INSTRUMENTATION FOR MONITORING THE EFFECTIVENESS OF RETAINING WALL DESIGN

HARFIZAH HARUDIN

A project report submitted in partial fulfilment of the
requirements for the award degree of
Master of Engineering (Geotechnics)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

DECEMBER 2016

To my parents.

My teachers.

My siblings.

My friends.

Selbst der längste Weg beginnt mit dem ersten Schritt

ACKNOWLEDGEMENT

Thanks to merciful Lord for all the countless gift you have offered me, and thanks to my family for their love, support and motivation in finishing my master's degree.

It is a great pleasure to acknowledge my deepest thanks and gratitude to everyone who had assisted me in the creation of this writing especially my supervisor, PM Ir. Dr. Azman bin Kassim.

My sincere thanks goes to my sister Nolia Harudin, for her co-ordination in extending every possible support for the completion of this project.

Not to mention, my colleagues, namely Fatin, Nurhafizah and Syafiq who had helped me through thick and thin during this whole programme.

Last but not least, i would like to thank all those who had helped direclty or indirectly towards the completion of this project.

Thank you.

ABSTRACT

Large excavation in urban areas can affect the foundations of existing structures close to the excavation. To eliminate this interacting effect, an effective retaining wall must be erected and its performance must be monitored continuously using proper instruments. This study established instrumentations monitoring process on a retaining wall design assessment dealing with a critical historical structure that require too many sensitivity element to be protected critically. *Museum textile* ages 120 years was constructed in 1896 is categorized as “Bangunan Warisan” was build up with no foundation detail. Without proper monitoring, failure on the structural, geotechnical movement, hairline cracks and several more can easily occurs. This study aims to determine the effectiveness of secant pile retaining wall design through instrumentation monitoring. Two ground investigations, comprising a total of 28 boreholes, with in-situ testing and soil sampling was performed on the site in the summer of 2014, by a local Contractor, Maxi Mekar Sdn Bhd. Finite element (FE) analyses using computer software “PLAXIS” used for modelling the excavation sequences in order to estimate the ground deformation around the excavation and the performance of the secant pile wall. Inclinometer installed in the secant bored pile wall to monitor the wall deflection, magnitude, direction and rate of lateral movement of the soil. The ground surface settlement marker is used to monitor ground movement at specific locations. Building settlement marker of the simple wall plug used to monitor the vertical movement of the structure. The BeanDevice® AX-3D Xrange been used 24 hours to monitor the vibration caused by the construction activities in nearby structure and vicinity. Through the total ground settlement contour, five monitoring point *(within museum textile adjacent area)* addressed as established ground settlement limitation points. The critical wall maximum ground deformation, props forces and response of wall for critical sections are summarize based on the ground settlement and structure established limit summarize by Finite Element (FE) analyses using computer software “PLAXIS”. The cumulative monitoring data for ground settlement markers are within 2.4mm to 6.9mm, Building Tiltmeter are from 1:2455 to 1:12808 ratio, Building settlement markers are 0.3mm to 1.4mm, Inclinometer within 1.29mm to 4.03mm in A and B direction and Vibration monitoring in between 0.37mm/s to 0.5mm/s. Based on instrumentation data analysis collected on daily basis from February’16 until August’16, the instrumentation readings was monitored against three trigger levels namely Alert, Alarm and Action levels for individual instruments on the instrumentation schedule. It can be concluded that all the monitoring data are within the design limit. The design considered as successful by meeting this limit. It is recommended to extend the monitoring stage up to completion of the excavation at B4 level in order to get critical view on the overall design wether within the spesified limit or not.

ABSTRAK

Aktiviti pengorekan di kawasan bandar boleh menjejaskan struktur asas yang sedia ada berhampiran dengan kawasan pengorekan. Untuk mengelakkan kesan ini, tembok penahan perlu didirikan dan prestasinya perlu dipantau secara berterusan dengan menggunakan instrumen yang tepat. Kajian ini menggariskan proses pemantauan instrumentasi yang tersusun bagi penilaian rekabentuk tembok penahan yang melibatkan struktur bangunan sejarah yang memerlukan banyak unsur sensitiviti untuk dilindungi. Muzium tekstil yang berusia 120 tahun telah dibina pada tahun 1896 dan dikategorikan sebagai "Bangunan Warisan" ianya telah dibina tanpa maklumat asas tapak yang direkodkan sebagai rujukan. Tanpa pemantauan menyeluruh, pergerakan struktur, geoteknik, retak dan beberapa lagi kecacatan boleh berlaku. Kajian ini bertujuan untuk menentukan keberkesanan rekabentuk tembok penahan melalui pemantauan alatan instrumentasi. Sebanyak dua peringkat analisis tanah dijalankan, iaitu terdiri daripada 28 lokasi, ujikaji dan sampel tanah telah dilakukan pada tahun 2014, oleh kontraktor tempatan, Maxi Mekar Sdn Bhd. Analisa "Finite Element (FE)" yang dijalankan menerusi perisian komputer " PLAXIS " digunakan sebagai model bagi kerja pengorekan secara berperingkat dalam mendapatkan anggaran pergerakan tanah disekeliling tapak bina dan juga untuk mengetahui keberkesanan dan prestasi rekabentuk tembok penahan "secant bored pile wall". "Inclinometer" dipasang di dalam dan di luar tembok penahan untuk memantau pergerakan tembok penahan dan pergerakan tanah disekelilingnya. "Ground settlement marker" digunakan untuk memantau pergerakan tanah di lokasi tertentu. "BeanDevice® AX-3D Xrange" digunakan selama 24 jam sehari untuk memantau setiap getaran yang disebabkan oleh aktiviti pembinaan di kawasan berdekatan. Melalui garisan kontur "total ground settlement" yang telah terhasil, sebanyak enam jenis instrumentasi telah dikenalpasti untuk dipasangkan (sekitar kawasan muzium tekstil) berpandukan pada had "ground settlement" yang telah ditetapkan. Had pergerakan tanah yang kritikal, beban tampungan untuk rekabentuk tembok penahan, telah dikenalpasti melalui analisa perisian komputer "PLAXIS. Melalui pemantauan kumulatif instrumentasi, dapat disimpulkan untuk "ground settlement marker" pergerakan tanah adalah diantara 2.4mm sehingga 6.9mm, bagi "Building settlement marker" adalah diantara 0.3mm sehingga 1.4mm, "Building tiltmeter" diantara nisbah 1:2455 sehingga 1:12808. Manakala bagi "vibration" adalah diantara 0.37mm/s sehingga 0.5mm/s dan bagi instrumen "inclinometer" diantara 1.29mm sehingga 4.03mm didalam arah A dan B. Berdasarkan analisis data harian instrumentasi dikumpulkan daripada bulan Febuari'16 sehingga Ogos'16, bacaan instrumentasi dipantau berdasarkan kepada tiga tahap iaitu "Alert", "Alarm" dan "Action". Daripada analisa data yang dijalankan, dapat disimpulkan semua data pemantauan berada di dalam had yang selamat. Rekabentuk tembok penahan dianggap berjaya dengan memenuhi had ini.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Design of earth retaining wall is an important problem in geotechnical engineering. A retaining wall may fail in sliding or rotation. A retaining wall is a structure used to enhance the stability of masses of earth that are unstable in their natural slopes. These soil slopes occur frequently in the construction of railways, highways, bridges, and other civil engineering projects. Therefore, minimum cost design of reinforced concrete retaining walls is an important design optimization task because of its frequent application in civil engineering. Design of retaining walls must satisfy geotechnical, structural, and economic requirements. A trial and error approach is typically necessary to design retaining walls. Designers must develop an initial trial design for the wall to reach a proper final design that satisfies all the requirements. However, there is no guarantee that the final design will be an economical design (Gandomi et al. 2015; Pain et al. 2016).

Optimal retaining wall design has been the subject of many studies in the past (Gandomi et al. 2015; Pei & Xia 2012; Sarıbaş & Erbatur 1996; Walls 1989; Damians 2016). Now, with the aid of integrated analysis system (PLAXIS) developed specifically for modelling the excavation aid the industrial player in reducing the criticality of the various aspect including ground settlement and structural movement risk. The simplification steps in designing retaining wall ease the author in focusing more towards the monitoring element especially when dealing with high risk project as the proposed development site conducted within this project.

Deep excavations in weak ground with a high ground water level provide significant challenges with regard to ground support and minimising ground water inflow. This is particularly important in urban environments where settlement resulting from ground loss or ground water draw down can result in damage to adjacent structures. The use of driven sheet piles or similar can result in unacceptable noise and vibration. In view, the proposed development site is surrounded by existing buildings and adjacent to Klang River, excessive ground movement and lowering of groundwater level during excavation may cause distresses to adjacent structures and utility services. Hence, a retaining system that can effectively control and minimise the ground movements induced from the temporary excavation is required.

Since the subsoil is highly permeable and surroundings existing buildings are susceptible to settlement due to the lowering of groundwater table, the adoption of secant bored pile wall are suitable due to its water tightness characteristic as compared to other wall types. In addition, secant pile wall construction generates minimum noise and vibration disturbances to adjacent structures. Secant pile wall is also a very stiff structural element and therefore, will minimize ground movements. Such characteristic is very important for proposed site due to the close proximity of public road and immediately adjacent to high-rise structures. An instrumentation monitoring programme is proposed to monitor various parameters that may affect the retaining system. All the data will be collected during construction of retaining wall and during the excavation activities. The instrumentation readings shall be monitored against the allowable design limit.

1.2 Problem Statement

Large excavation in urban areas can affect the foundations of existing structures close to the excavation. To eliminate this interacting effect, an effective Retaining wall must be erected and its performance must be monitored continuously using proper instruments.

1.3 Objectives

This study aims to determine the effectiveness of secant bored pile retaining wall design. In order to achieve the aims, below listed objectives are designed accordingly:

1. To determine the ground settlement and structural limit by referring to a secondary geotechnical data.
2. To design the selected critical retaining wall section based on the ground settlement and structural allowable design limit.
3. To collect and analyse data collected from instrumentation installed for critical wall design verification.

1.4 Scope of Study

The study is limited to the problems involving:

1. Overall Wall analysis using secondary data from Contractor Design.
2. To collect the instrumentation data until end of excavation
3. Wall type involved Type 8 and 9a only
4. Analysis is carried out using cumulative calculated data and instrumentation software.

1.5 Significant of the study

Excavation in sensitive urban areas require proper design of Retaining Wall. Performance of the Retaining wall can be effective by installing proper design of the instrumentation.

1.6 Organization of Thesis

Chapter 1 describes the background of research, problem statement, objectives, scopes and significance of research.

Chapter 2 discussed about the need and important aspects of retaining wall design including the geotechnical parameter analysis and instrumentation monitoring process and devices been commonly used by previous researchers or industrial players.

Chapter 3 describes in detail the research methodologies employed in the study which mainly focused on the instrumentation monitoring to verify the effectiveness of retaining wall design at the identified areas.

Chapter 4 discussed the result from the assessment conducted in three main areas including ground settlement assessment gain from the secondary data, design wall assessment using PLAXIS and instrumentation monitoring that covers five instrumentation which are ground and building settlement markers, building Tiltmeter, vibration and Inclinometer. Data taken from February'16 until August'16 was used in discussing the final result for the seven months of monitoring period.

Chapter 5 presents the conclusions for the research work and divides it into four sections. It starts with the research contributions followed by fulfillment of research objectives, limitations of this research and discusses possible future research that can be done by other researchers.

REFERENCES

Boscardin, B.M.D. & Cording, E.J., 1989. Building r e s p o n s e t o excavation-induced settlement. , 115(1), pp.1–21.

Burland, J.B. & Hancock, R.J.R., 1977. Underground Car park at the House of Commons: geotechnical aspects. *The Structural Engineer*, 55(2), pp.87–105.

Damians, I.P., 2016. Sustainability assessment of earth-retaining wall structures.

Gandomi, A.H. et al., 2015. Optimization of retaining wall design using recent swarm intelligence techniques. *Engineering Structures*, 103, pp.72–84. Available at: http://dx.doi.org/10.1016/j.engstruct.2015.08.034.

Geotechnical Design Report. March 2016. Cadangan meroboh 1 blok 6 tingkat bangunan sediada (citypoint) beserta 2 tingkat basement dan membina semulablok bangunan 60 tingkat. Meinhardt (Malaysia) Sdn Bhd

Geotechnical Report For Scheme Design. November 2014. Proposed Mixed Development of Kompleks Dayabumi Phase III, Kuala Lumpur. Jacobs China Limited

Görög, P. & Török, Á., 2007. Slope stability assessment of weathered clay by using field data and computer modelling: a case study from Budapest. *Natural Hazards and Earth System Science*, 7, pp.417–422.

Kimmance, J.P., Bradshaw, M.P. & Seetoh, H.H., 2000. Geographical Information System (GIS) Application to Construction and Geotechnical Data Management on MRT Construction Projects in Singapore. *Science*, 14(4), pp.469–479.

Kowalska, M., 2010. Various Aspects of Parameters in Geotechnics. *Architecture Civil Engineernig Environment*, 1, pp.47–52.

Loganathan, N., 2011. An Innovative Method For Assessing Tunnelling-Induced Risks To Adjacent Structures. *PB2009 William Barclay Parsons Fellowship Monograph 25*, (January), p.118.

Mohamad, H. et al., 2011. Performance Monitoring of a Secant-Piled Wall Using Distributed Fiber Optic Strain Sensing. , 137(December), pp.1236–1243.

Pain, A., Choudhury, D. & Bhattacharyya, S.K., 2016. Seismic rotational displacement of retaining walls: a pseudo-dynamic approach. *Innovative Infrastructure Solutions*, 1(1), p.22.

Pei, Y. & Xia, Y., 2012. Design of Reinforced Cantilever Retaining Walls using Heuristic Optimization Algorithms. *Procedia Earth and Planetary Science*, 5(2011), pp.32–36.

Sarıbaş, A. & Erbatur, F., 1996. Optimization and Sensitivity of Retaining Structures. *Journal of Geotechnical Engineering*, 122(8), pp.649–656.

The Soil Investigation Works For The Proposed Mixed Commercial Development On Lot 91 Within Kuala Lumpur City Center Development - Final soil investigation report, December 2014. Maxi Mekar Sdn Bhd.

Walls, R., 1989. SYSTEM ANALYSIS I N CALCULATION OF CANTILEVER. , 13(January 1987), pp.599–610.

Waltham, a. C. & Fookes, P.G., 2003. Engineering classification of karst ground conditions. *Quarterly Journal of Engineering Geology and Hydrogeology*, 36, pp.101–118.

Williams, M.B., Griffiths, D. V. & Fenton, G. a., 2005. Reliability of traditional retaining wall design. *Géotechnique*, 55(1), pp.55–62.

Zabidi, H. & Freitas, M.H.D.E., 2006. Structural studies for the prediction of karst in the Kuala Lumpur limestone. , (264), pp.1–7.