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Feasibility of indirect determination of blast induced ground vibration based on support vector machine

Mahdi Hasanipanah [a], Masoud Monjezi [b,*], Azam Shahnazar [c], Danial Jahed Armaghani [d], Alireza Farazmand [e]

[a] Department of Mining Engineering, University of Kashan, Kashan, Iran
[b] Department of Mining, Faculty of Engineering, Tarbiat Modares University, Tehran 14115-143, Iran
[c] Department of Computer Engineering, Faculty of Engineering, Islamic Azad University, South Tehran Branch, Tehran, Iran
[d] Young Researchers and Elite Club, Qaemshahr Branch, Islamic Azad University, Qaemshahr, Iran
[e] Head of Geophysics and Earthquake Group, Moshanir Power Engineering Consultants, Tehran, Iran

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ABSTRACT

Mines, quarries, and construction sites face blasting environmental problems due to high level of ground vibrations. This phenomena can cause injury to both human and damage to structures in the blasting environment. To estimate ground vibration, several empirical predictors have been established by various researchers, while these predictors are not commonly enforceable beyond the particular conditions. However, ground vibration prediction is a complicated issue in consequence of the fact that a large number of influential factors are involved. In this study, a support vector machine (SVM) was applied and developed to predict ground vibration in blasting operations of Bakhtiari Dam, Iran. To achieve this aim, 80 blasting works were investigated and results of peak particle velocity (PPV) as a vibration index, distance from the blast-face and maximum charge per delay were measured and monitored to utilize in the modeling. To demonstrate applicability of the SVM model for prediction of PPV, several empirical equations were also employed and the relevant site constants were proposed. In the analyses procedure of this study, 60 datasets were used for model development and remaining 20 datasets were applied to check the performance capacity of the developed model. After comparing the results obtained from SVM and empirical equations, it was found that the SVM method provides higher performance capacity in predicting PPV compared to empirical equations.

1. Introduction

In blasting operations, only 20–30 percent of the produced energy is used for fragmentation purposes and the rest of this energy is wasted to create unwanted blasting environmental issues like back-break, air-overpressure, flyrock and ground vibration [1–6]. The wasted energy exposure creates problems for the workers associated in the excavation process as well as the local in habitants in the nearby area [7]. Among environmental impacts of blasting, ground vibration is considered as one of the important blasting environmental issues [8]. Although blasting vibration is short term transient phenomena, the residents in the vicinity of operations feel that if vibration continues then its swelling may get damaged [9]. High ground vibration resulting from blasting has undesirable effects on the structural integrity, groundwater, and ecol-

* Corresponding author. Tel.: +98 9122970377; fax: +98 2182883381.
E-mail addresses: hasanipanah.m@grad.kashanu.ac.ir (M. Hasanipanah), monjezi@modares.ac.ir (M. Monjezi), a_shahnazar211@yahoo.com (A. Shahnazar), danialarmaghani@gmail.com (D. Jahed Armaghani), afarazmand@yahoo.com (A. Farazmand).

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ogy of the nearby area [10]. Therefore, prediction of ground vibration is a significant criterion for future blasting operations to minimize the blasting environmental problems.

Normally, ground vibration is recorded in terms of two different parameters namely peak particle velocity (PPV) and frequency. Among them, PPV is considered as a vibration index, which is an important indicator for controlling the structural damage criteria. Many vibration predictors have been developed empirically to estimate PPV induced by blasting. Nevertheless, these methods considered only limited numbers of effective parameters on PPV whereas, this phenomenon is also affected by other controllable or non-controllable parameters [10,11]. As a result, empirical methods are not accurate enough in many cases, even though PPV prediction with high degree of accuracy is necessary to estimate the blast safety area [12]. Apart from that, simple and multiple regression techniques in estimating PPV have drawn attention [2,13,14]. Nevertheless, implementing the statistical predictive methods is not reliable if new available data are different from the original ones as the form of the obtained equation needs to be updated. Aside from that, feasibility of soft computing techniques like artificial neural network (ANN), fuzzy interface system (FIS) and neuro-fuzzy system (ANFIS) in solving geotechnical engineering problems [15–20] and more specific, for prediction of PPV resulting from blasting [10,21–23] has been reported in many studies. In the present study, support vector machine (SVM) is used to predict ground vibration resulting from blasting operations in Bakhtiari Dam, Iran. For the sake of comparison, empirical predictors are also employed to predict PPV.

2. Ground vibration and its effective parameters

When an explosive is detonated in a blast-hole, the explosive chemical reaction creates some gases with high pressure. These gases pressure crush the rock adjacent to the blast-hole. A wave motion is created in the ground by the strain waves conveyed to the surrounding rocks [24]. Due to various breakage mechanism like, crushing and radial cracking the strain energy carried out by these strain waves fragments the rock mass. During the propagation of the stress wave, high pressure gases extend discontinuities such as fracture and joint [25]. These waves are identified as ground vibration.

Two main groups of parameters that affect ground vibration produced by blasting are included controllable and uncontrollable parameters. The first group consists of controllable or blast design parameters like burden, spacing, sub-drilling, blast-hole depth, blast-hole diameter, number of blast hole, bench height, stemming height and type and weight of the explosive. Some of the controllable parameters of blasting are displayed in Fig. 1. Rock mass properties are considered as uncontrollable blasting parameters [26,27]. It is essential to optimize blasting design parameters to decrease ground vibration based on the properties of rock mass which include rock strength, density, wave velocity, discontinuity conditions [3,8,10]. In Indian Standard Institute [28], as a vibration index, PPV is introduced to control the structure damage.

Several empirical equations were developed by some researchers or institutions to predict the PPV induced by blasting. There are only two factors namely charge weight and distance from the blast-face in these equations [28–30]. Table 1 shows some empirical predictors for prediction of PPV. In this table, W is the maximum charge weight in kg, D is the distance from the blasting face (m), and K, a, b and n are the site constants.

In addition to empirical predictors, artificial intelligent techniques have been extensively-used by several researchers to predict PPV. Iphar et al. [21] utilized two different methods including simple regression and ANFIS models to predict PPV. They used 44 PPV values obtained from blasting operations in Turkey. The results indicated that the proposed model yields better results compared to regression analysis. Khandelwal and Singh [33] used ANN and multivariate regression analysis (MVRA) techniques to predict PPV and frequency. Finally, ANN results show closer agreement with the measured datasets in comparison to MVRA prediction. An ANN model with four input parameters including distance from blast-face, charge per delay, hole depth and stemming length was developed by Monjezi et al. [34] to predict PPV. For this purpose, a number of 182 datasets was measured around the Kandovan tunnel in Iran. They demonstrated that ANNs are enforceable tools for prediction of PPV. ANN technique and empirical equations were utilized by Monjezi et al. [3] for prediction of PPV. They compared the obtained results from ANN model with the actual field data obtained from Shur River Dam in Iran. Finally, they concluded that the ANN is more accurate technique in predicting PPV in comparison with empirical equations. Fisne et al. [35] employed FIS and regression model in order to estimate PPV considering some blasting data obtained from Akdaglar quarry in Turkey. Similar to many studies, they used the weight of explosive material and distance from blast-face as model inputs to predict PPV. They found that FIS model can provide higher performance capacity in predicting PPV in comparison to statistical model. Hajihassani et al. [23] proposed a new hybrid of artificial intelligence model namely imperialist competitive algorithm (ICA)-ANN for prediction of PPV values obtained from Harapan Ramai quarry, Malaysia. For comparison purpose, a pre-developed ANN model was also applied to predict PPV. It was found that ICA-ANN predictive model can predict PPV values with higher level of accuracy in comparison to pre-developed ANN approach. Verma and Singh [36] utilized three models including MVRA, ANN and SVM to predict PPV induced by blasting. They utilized results of 137 blasting operations obtained from Chhattisgarh site, India. They successfully showed that SVM model can be performed to optimize PPV with greater degree of confidence due to its robustness compared to other predictive models. In the other study of SVM, Mohamadnejad et al. [37] investigated the results of ground-vibration measurements carried out in Masjed-Soleiman dam in Iran. They used two intelligence techniques namely ANN and SVM and concluded that the SVM is a more precise and faster technique than the ANN model. Table 2 shows several recently-investigations with their performances in predicting PPV using soft computer techniques.