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Optimizing overbreak prediction based on geological parameters comparing multiple regression analysis and artificial neural network

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ABSTRACT

Underground mining becomes more efficient due to the technological advancements of drilling and blasting methods and the developing of highly productive mining methods that facilitate easier access to ore. In the perspective of maximizing productivity in underground mining by drilling and blasting methods, overbreak control is an essential component. The causing factors of overbreak can simply divided as blasting and geological parameters and all of the factors are nonlinearly correlated. In this paper, the blasting design of the tunnel was fixed as the standard blasting pattern and the research focus on effects of geological parameters to the overbreak phenomenon. 49 sets of rock mass rating (RMR) and overbreak data were applied to linear and nonlinear multiple regression analysis (LMRA and NMRA) and artificial neural network (ANN) to predict overbreak as input and output parameters, respectively. The performance of LMRA, NMRA, and optimized ANN models was evaluated by comparing coefficient correlations (R^2) and their values are 0.694, 0.704 and 0.945, respectively, which means that the relatively high level of accuracy of the optimized ANN in comparison with LMRA and NMRA. The developed optimum overbreak predicting ANN model is suitable for establishing an overbreak warning and preventing system and it will utilize as a foundation reference for a practical drift blasting reconciliation at mines for operation improvements.

1. Introduction

In underground mining, overbreak has long been recognized as the principal cause of hazards and deterioration costs in mine management and as such numerous related research projects have been conducted. Many research papers have been devoted to clarifying the overbreak phenomenon, but they are still unable to explain the exact occurrence process. According to former research, factors causing overbreak can be classified into two groups. Different terminology has been used by different researchers, but geological and blasting factors were the principal groups influencing overbreak (Mahtab et al., 1997; Mandal et al., 2008).

Blasting parameters are changeable factors. Excavation conditions affect the likelihood of overbreak and these influencing parameters are highly correlated with each other. Some particular overbreak occurrences can be accounted for certain major influencing parameters, but it cannot be generalized without interpreting other influencing factors. In modern underground blasting, techniques are reasonably organized with advanced final wall blasting methods such as, smooth blasting and presplitting. Along with the advanced blasting methods, final wall customized explosives and computer base drill operating systems significantly reduce the possible failures on blasting operations. Geological factors, however, are unchangeable and they have a significant influence on the overbreak phenomenon. In fact, if the rock is not strong enough to support itself, possibly no blasting techniques can stop the occurrence of overbreak.

Notwithstanding the significance of overbreak in underground mining and tunneling, it is known as an unpredictable phenomenon. Acknowledging the importance of overbreak phenomenon, it is critical that it should be managed by proper systems. Predicting overbreak is the first step in developing an overbreak management and blasting reconciliation system. Throughout the history of mining and tunneling, there has been only one attempt to predict overbreak. Murthy et al., 2003 reported an overbreak prediction formula, comparing with the maximum charge per delay at Koyna Hydro-electric Project in India and the research used the peak particle velocity (PPV) threshold levels for damage estimation. However, the proposed overbreak prediction formula is not reliable and cannot be generalized for further use. The reason is that the formula used only the maximum charge per delay, which is only one factor of many others that need to be considered, and the PPV is a site specific value that cannot be generally applied to different sites.

In this paper, the blasting design of a tunnel was fixed as a standard blasting pattern and the study focuses on the effects of geological parameters to the overbreak phenomenon. RMR param-

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eters were collected through 49 blasting sections as geological data and overbreak data were individually investigated. Various methods have been applied in engineering for overbreak prediction. In this study, linear and nonlinear multiple regression analysis (LMRA and NMRA) and artificial neural network (ANN) are used to predict potential overbreak. The geological data sets are put as input parameters and encountered overbreak results are used as output parameters to ANN models and simultaneously to LMRA and NMRA. Consequently, the optimum overbreak predicting model is selected by comparing measured and predicted overbreaks and the correlation coefficient (R^2) of each proposed model.

2. Characteristics of overbreak

Overbreak is a surplus excavated area of rock beyond the theoretical contour in an excavation, and it can occur in any kind of underground excavation method. It is known to be inevitable when drilling and blasting method, and it is affected by the majority of conditions of excavation. Although excavation by drilling and blasting is known to be an inexpensive method, it becomes exorbitant when safety of structures is endangered. Overbreak of rock beyond the designed periphery of a tunnel is one major factor that puts excavated spaces at risk and significantly affects operational and management efficiency. Overbreak jeopardizes both workers and equipment in the underground excavations and increases dilution of the ore in mine operations. In addition, it adversely affects mine management by creating unproductive works such as dilution, requirements for additional supports and their removal, all of which adds to production costs. For example, Chakraborty et al. (1996) demonstrated the adverse effects of overbreak during the Koyna Hydro-electric project in India that was excavated by drilling and blasting methods. The area was predominantly covered with basalt and volcanic breccia with dense joint sets that caused 7–12% of overbreak of total excavation. Undesired excavations in the form of overbreak increased the total construction cost by about 19%. Fig. 1 illustrated the typical overbreak and underbreak in a tunnel after blasting.

2.1. Factors influencing to overbreak

Overbreak is known as an unavoidable phenomenon, and the causing factors for overbreak have significant mutual correlation. As mentioned earlier, the causing factors of overbreak can split into two categories – blasting and geological parameters.

2.1.1. Blasting parameters

As blasting parameters are able to be modified, overbreak can be managed by varying these parameters. The components of blasting parameters include blasting geometry, subdrilling, guide holes, firing sequences, cut design, blasting hole deviation, explosive characteristics, charge concentrations, coupling ratio, powder factors, blast-induced shock wave and energy levels, etc. All blasting parameters affect overbreak in complex mutual correlation within just a few milliseconds. Actually, to obtain a smooth fracture plane without any wall damage, proper blasting design and accurate drilling should take precedence and influence the selection of other blasting parameters. With these large influences on overbreak and the flexibility to manipulate blasting parameters, many research projects have been undertaken to understand the management of overbreak and to unveil the influences of blasting parameters on the overbreak phenomenon. For example, Rustan (1998) conducted model and field blasting tests to define the optimal delay time between contour holes in lock blasting by comparing simultaneous and micro-sequential initiation systems. Both systems have advantages and disadvantages, but simultaneous initiation system was found to be superior in minimizing overbreak. As a result, field tests showed the maximum radial crack length into the remaining rock mass of simultaneous initiation systems created a 1.3–9.0 times less than the micro-sequential initiation system which had only 1 ms firing delay between contour holes.

2.1.2. Geological parameters

Geological parameters are fixed factors and most of them, such as the strength of rock mass, discontinuous characteristics, water conditions, stress conditions, and the topography of the surrounding area, have significant influence on the overbreak phenomenon. Many research projects have been conducted to understand the relationship between geological factors and overbreak. For instance, Hagan (1992) emphasized the importance of pre-existing joints and beddings on in situ rock. According to his paper, fractures in the rock tend to dominate the nature of the blast-induced fracture pattern and it usually influences overbreak more than the mechanical and physical properties of the rock.

Among the geological factors, the orientation of discontinuity is one of the major factors influencing overbreak phenomenon. Hoek and Brown (1980) reported that a discontinuity plane having strike parallel to the tunnel axis is considered to have an unfavorable effect on overbreak. Generally, less overbreaks and under-breaks are observed where the strike of the discontinuity is nearly perpendicular to the tunnel axis and contrastively greater when they are nearly parallel. In detail of other orientations, drives with dip are more favorable than drive against dip where the strike of discontinuity is perpendicular to tunnel axis and fair and very unfavorable for dip has angle of 20–45° and 45–90°, respectively, when the strike is parallel to tunnel axis (Bieniawski, 1973).

Although the perpendicular orientation of discontinuity strikes against tunnel axis has been considered to have advantageous drivage conditions than parallel, it still has significant influences to

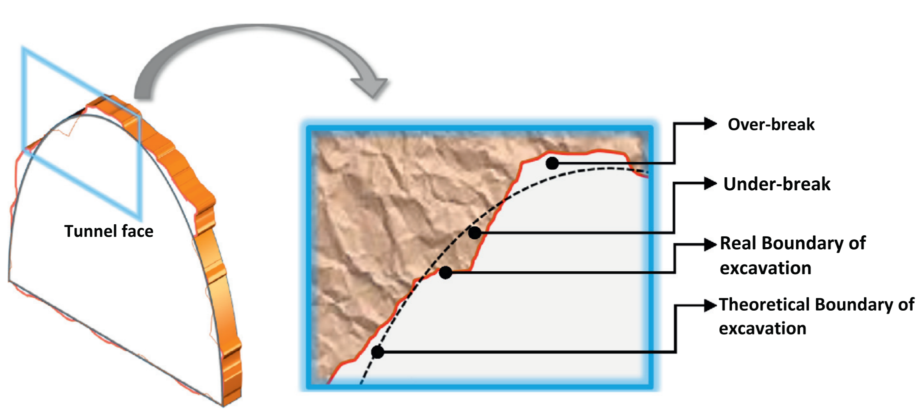

Fig. 1. Overbreak and under-break in tunnels conventionally excavated.