Prediction of TBM advance rate; A comparative study of RME classification index and fuzzy logic

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ABSTRACT

A comparative study was carried out on TBM average rate of advance (ARA) predicted from conventional Rock Mass Excavability (RME) index and fuzzy modeling using a database developed in mostly hard to very hard volcanic rocks in Gilgel Gibe II Headrace TBM driven tunnel in Ethiopia. Comparison of measured ARAs with those predicted by the fuzzy model showed a good agreement with correlation coefficients of 0.87 which is more than 0.75 that achieved for conventional RME classification system. This highlights the potential of fuzzy rock mass classifications as a more promising tool in TBM performance prediction compared to conventional rock mass classification systems.

Keywords: TBM average rate of advance (ARA), Rock Mass Excavability (RME) index, fuzzy set theory.

INTRODUCTION

Generally speaking, most geosciences and engineering geological problems are complex. As a consequent, exact solutions of such engineering problems rarely exist, therefore, exploring the exact relationships among the different variables has been always a hard nut to crack. Moreover, imprecision and uncertainty are always present. Under such circumstances, it becomes difficult or even in most cases impossible to employ a precise mathematical modeling tool. By using the rules of probability, scientists were capable of dealing with such uncertainties in information. With fuzzy set theory coming into existence, it is done better by fuzzy logic. The main reason why fuzzy logic works better relates to the type of uncertainty that has to be dealt with. These uncertainties are semantic in nature rather than probabilistic. Semantic uncertainty arises when we are not able to describe a "cause-effect" relationship sharply. This type of uncertainty can be represented by means of fuzzy sets. Fuzzy sets theory, as a soft computing technique, has established itself as a new methodology for dealing with any sort of ambiguity and uncertainty. Soft computing, as introduced by Zadeh (1992), includes approaches to human reasoning, which try to make use of the human tolerance for incompleteness, uncertainty, imprecision, vagueness, and fuzziness in decision-making problems (Jang et al. 1997).

The performance prediction of a tunnel boring machine (TBM) is a typical example of a complex engineering system. The TBM performance prediction requires estimating the rate of penetration, machine utilization and machine advance rate. However, the main task in estimating the schedule and cost of a TBM tunneling project is the prediction of machine advance rate which is generally estimated from the knowledge about the penetration rate and utilization in a given set of geological conditions by multiplying the two. In general, the TBM penetration rate primarily reflects the machine efficiency in rock breakage. The utilization and advance rate relate to the suitability of the TBM, the rock mass quality and stand-up time, and the project management (Zhao et al. 2007).

Bieniawski et al. (2006) proposed the RME classification system for estimating TBM advance rate. Like most rating based classification systems, RME index has some limitations in practical application which may result in their misuse. The most important deficiencies of such rating based classification systems are the existence of sharp transition boundaries between two adjacent rock classes contrary to the gradational variation nature of rock and inclusion of subjective uncertainties which necessitate an expert judgment. Complete descriptions of these deficiencies may be found in previously published paper by the authors and are not repeated here (Khademi Hamidi et al. 2010). In this study, a comparison of TBM advance rate predicted using conventional RME index and fuzzy set theory is presented.

THE GILGEL GIBE II HEADRACE TUNNEL

Gilgel Gibe II Headrace project consists of a 26 km long, 7 m diameter tunnel driven by two Double Shield (DS) TBMs starting from the opposite Intake and Outlet portals. The foreseen rock formations were hard volcanic rocks (basalts, rhyolites, dolerite and trachyte) with high to very high uniaxial compressive strength (UCS) and good to fair RMR classes (Fig. 1). The DS TBM was supplied by the SELI Tecnologie Company which awarded the subcontract from Salini