UNIVERSITI PUTRA MALAYSIA

ANALYSIS AND DESIGN OF PASSIVE PILE IN OPEN EXCAVATION

KOK SIEN TI

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ANALYSIS AND DESIGN OF PASSIVE PILE IN OPEN EXCAVATION

By

KOK SIEN TI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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ANALYSIS AND DESIGN OF PASSIVE PILE IN OPEN EXCAVATION

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September 2010

Chairman: Prof. Bujang Kim Huat, PhD

Faculty: Engineering

In recent years, there are rapid development in the construction of massive superstructures. These buildings are often supported by deep foundations such as piles. When construction space becomes a limitation, deep excavation had to be carried out with the presence of existing piles. These piles will eventually be exposed during excavation works, and are expected to provide significant resistance to soil movements even before the full mobilization of designed lateral load. The prediction of soil movement under this condition is only using simplified approach. This leads to underestimation of cracking moment especially when excavation was carried out in a soft clay layer. Underestimating the bending moment in these piles will results in cracked and broken piles. Advances could be realized in design of economical pile-supported foundations with the behaviour accurately predicted if the lateral resistance could be accurately and easily obtained.

This research looks into the literature review on the current research on piles under various horizontal loading and focusing on *passive* piles. The outline of research

work conducted in this study includes developing a simple 1-g laboratory model test, conducting few tests of horizontally loaded pile and analyzing the result with an existing three-dimensional finite element software. A case study of a group pile failure in open excavation was modelled. Lastly, parametric study of single spun piles in open excavation was carried out in order to develop pile design guidelines.

PLAXIS 3D FOUNDATION software which offers three-dimensional finite element modeling for rock and soil was utilized to develop an analytical model of single pile in open excavation. This model was verified using 1-g laboratory model test result, published centrifuge data and case study. The model verification results showed that this mathematical model was able to predict the magnitude of horizontal soil movement reliably provided the selection of soil constitutive model parameters were done reasonably.

Major highlight of the research is based on the model which was used to model a geometry of an open excavation where the single pile is at the toe of the excavation. The soil stiffness ranges from very soft to medium stiff clay underlain by a hard layer. The effects of few parameters are clearly shown in charts namely the soil stiffness, spun pile diameter, excavation slope and depth function.

This research also develops practical and suitable design guidelines that are applicable for design use is developed to predict the response of single pile in soft clay excavation. The result of this research was expected to enhance and to contribute to the current state of knowledge and practice regarding pile groups in soft clay excavation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

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KOK SIEN TI

September 2010

Pengerusi: Prof. Bujang Kim Huat, PhD

Faculti: Kejuruteraan

Kebelakangan tahun ini telah mendapat perkembangan pesat dengan super-struktur yang tak terhitung jumlahnya. Bangunan-bangunan ini sering disokong oleh asas dalam seperti asas cerucuk . Ketika ruangan pembinaan menjadi satu faktor yang menghambat, kehadiran cerucuk adalah diperlukan sebelum penggalian dalam dilakukan. Kumpulan-kumpulan cerucuk yang akan didedahkan semasa penggalian dilakukan adalah diharapkan untuk membekalkan resistensi yang signifikan terhadap gerakan tanah. Namun, hanya cara yang disederhanakan umumnya dipraktikkan untuk menganggarkan kebesarannya pergerakan tanah dalam keadaan ini. Untuk alasan ini, momen retakan cerucuk biasanya dianggar rendah, terutama ketika penggalian dilakukan pada satu lapisan tanah liat yang lembut.

Mengangar rendah momen dalam tumpukan ini akan menyebabkan cerucuk meretak dan patah. Kemajuan dalam merekabentuk asas cerucuk yang ekonomi dengan anggaran kelakuan cerucuk yang tepat dapat dicapai jika resistensi sisi dapat dianggar secara tepat dan mudah diperolehi.

Penyelidikan ini memberikan sarana untuk menilai dan menguji literatur yang sediada yang mengenai cerucuk dibawah kes-kes dengan beban sisi yang berbeza, dengan signifikansi sebagai cerucuk pasif. Garisan kasar kerja yang dilakukan dalam kajian ini meliputi membina satu 1-g model ujian makmal, melaksanakan beberapa ujian beban sisi pada cerucuk dan kemudian kembali-menganalisis hasilnya dengan mengunakan perisian elemen hingga tiga-dimensi. Selepas ini, satu kes kajian bagi kegagalan cerucuk dalam penggalian terbuka dimodelkan bersama-sama dengan pengajian parameter cerucuk kelompang dalam penggalian terbuka untuk mengembangkan graf rekabentuk yang dapat digunakan.

Paket yang sediada yang menawarkan pemodelan elemen hingga tiga-dimensi untuk batu dan tanah, 'Plaxis 3D FOUNDATION' telah digunakan untuk mengembangkan suatu model analitis bagi satu cerucuk di penggalian terbuka. Pretasi perisian diuji dengan perbandingan dengan keputusan ujian makmal 1-g model dan kes kajian . Perbandingan menunjukkan bahawa program ini dapat menganggarkan kebesarannya gerakan melintang tanah yang dapat dipercayai, dengan syaratya pilihan parameter untuk model konstitutif tanah dilakukan secara wajar.

Graf rekabentuk yang praktikal dan sesuai untuk kegunaan merekabentuk dihasilkan untuk meramalkan respons satu cerucuk di penggalian tanah liat yang lembut. Keputusan kajian ini diharapkan untuk meningkatkan dan memberikan sumbangan kepada negara masa ini dalam pengetahuan dan amalan mengenai kumpulan cerucuk dalam penggalian tanah liat lembut.

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I dedicate this theses to my beloved mother, Ginny for her inseparable support and prayers. As a single parent, she raised us sincerely with her love and devotion. I owe my achievements to her. Zenith and Sanee, thanks for being supportive and caring siblings. To Fouzi Al-Utaibi, I am indebted to him more than he knows.

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Finally, I would like to thank everyone that had helped me in any other way to the successful completion of this theses.

APPROVAL SHEET 1

I certify that a Thesis Examination Committee has met on (1st Sept 2010) to conduct the final examination of Kok Sien Ti on her thesis entitled **"Analysis and Design of Passive Pile in Open Excavation"** in accordance with the Universities and University Colleges Act 1971 and the Constitution of University Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were follows:

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Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Doctor of Philosophy**. The members of the Supervisory Committee were as follows:

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Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that is has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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KOK SIEN TI

Date: 1 September 2010

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