HSG embankments. The BGC system was best modelled as a geogrid element using PLAXIS 2D software. Although the drainage capability as well as the buoyancy effect of the BGC system could not be modelled, the settlement at the centre point of BGC embankment showed that the result from FE model differs only 1% from the field settlement at the end of construction while at Day 418, the model overestimated about 6%. For the lateral movement, the model predicted about 100% higher than the field value while the location of the maximum lateral movement was predicted to occur at a greater depth compared to the field performance. Hence, it can be deduced that the BGC embankment can be modelled using PLAXIS 2D software, in which the prediction for settlement can be better represented.

ABSTRAK

Tambakan jalan dan binaan lain di atas endapan tanah liat lembut semulajadi masih lagi menjadi cabaran dalam kerja-kerja kejuruteraan geoteknik. Penggunaan pelbagai kaedah pembaikan tanah untuk menstabilkan tanah liat lembut perlu dilakukan untuk meningkatkan keupayaan galas dan mengurangkan enapan. Kebanyakan kaedah adalah sangat mahal dan mengambil masa yang lama untuk selesai. Kumpulan Penyelidikan Tanah Lembut Universiti Teknologi Malaysia telah mencadangkan pengunaan gabungan buluh sebagai teknologi hijau dan selapis geotekstil yang berkekuatan rendah, untuk menjadi sistem tetulang dikenali sebagai "Komposit Buluh-Geotekstil" (BGC). Tambakan-tambakan berskala penuh di atas tanah liat lembut yang diperkukuh dengan sistem BGC (tambakan BGC) bersama-sama dengan tambakan ke atas tanah liat lembut tidak diperkukuh (tambakan UR) dan juga tambakan di atas tanah liat lembut diperkukuh dengan geotekstil berkekuatan tinggi (tambakan HSG) telah dibina. Setiap tambakan adalah berukuran 10 m panjang, 16 m lebar and lebih kurang 3 m tinggi. Buluh Semantan yang bergaris pusat luaran lebih kurang 8 cm dengan kekuatan tegangan 48-94 MPa dan kekuatan lenturan 43-49 MPa, dan Geotekstil TS40 dengan kekuatan tegangan 13.5 kN/m panjang, telah dipilih sebagai bahan untuk sistem bertetulang tersebut. Bagi sistem BGC, batang buluh diatur dalam bentuk segiempat sama 1m x 1m di atas lapisan tanah liat lembut dan kemudian geotekstil dihampar di atasnya. Objektif peyelidikan ini adalah untuk menentukan prestasi tambakan BGC dan untuk membangunkan suatu kaedah perwakilan bagi memodelkan tambakan BGC melalui penilaian data lapangan menggunakan model unsur terhingga (FE) dari perisian komputer PLAXIS 2D. Tambakan-tambakan telah dipantau dari awal pembinaan sehingga Hari Ke-418. Data pemantauan lapangan menunjukkan bahawa penggunaan sistem BGC telah mengurangkan enapan serta merta lebih daripada 20% dan 57% pergerakan sisi semasa pembinaan berbanding dengan tambakan UR. Pengurungan tanah liat lembut dalam bentuk segi empat sama meningkat kekukuhan buluh manakala rintangan tegangan rusuk ufuk dan rintangan mampatan rusuk tegak buluh boleh menghalang enapan berlebihan. Sistem BGC menahan beban yang dikenakan dan hanya menyebarkan beban yang kecil kepada lapisan tanah liat lembut menyebabkan enapan pengukuhan yang lebih kecil berlaku jika dibandingkan dengan tambakan UR dan HSG. Sistem BGC terbaik dimodelkan sebagai elemen geogrid dengan menggunakan perisian PLAXIS 2D. Walaupun keupayaan saliran dan kesan apungan sistem BGC tidak dapat dimodelkan, enapan di titik tengah tambakan BGC di akhir pembinaan menunjukkan keputusan dari model FE hanya berbeza 1% daripada data lapangan manakala pada Hari Ke-418, model FE meramal lebih iaitu sekitar 6% enapan. Bagi pergerakan sisi, model meramalkan 100% nilai yang lebih besar dari nilai lapangan manakala kedudukan pergerakan sisi maksimum diramalkan berada pada kedalaman lebih besar dibandingkan dengan prestasi lapangan. Oleh itu, dapat disimpulkan bahawa tambakan BGC boleh dimodelkan menggunakan perisian PLAXIS 2D yang mana ramalan terhadap enapan boleh dimodelkan dengan lebih baik.