Tunnelling and Underground Space Technology 80 (2018) 1–9

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Overbreak prediction in underground excavations using hybrid ANFIS-PSO model

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ARTICLE INFO

Keywords:
Overbreak
Tunneling
Blasting
Prediction
ANFIS
PSO

ABSTRACT

In underground excavations and tunneling, several methods used for excavating process. Drilling and blasting is one of these methods, which are globally used for rock excavation due to low investment and high flexibility against ground condition variations. However, negative effects of blasting to the peripheral rock mass around the excavation are inevitable. One of these blasting damages known as overbreak phenomenon and must be predicted and controlled. Many of prediction problems can solve by using multiple regression analysis, but in some issues like mining and tunneling engineering, there are many uncertainties in nature of problems, which engineers cannot overcome these difficulties only using statistical methods. Then, soft computing methods can be curing this difficulty. In this study, 270 datasets were used with adaptive neuro-fuzzy inference system (ANFIS) and ANFIS-particle swarm optimization (PSO) to develop the predictor models. Input variables for models construction were considered tunnel section area; perimeter holes powder factor, specific drilling and spacing to burden ratio of contour holes. Determination coefficient and root mean square values of ANFIS and ANFIS-PSO models were obtained 0.945, 0.077 and 0.961, 0.064 respectively. The results indicate that ANFIS-PSO model showed better performance for overbreak prediction than ANFIS model.

1. Introduction

Tunnels and underground excavations are an inseparable part of mining engineering. Versus to the mechanized excavating methods like tunnel boring machine (TBM); drilling and blasting as a traditional method can used for excavations with different shape and size and due to the high flexibility and low finance need, drilling and blasting method is the initial expecting excavation method (Innaurato et al., 1998). However, duo to the using of explosives for rocks breakage, damages to the peripheral rock mass around the excavation are inevitable. Overbreak is one of the theses damage that we are encountering in the drill and blast method. Jang and Topal (2013) defined overbreak as a surplus blasted area of rock further than the designed contour line in the tunnel. Then, underbreak must be defined as remained rocks within the designed contour line in the tunnel. Fig. 1 illustrated the overbreak and underbreak in one of the Tazare coal mine tunnels that excavated by drilling and blasting method. As can be seen, hatched parts are unwanted remained rocks that blasting was not able to remove them during rock breakage that named as underbreak, and black parts are unwanted removed rocks beyond the designed excavation periphery that named as overbreak.

Overbreak caused by geological, blasting or geometrical factors, or a combination (Maerz et al., 1996; Mahtab et al, 1997; Rustan, 1998; Singh and Xavier, 2005; Jang and Topal, 2013). Then, overbreak causing factor can be divided to the Controllable and uncontrollable and semi-controllable factors. Controllable factors consist of blasting parameters and can be settlement by engineers. Uncontrollable factors consist of geological parameters and restricted to the operation by rock mass condition. Semi-controllable parameters consist of tunnel geometry and size. According to the Mahtab et al. (1997), in excavations with complex profile, there is a high potential of overbreak occurrences.

Uncontrollable factors like the strength of rock mass, joints orientation that have important effect on the overbreak are fixed parameters (Jang and Topal, 2013). As an example, the filling material within a rockmass joints and discontinuities walls changes its wave transmission characteristics. Filling material with the small width and the impedance closer to the host rock impedance caused better transmission of strain energy (Mottahedi et al., 2018). In tunnel contour section (Fig. 2b), blasting waves refracted and reflected due to the joints orientation and impedance difference between joints filling material and rockmass (Fig. 2c). These wave refractions and reflections can lead to create tensile crack between joints planes. These cracks progressed and linked to the joints surface due to the expansion of blasting gases and create a simple and weak paths for gases transmission. When the

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https://doi.org/10.1016/j.tust.2018.05.023
Received 24 April 2017; Received in revised form 10 May 2018; Accepted 28 May 2018

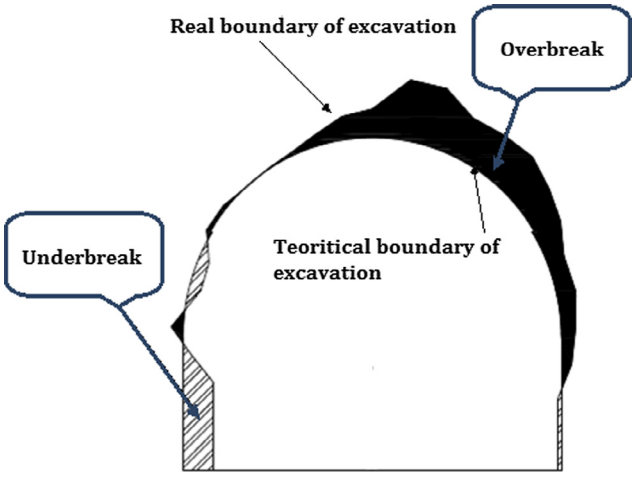

Fig. 1. Overbreak and underbreak in drill and blast tunneling.

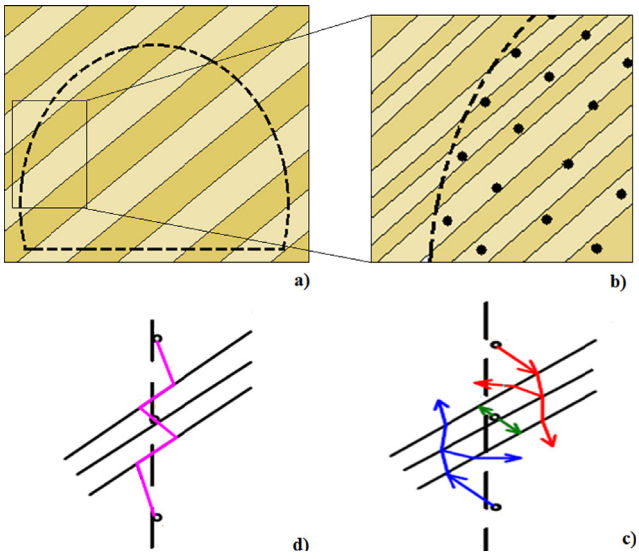

Fig. 2. Effect of discontinuities and their filling material on blasting wave transmission. (a) Tunnel cross section before blast holes drilling. (b) One part of the contour section after drilling. (c) Blasting wave refraction (Shiwei et al., 2013). (d) Creating jagged tunnel wall after blasting (Shiwei et al., 2013).

gases expanded in these paths, overbreak and underbreak are inevitable and create a jagged tunnel wall (Fig. 2d) (Singh, 2001, Mandal et al., 2008; Shiwei et al., 2013).

Controllable factors like specific charge or drilling, contour holes spacing, burden and delays are adjustable and engineers can change them during the blasting rounds. Proper design and correct implementation of drilling and blasting pattern are very important for overbreak prevention. For instant, each hole must be drilled at own location which designed and marked out, specifically at contour holes section. Any deviation from designed pattern may be lead to getting away or approaching the holes ends and due to the explosive concentration increment or reduction cause to overbreak or underbreak (Fig. 3). Moreover, delays number, especially in contour holes, have critical influence on overbreak occurrence. In contour section, holes that blasted simultaneously have less overbreak potential than holes that blasted with delay (Rustan, 1998). According to the Rustan (1998), using short delay (1–2 ms) for contour holes blasting can reduce the ground vibration and radial cracks frequency (Fig. 4b), but it is inefficient in order to overbreak preventing and radial crack length reduction. On the contrary, when contour holes blasted simultaneously overbreak and radial crack length can reduce, but ground vibration and

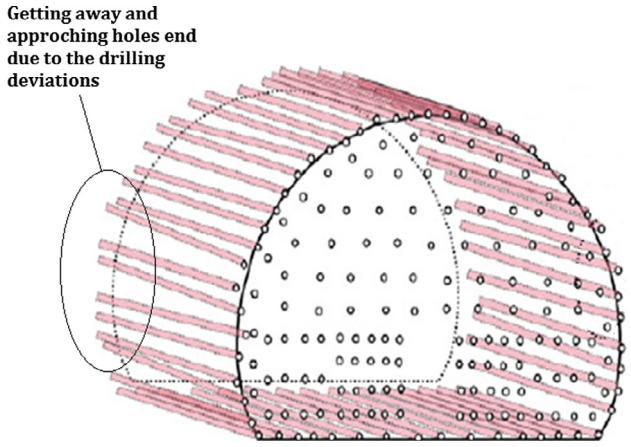

Fig. 3. Holes deviations due to the improper drilling practice.

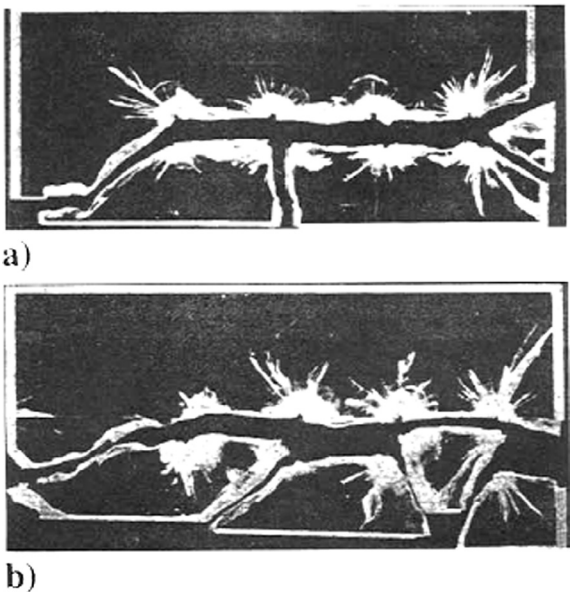

Fig. 4. Blasting with difference delays. (a) Simultaneously blasting. (b) Short delay blasting (Rustan, 1998).

radial cracks frequency will increase (Fig. 4a).

If overbreak occurred, undesirable effects will be showed up. In other side, Safety reduction of working space, ore dilution in mining excavations and time-consuming duo to the creating unproductive works are such as these negative effects. It is obvious that overbreak must be predicted and then controlled.

In present study, the proposed method for overbreak prediction is based on the combination of ANFIS and PSO algorithm. ANFIS-PSO was selected because ANFIS is the combination of ANN and Fuzzy logic and uses both of learning ability of ANN and inference ability of Fuzzy logic, then capability of ANFIS in prediction is more than ANN and Fuzzy logic when they use separately. Moreover, in recently years, PSO is used to increase the capability of ANFIS with adjusting the membership functions (MFs) parameters for decreasing prediction errors (e.g., Basser et al., 2015; Hasanipanah et al., 2016a, 2016c; Shahnazar et al., 2017). Hence, ANFIS-PSO can be more capable than ANFIS for prediction issues. The application of Soft computing methods like ANFIS, PSO and ANFIS-PSO in the mining industry is extensive and covers a considerable number of applications according to the Jang and Topal (2014). Here are some of the published works in the field of using ANFIS and PSO in engineering that presented in Table 1. In the next section, previous works on overbreak prediction are described