PROBE DRILLING BASED PREDICTION OF ROCK MASS STRENGTH, NATM-4, PAHANG-SELANGOR RAW WATER TRANSFER TUNNEL, HULU LANGAT, SELANGOR, MALAYSIA

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by

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LIST OF ABBREVIATIONS

AIV	Aggregate Impact Value
Ch.	Chainage
ISRM	International Society for Rock Mechanics
JH	Japanese Highway
JHPC	Japan Hihgway Public Corporation
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air
NATM	New Austrian Tunnelling Method
PLT	Point Load Test
PSRWT	Pahang-Selangor Raw Water Transfer
TBM	Tunnel Boring Machine
TD	Tunnel distance
TSP	Tunnel Seismic Prediction

LIST OF SYMBOLS

k	Number of cluster
C	Degree Celsius
D	Specimen diameter
L	Length of the specimen
W	Width of the specimen
P	Maximum load at failure

DATA PENGGERUDIAN BERASASKAN RAMALAN KEKUATAN BATU, NATM-4, TEROWONG PERPINDAHAN AIR PAHANG-SELANGOR, HULU LANGAT, SELANGOR, MALAYSIA

ABSTRAK

Ramalan keadaan tanah dan batuan geologi terowong adalah salah satu aktiviti penting semasa pembinaan terowong. Sebelum penggalian, ciri-ciri geologi dianggarkan untuk mengelakkan masalah sebagai contoh kemasukan air yang berlebihan atau keruntuhan terowong yang boleh menyebabkan kematian. Kebiasaannya, jumbo terowong dengan gerudi pukulan digunakan untuk siasatan penggerudian. Data yang diperoleh daripada kaedah siasatan penggerudian telah diambil di Hulu Langat, Selangor, Malaysia. Perubahan diperhatikan pada ciri penggerudian semasa siasatan dijalankan dan ia memberikan petunjuk kepada kekuatan tanah, kehadiran rongga besar, jenis batu dan jumlah air bawah tanah. Rekod maklumat yang telah diperolehi ditafsirkan dengan menggunakan kelompok algoritma *k-means* untuk meramal keadaan tanah yang akan datang. Parameter yang diambil kira adalah kelajuan penggerudian dan peratusan batuan penggerudian memandangkan kedua-dua parameter ini memainkan faktor penting dalam keadaan tanah ramalan hadapan. Parameter ini digunakan untuk mengumpul data dan mengklasifikasi kekuatan batuan di mana ia digunakan untuk membezakan kumpulan kekuatan batu. Berdasarkan kelompok algoritma *k-means*, kelajuan penggerudian, peratusan keadaan batuan penggerudian dan ramalan ketepatan dikira untuk setiap kelas. Kaedah pengkelasan Japanese Highway (JH) digunakan untuk mengelaskan kelas batuan. Batu kelas B ditakrifkan sebagai kualiti batu yang baik, keras dan sedikit terjejas oleh luluhawa manakala kelas batu E ditakrifkan sebagai batuan yang sangat teruk kualiti and terjejas teruk oleh luluhawa. Dengan menggunakan kaedah kelompok algoritma k-means, ramalan ketepatan diperolehi untuk semua batuan kelas B, CI, CII, D dan E

masing-masing adalah 76.2%, 60%, 25.8%, 42.3% dan 51.9% manakala ramalan dari penggerudian pengesanan untuk batuan kelas B, CI, CII, D dan E masing-masing adalah 100%, 30.3%, 36.6%, 84.7% dan 85.2%.

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ABSTRACT

Probe drilling in tunnelling is carried out to collect information on the rock mass conditions ahead of a tunnel face. Prior to excavation, geological features are thoroughly studied in order to avoid unexpected difficult ground condition, for example excessive water ingress or tunnel collapse that may cause fatality. Usually, the tunnel jumbo with percussive drill is used for a probe drilling campaign. In this study, probe drilling data was collected from drilling activities recorded at Hulu Langat, Selangor, Malaysia. The observed changes on the drilling characteristic of probe drilling carried out provide us indication on the strength of ground, presence of large cavities, type of rock and the volume of groundwater. The information recorded were interpreted using k-means clustering algorithm to predict the ground condition. Parameters considered are drilling speed and percentages of rock chipping as both play important factors in prediction of ground condition ahead. Both parameters were used to cluster the data and classification of rock strength class. Based on k-means clustering algorithm, range of drilling speed, percentage rock chipping and accuracy was determined for each rock class. Japanese Highway (JH) classification method is used to classified the rock class. Rock class B is defined as a good quality rock, hard and fresh slightly affected by weathering whilst rock class E is defined as very poor to extremely poor-quality rocks and considerably weathered rock mass. By using k-means clustering method, the accuracy prediction was obtained for all rock class B, CI, CII, D and E is 76.2%, 60%, 25,8%, 42.3% and 51.9% respectively whereas prediction from probe drilling for rock class B, CI, CII, D and E is 100%, 30.3%, 36.6%, 84.7% and 85.2% respectively.

CHAPTER ONE
INTRODUCTION

1.1 Research Background

Infrastructure projects worldwide often face the same demands of producing short cuts in order to keep up with the increase in public traffic and transportation. Particularly in urban areas where the widening or adding of roads is no longer an option. One practicable solution is to go underground (Jetschny, 2010). One of the well-known method used up to now is conventional tunnelling which is also known in underground tunnelling as drill and blast. New Austrian Tunnelling Method (NATM) is by far the oldest method of tunnelling, still in use and a focus of continuing improvements. In general, a conventional tunnelling approach is safe, reliable and well researched method of tunnel construction. In spite of the advantages, there are certain disadvantages such as low safety at work of close to the tunnel face, and limited progress in tunnelling in soft rock is almost impossible. However, this conventional tunnelling is exceptional when constructing reasonably short tunnels due to its low costs (Singh & Singh, 2006).

To make it safe and to optimum the cost of a project, ground investigation is very important in any underground construction. It is required to study the ground condition ahead and make prediction from various methods such as Tunnel Seismic Prediction (TSP), seismic imaging technique, probe drilling method and drilled hole imaging method. It is essential to know the properties of the rock ahead of the face when digging a tunnel therefore lot of research studies of prediction of rock properties ahead of a tunnel face by using exploration drilling (Schunnesson, 1998; Yamashita et.al, 2008; Steele et.al, 2014) have been done. Identification on the properties of rock ahead of a tunnel face is one of the most important practices in tunnelling as it gave

advantages, increase safety and efficiency of tunnel construction. Probe drilling is used in this study to give information for the prediction. Info on drilling speed, rock chippings and water flow are some of the parameters given from the probe drilling.

By correlating predicted geological features, for instance weak or water bearing zones and lithological interfaces, with the known geological situation, the tunnelling process can be improved. Time consuming and expensive downtime can be avoided and the construction site as well as the surface is less exposed to safety threat. This is particularly essential for the tunnelling in urban areas, which mainly includes the utilization of tunnel construction machines below the water table.

1.2 Problem Statement

Prediction of ground condition ahead of tunnel face have developed and improved significantly over recent times. The most studied methods are; Tunnel Seismic Prediction (TSP), probe drilling method and the latest is drilled hole imaging technique (Kim et.al, 2015). In this research, data collected from prove drilling campaign at NATM-4 site of Pahang-Selangor Raw Water Transfer (PSRWT) tunnel project was used to study the ground condition ahead. It is presumed that the changes of drilling characteristics of probe drilling gave indication on the strength of ground/bedrck, presence of large cavities, type of rock and the volume of groundwater. All these factors will influence the high and low on values of parameters such as drilling speed, percentage of rock chipping, and slime colour that significant to ground conditions. The information records will be interpreted in order to predict the anticipated ground condition.

However, probe drilling is a brief data. More as a pinpoint data (Moritz et.al, 2004). Probe drilling data gave slight information regarding the ground conditions and

cannot be used to predict the ground condition ahead and not detail enough to be used without any aid from others method. Therefore, in predicting the ground conditions ahead tunnel face further testing like TSP and drilled hole imaging equipment are required.

Rock engineer is normally encountered with the need to work out at a number of design decisions in which judgement and practical experience must play an important part (Palmstrom, 1995). Prediction and/or evaluation of support requirements for tunnels is largely based on observations, experience and personal judgement of those involved in tunnel construction (Howard & Brekke, 1972). Thus, we want to make it as small as possible the uncertainties of prediction.

In summary, problem statement encounter in this study are:

i. Probe drilling data extraction

ii. Prediction of ground conditions ahead by using probe drilling

1.3 Objectives

To get the optimum information from probe drilling data, few objectives are set as follows:

1. To determine the geological factors affect the performance of probe drilling
2. To develop a method to predict ground conditions ahead using probe drilling
3. To correlate drilling speed & percentage of rock chipping parameters with rock strength.

1.4 Scope Limitations

Considering that there are a lot of parameters (drilling speed, percentage of rock chipping, slime colours, involved in probe drilling), therefore few scopes of

limitations has been decided. First scope is to choose the parameters related to this study such as rock cutting condition (chipping discharge from the drilling), water flow and drilling speed. Quantitative data is required in the analysis. Studies are solely based on the collected field data, defined as uncontrolled parameters. Further testing under the controlled environment are required to really identified the relationship thus to predict the ground ahead.

Another limitation of this study is referred to NATM tunnelling method. NATM is opted in outlet site which is in Langat area provides a good opportunity to study the ground condition. NATM-4 was chose as study area and constructed in the Main Range Granite. This granitic formation is idyllic for tunnelling since their characteristics which are massive, relatively "homogeneous" and competent. Figure 1.1 shows geological structure along the tunnel alignment. Method adopted for this prediction deals with short term settlement only. Normally the short-term settlements take place during or after excavation within a certain period of time, assuming that the condition of the ground is in the dominant undrained condition (Latif et al., 2013; Yahya & Abdullah, 2014). Long term settlements which consist of creep behaviour, consolidation and other factors are not within the scope of this study.

1.5 Thesis Outline

This dissertation is divided into three major parts. The first part deals with the analysis of the probe drilling data and geological data; the second part is investigating the rock properties of tunnel; and the third part correlates on the above mention factors leading to the prediction of ground condition ahead. This dissertation, however has five chapter. The contents of each chapter are outlined as follows:

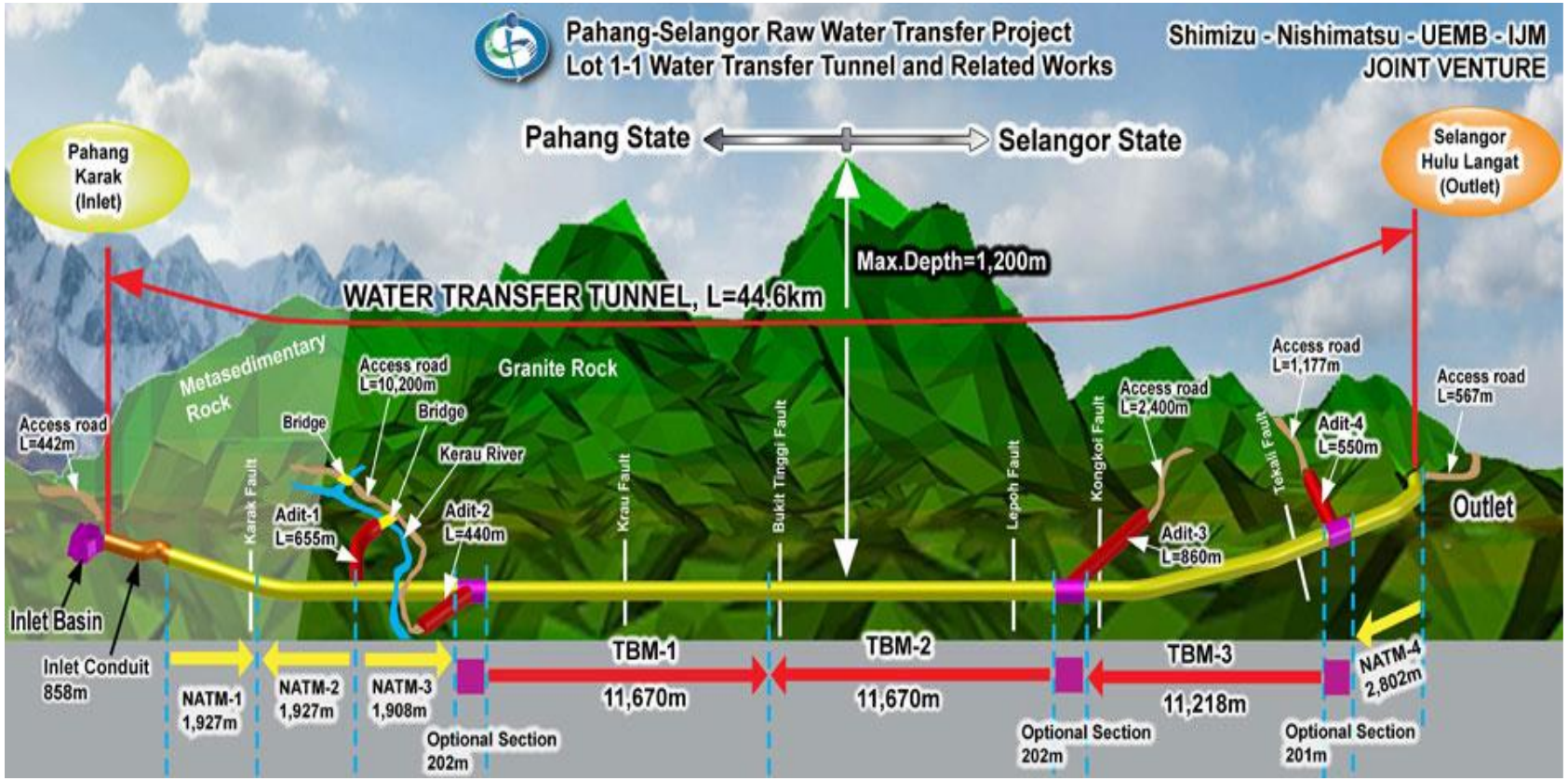

Figure 1.1: Geological structure along the tunnel alignment. The red circle shows the study area. (After KeTTHA)

Chapter 1: This chapter introduces the brief overviews on the problem statement, background research, study area and scope of limitations. Objectives of the research are stated and the workflow are given to correlate the parameters, methodologies, and relationships in prediction analysis.

Chapter 2: This chapter presents literature study which deals with the parameters and methodologies chosen. This chapter also enlighten the importance of prediction ground condition ahead.

Chapter 3: This chapter discusses methodologies chosen for each parameter. Lab tests could help to study the geomechanics properties.

Chapter 4: This chapter is a compilation results of the analyses. End results from the analyses will then be used for make a prediction of ground condition ahead.

Chapter 5: This chapter discusses the output towards conclusion and recommendations for future work.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide an overview on the methods and analyses that have been carried out by the previous researchers. The limitations in this study is the accessible probe drilling data from the project. There is neither specific equation not empirical scheming which is suitable for every underground condition study since the geological conditions is varies in every construction. In this chapter, geology of study area will be explained in details as well as the methods used in prediction of tunnelling.

2.2 General Background of Pahang-Selangor Raw Water Transfer (PSRWT) Project

2.2.1 Project Details

PSRWT project is located in the central area of the Peninsular Malaysia. Figure 2.1 shows the geological map around the project area. Topographically, the project area in Pahang side is drained by a number of rivers. The main rivers are the Semantan River, Telemong River and Kelau River.

A scheme to transfer water from Pahang to Selangor has been proposed to meet the increasing water demand in the commercial and industrial development centres. Selangor/Kuala Lumpur has the highest these demands but the water resources within the Selangor/Kuala Lumpur are not able to meet the demands in the near future. Therefore, the Pahang-Selangor Raw Water Transfer (PSRWT) tunnel project has been constructed to fulfil the demands.