VOLUME LOSS ASSESSMENT FOR TWIN TUNNELING OF KLANG VALLEY MASS RAPID TRANSIT LINE 1

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DEDICATION

To All People

By Al-'Asr (the time). Verily, man is [deep] in loss, except for those who believe and do good deeds, urge one another to the truth and urge one another to patience." (Quran 103)

Sincerely,
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ABSTRACT

Ground settlement during tunneling works often affect the above ground structure. This problem may lead to safety risk impact and most worried its possible impact to the surrounding. In this case, the magnitude of ground settlement can be reduced by knowing the sufficient amount of volume loss (V_L) to be adopted during the design stage. However, the prediction of optimum V_L to be used in the design process relies on the data from previous actual case study area that shares similar ground condition. Although generally it is unusual to obtain homogeneous conditions for every tunneling work, it is preferable to study V_L references based on geometrical properties of the same geological area. Realizing unavailability of V_L data based on Klang Valley geological conditions, this study aims to provide actual V_L magnitude in relation with geometrical properties, within the Klang Valley vicinity. In this research, the actual ground settlements during the twin tunneling works of Klang Valley Mass Rapid Transit Sungai Buloh Kajang Line (KVMRT SBK) are monitored. This study focuses on 1.38 km Earth Pressure Balance (EPB) tunnel machine tunneling works from Semantan North Portal to Museum Station. From the actual maximum settlement occurred during tunneling, V_L was then evaluated by using back analysis formula proposed by Mair to get the V_L percentage. It was found that the average maximum percentage of V_L induced both tunneling is less than 1.0%. Comparison on both ground settlement results shows that the second tunnel induced large magnitude of ground movement than that of the first tunnel. This difference can be related to the effect of superposition theory. When twin tunneling works occur in equivalent condition (workmanship, geology, tunnel speed and tunnel type), the superposition effect will take place, and this has resulted in higher V_L readings in the second tunnel. Overall, results of V_L found in this research are in line with previous research findings where the range of V_L for tunneling works falls in the range of 0.2% to 2.0%.

ABSTRAK

Mendapan tanah semasa kerja pengorekan terowong sering memberi kesan ke atas struktur binaan di permukaan tanah. Hal ini boleh menimbulkan risiko keselamatan dan paling dibimbangkan kesan yang mungkin berlaku terhadap kawasan sekitarnya. Di dalam kes ini, magnitud mendapan permukaan boleh dikurangkan dengan mengetahui jumlah bagi isipadu hilang (V_L) yang menukupi untuk digunapakai semasa proses rekabentuk. Walaubagaimanapun, jangkaan V_L optimum untuk digunapakai dalam proses rekabentuk bergantung kepada data kes sebenar dari hasil kajian terdahulu di suatu kawasan yang berkongsi kondisi tanah yang sama. Walaupun secara umumnya jarang untuk mendapatkan dua keadaan homogen bagi setiap kerja terowong, adalah wajar untuk mengkaji rujukan V_L berdasarkan sifat-sifat geometri bagi kawasan geologi yang sama. Menyedari tiada data V_L yang tersedia berdasarkan keadaan geologi Lembah Klang, kajian ini bertujuan untuk memberi magnitud V_L sebenar berhubung dengan ciri geometri di sekitar Lembah Klang. Dalam kajian ini, kuantiti sebenar mendapan tanah semasa kerja pengorekan terowong kembar bagi projek Jajaran Keretapi 'Mass Rapid Transit' Lembah Klang laluan Sungai Buloh Kajang (KVMRT SBK) dipantau. Kajian ini mengfokuskan kepada penggunaan Mesin Pengorek Terowong Keseimbangan Tekanan Bumi (EPB) sepanjang 1.38 km melalui jajaran bawah tanah dari Portal Utara Semantan ke Stesen Muzium. Dari mendapan maksimum sebenar yang berlaku ketika proses pengorekan, V_L telah dinilai menggunakan formula analisa berbalik yang dicadangkan oleh Mair bagi mendapatkan peratusan V_L. Didapati bahawa purata peratusan V_L maksimum bagi kedua-dua terowong adalah kurang dari 1.0%. Perbandingan bagi kedua-dua mendapan tanah menunjukkan bahawa terowong yang kedua menghasilkan magnitud pergerakan tanah yang lebih besar berbanding dengan magnitud pergerakan tanah bagi terowong pertama. Ini boleh dikaitkan dengan teori kesan pertindihan. Bagi kerja-kerja terowong kembar yang berlaku di dalam kondisi yang sama (mutu kerja, geologi, tempoh kerja dan jenis mesin terowong), kesan pertindihan akan berlaku, dan ini telah menyebabkan bacaan nilai V_L yang tinggi pada terowong kedua. Secara keseluruhannya, dapatan nilai V_L dari kajian ini selari dengan hasil kajian sebelumnya yang mendapati bahawa peratusan V_L bagi kerja pengorekan terowong berada pada kadar 0.2% ke 2.0%.

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LIST OF ABBREVIATIONS

D&B	Drill and blast
EPB	Earth Pressure Balance
GSM	Ground settlement marker
LF	Load factor
LOP	Level of percentage
NATM	New Austrian tunneling Method
SCL	Spray concrete Lining
TBM	Tunnel Boring Machine
TOD	Transit Oriented Development
VD	Variable density
V_L	Volume loss
Sv_1	Ground Settlement induced by TBM 1
Sv_2	Ground Settlement induced by TBM 2
Vs	volume of settlement
KVMRT	Klang Valley Mass Rapid Transit
SBK	Sungai Buloh Kajang
SEM	Sequential excavation
OGL	Original ground level
Tc	Tunnel Crown
NB	Northbound
SB	Southbound
exp.	exponential

LIST OF SYMBOLS

ΔV	difference in ratio between amount of subsurface excavated material
π	Phi
i	horizontal distance from tunnel centerline to the point of inflection in Gaussian Distribution Curve
γ	soil bulk unit weight
Cu	undrained shear strength of soil.
c'	Effective Cohesion
φ	Efective friction angle
E_{50}	Young's Modulus
&	And

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The expansion of urban population and economic growth in city centre presents new challenges to the development plan. Thus, demand of efficiency public transport together with sustainable growth seeks high attention in developing better tomorrow. Recognizing this issue, one of the comprehensive strategy to foster public transport is by providing convenient infra system to the public. By implementing railway tunnel as part of transport and infrastructure work, land use in urban area can be optimized to support Transit Oriented Development (TODs) approach. Use of urban underground space needs to be considered in long term city development Masterplan (Bobylev, 2009). Although the development of underground transport system has it perks, the construction of tunnel has raised public concern to the tunnel induced ground movement, at adjacent subsurface structure. As such, assessing of ground settlement and the building deformation caused by tunneling activity needs to be prioritize in the preliminary process, as part of safety measure and requirements.

One of the design preliminary assessment prior to tunnel work is prediction of ground deformation in greenfield condition (i.e. neglecting any surface load). In this stage, the value of ground loss during tunneling is assumed to fall in certain range which to be set as one of the key parameters. Ground loss or often called volume loss (V_L) is defined as the volume of material that has been excavated in excess of theoretical design volume of excavation' (Loganathan, 2011). In other words, V_L is the amount of excessive material compared with what required in theoretical design. Ground deformation caused by tunnel excavation is inevitably associated with ground movement.

There are few factor affects the magnitude of V_L. This divides by two main group which describe as constructional factor and ground properties (Attewell and Farmer, 1974). Yet, another key point to be considered and often effect the V_L amount is geometrical properties. This factor weighting the contribution of tunnel cover-to-diameter ratio and it pillar width. The construction of tunnel often occurred in geological area that may not share same soil properties, therefore, the perk of studying geometrical properties as variable in finding V_L will further become good reference for preliminary ground assessment in tunnel design, especially those relates with Malaysia local geological area. Among the finding by previous research is that for shallow overburden area, the V_L found to be increase by decreasing tunnel depth (Ngan, Broere and Bosch, 2016).

There are three common methods broadly used in assessing the ground deformations induced by tunneling. Every methods has their own advantages, depending on data available to be applied on each methods. These are the numerical method, analytical method and empirical methods. For the study of V_L based on historical data, empirical method is widely used due to its capability to directly apply actual ground movement induced in its analysis to find the actual V_L. Nowadays, the construction of more than one tunnel within close space in urban area becomes common. The anticipate V_L induced especially from second tunnel recorded higher than the first tunnel. This due to superposition effect that take place during tunneling (Mair and Taylor, 1997). This statement supported by numerical findings by Addenbrooke (Addenbrooke T.I., 1996) where the area of second tunnel have already been affected by shear strains produced by first tunnel resulting in reduced stiffness which leads to higher V_L in second tunnel. Although much research have been initiated to find correlation between ground deformation and its V_L contribution, it is worth nothing to find those factors that relates to Malaysia local tunneling project.

1.2 Problem Statement

Early study conducted explained that prediction of ground surface movement associated with tunneling can be distinguished by two phases ; Prediction of volume of 'ground' loss during tunneling activity and the long term volume change occurred , in the ground (Glossop, 1978). In most cases, the V_L much depending on geological conditions of the tunneling associated with excavation technique. Preceding research conducts to identify the range of V_L. This was done by taking actual settlement occurred during tunnel activity and back calculated, in order to find the actual volume loss. As results from previous case historic data, V_L varying in the range of 0.2 % to 2.0 % were determined and used in practices. Nevertheless, there are three parameters which makes the V_L ranges unique and distinguished, which are geological condition, excavation method or in other word is tunneling techniques, and geometrical condition. As the range of proposed V_L is not self-dependent, therefore, it is deemed important to understand and investigate the V_L with close proximate to the local geological condition and tunneling techniques. As such, in this project where tunneling and geological condition occurred in same environment which are Kenny Hill and EPB, the variables of research is more focus on geometrical effect towards amount of V_L. With this, the outcome and recommendation of the study will provide future direction for further comprehensive and better justification for ground settlement analysis occurred, during tunnel excavation.

1.3 Significance of the Study

During tunnel excavation, changes of stress and ground mass around the excavation area likely cause the vertical and horizontal ground settlement. As result, the ground deformation occurs may cause the adjacent building to face the risk of collapse and damage. Thus, V_L is one of the main parameter being used in ground settlement analysis. It significantly controlled the predicted amount of maximum settlement, in preliminary green field analysis (i.e. no building , structures on the ground.) . To date, proposed of V_L ranges over tunnel relies on case study experiences in UK and beyond , as suggested by Mair (1996). Practically, the V_L values are estimated from back analysis of similar location. Although, not much research done during early tunneling in Malaysia ,especially those relates to the ground settlement associated with V_L occur, during tunneling. As the range of V_L governs by localized geotechnical properties and excavation techniques, it's deemed important to establish the V_L range which reflects to Klang valley local geological condition. In this research, the actual settlement value during tunnel section of Klang Valley Mass Rapid Transit Sungai Buloh Kajang Line (KVMRT SBK) were monitored. The actual settlement is then back- analyzed to get their actual V_L. Apart from that, the theoretical V_L amount is evaluated from semi-empirical method.

1.4 Research Aim and Objectives

The aims of this research are to determine the V_L occurrence and its behavior during KVMRT SBK tunneling activity, in relation with Kenny Hill geological and EPB tunneling technique. This can be achieved by the following objectives:

1. To determine the volume loss and ground settlement magnitude of twin tunnel.
2. To monitor the ground uplift movement (heave) occurred during tunneling.
3. To identify the effect of cover-to-diameter (C/D) ratio towards the amount of V_L.

1.5 Scope and Limitation of the Study

This research based on actual instrumentation data collected during KVMRT SBK underground twin tunnel section from Semantan North Portal to Museum Station.

Throughout monitoring work, over hundred data, were collected from the first tunneling until completion of second tunnel through. The tunnel section divided into two; Underground 1 (UG1) and Underground 2 (UG2). This research is focuses on tunneling of UG1 from Semantan North Portal to Museum Station, where the geological profile underlain by Kenny Hill Formation.

Moreover, for tunneling in Kenny Hill Formation, a closed face tunneling method was adopted. Twin Tunnel with stretch 4.4km long, over 9.5km in total were bored through by using Earth Pressure Balance (EPB) machine. For this project, research focuses on the tunneling about 1.38km from Semantan North Portal to Museum Station by EPB machine.

For the purpose of measuring localized settlement or heave caused by tunneling activity, ground settlement marker (GSM) were placed on ground. GSM were installed within range of 20m to 100m intervals. The monitoring of settlement marker was carried out by leveling survey and readings taken in between December 2013 to July 2014, , to monitor any settlement or heave. As the ground condition and tunneling technique remain constant, this research drills down the effect of geometrical properties as main key parameter varying the V_L.

1.6 Thesis Organizations

The thesis is presented according to the following chapter headings, the content of which is also briefly described below:

Chapter 1 discusses the background of study and problem statement as well significance of research paper. Scope and limitation of research is elaborating in detail, in this chapter.

Chapter 2 describes the current engineering practices for ground movement assessment of green field conditions. Discussion of assessment of ground movement induced by twin tunnel is described afterwards. Next, V_L effect and factor governs it amount are discusses in detail followed by discussion in heave formation.

Chapter 3 provides the flowchart of research procedure and elaborates detail of case study and it geological profiles. Next, field work and site monitoring is described comprehensively.

Chapter 4 elaborates analysis and result of V_L occurred. These include result and discussion on ground movement induced during tunneling, and its V_L results. Then, discussion on analysis comparison of actual ground movement with the theoretical is discussed further.

Chapter 5 emphasizes the result and finding in relation with research objective. Then, conclusions and recommendation are explained further.

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