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Evaluating the Thickness of Broken Rock Zone for Deep Roadways using Nonlinear SVMs and Multiple Linear Regression Model

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Abstract

Since the traditional methods to estimation of the thickness of broken rock zone (BRZ) are usually difficult, expensive and not feasible in many cases, the development of some predictive models for the thickness of broken rock zone (BRZ) for deep roadways will be useful. To describe the complex relationship between geological factors and BRZ, a nonlinear model-based support vector machines (SVMs) analysis was applied on the data pertaining to China mine to develop some predictive models for the thickness of BRZ for deep roadways from the indirect methods in this study. The type of kernel function was Radial basis function (RBF). 132 samples were trained by proposed models; the other 10 samples that were not used for training were used to validate the trained models. For the same two similarity groups, the developed SVMs model was also compared with the multiple linear regression analysis (MLRA) models and measured data. As a result of SVMs analysis, very good model was derived for BRZ estimation. It was shown that SVMs models were more reliable and precise than the regression models. Concluding remark is that the thickness of BRZ values of deep roadways can reliably be estimated from the indirect methods using SVMs analysis.

Keywords: broken rock zone (BRZ); surrounding rock; support vector machines (SVMs); multiple linear regression analysis (MLRA)

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1. Introduction

In the development of a deep mine tunnel, the original stress balance is destroyed. When stress redistribution occurs, the radial stress decreases with distance while the tangential stress increases along with stress concentration. Furthermore, the three-dimensional stress state of the in situ rock mass can be approximated to a two-dimensional one, and the rock strength is greatly reduced. Consequently, the surrounding rocks will be unavoidably broken, and the area in which the rocks are broken is called broken rock zone around drifts (Dong 2001[1]; Kruschwitz and Yaramanci, 2004[2]; Cai and Kaiser, 2005[3]). According to the formation mechanism of the rock broken zone, the deformation of surrounding rock are mainly from the volume expansion of rock broken in the loose circle, and confining pressure of roadway is also caused mainly by loose circle (Jing 2004[4]). Therefore, Knowledge of the degree and extent of the excavation disturbed zone (EDZ) or identification of the broken rock zone (BRZ) thickness is important for the design and construction of deep underground engineering.

In order to study the stress distribution features of the surrounding rocks along the mine roadway after the roadway excavated and the radius size of the released circle, many methods is used to determine the scope of broken rock zone, such as acoustic method, seismic wave method, multipoint extensometer method, complex resistivity method, infiltration method and geologic radar method etc., among which acoustic method was used commonly (Kruschwitz and Yaramanci, 2004[2]; Jing 2004[4]; Chen et al. 2008[5]). However, the acoustic method is expensive, and is not feasible in many cases. Therefore, it is imperative to explore a more reasonable way to study the thickness of the loose ring. The extent and degree of the EDZ has been quantified by Cai and Kaiser, 2005[3] using microseismic monitoring data and the anisotropic softening model for the rock mass has been confirmed by field velocity measurement. Zou and Xiao 2010[6] put forward the mathematical model for determining EDZ of underground caverns. Jing et al. 2001[7] present a concept of “key part” of roadways and its stability criterion using the program of discontinuous deformation analysis (DDA) while Chen et al. 2008 [5] proposed a new arrangement mode of acoustic measuring boreholes for broken rock zone in gently inclined thin layer weakness structure. The broken zones of rectangle cavity under different conditions were calculated by Xia et al. 2010 [8] using FLAC3D. However, the thickness can not be gotten in advance. To solve this problem, the artificial neural network (ANN) was introduced by Zhu 1999[9] to predict the thickness of BRZ. Gao and Zheng, 2002[10] presented an evolutionary neural network (ENN) model on prediction of the thickness of the loosen zone around roadway. Jing 2004[4] and Xu et al. 2005 [11] introduced an emerging intelligent prediction method with adaptive neuro fuzzy inference system (ANFIS) into the thickness of BRZ prediction. Research shows that, the developed ANN model has some limitations, such as black box approach, arriving at local minima, less generalization capability, slow convergence speed, overfitting problem and absence of probabilistic output (Zhu 1999[9]; Gao and Zheng, 2002[10]). Furthermore, there is no proper method to determine the number of hidden layers in the ANN model. The developed FIS model determines the fuzzy rules with difficulty (Jing 2004[4]).

Among artificial intelligence (AI) tools, Support vector machines(SVM) is an efficient machine learning (ML) technique derived from statistical learning theory by Vapnik 1995 [12]. It is a machine learning tools being based on statistical theory and following the structural risk minimization principle. As a representative nonlinear technique, SVM will be used since it has been shown to be an effective technique for regression nonlinear dataset (Gun 1998[13]; Gopalakrishnan and Kim, 2011[14]; Chang and Lin 2000[15]). It is therefore motivating to investigate the capability of SVM in broken zone thickness prediction.

In the current study, the SVM is applied to predict the broken zone thickness and the predicted values accord well with the in situ measured ones. Thereby the SVM provides a new approach to obtaining the broken zone thickness.