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Prediction of pore-water pressure using radial basis function neural network

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ABSTRACT

Knowledge of soil pore-water pressure variation due to climatic changes is fundamental for slope stability analysis and other problems associated with slope stability issues. This study is an application of Radial Basis Function Neural Network (RBFNN) modeling for prediction of soil pore-water pressure responses to rainfall. Time series data of rainfall and pore-water pressures were used to develop the RBFNN prediction model. The number of input neurons was decided by the analysis of auto-correlation between pore-water pressure data and cross-correlation between rainfall and pore-water pressure data. Establishing the number of hidden neurons by method of self learning network architecture determination and also by trial and error method was examined. A number of statistical measures were used for the evaluation of the network performance. Prediction results with a network architecture of 8–10–1 and a spread $\sigma = 3.0$ produced the lowest error measures (MSE, RMSE, MAE), highest coefficient of efficiency (CE) and coefficient of determination (R^2). The results suggest that RBFNN is suitable for mapping the non-linear, complex behavior of pore-water pressure responses to rainfall. Guidelines for choosing the number of input neurons and eliminating possibility of model over-fitting are also discussed.

1. Introduction

Pore-water pressure (PWP) is the pressure exerted by water in soil pores or voids. Fluctuations in soil pore-water pressures are mainly caused by dry and wet climatic conditions. Negative pore-water pressure gives additional shear strength to unsaturated soil zone while positive or even less negative pore-water pressures are undesirable for slope stability. Rainfall increases the pore-water pressure which decreases the soil shear strength and under adverse conditions may trigger slope instability. Shear resistance primarily depends on shear strength of the soil. Therefore, an increase in pore-water pressure due to rainfall decreases the shear strength of the soil resulting in the reduction of shear resisting capacity of a soil and finally causes slope failure. Thus, pore-water pressure plays a significant role in slope stability (Schnellmann et al., 2010).

A number of studies have also been conducted around the world on slope instability due to rainfall or to evaluate the effect of increase in pore-water pressure on slope stability (Yoshinaka et al., 1997; Au, 1998; Rinaldi and Casagli, 1999; Dapporto et al., 2001; Rahardjo et al., 2003; Wang and Sassa, 2003; Furuya et al., 2006; Yang and Zou, 2006; Kuriakose et al., 2008; Matsuura et al., 2008; Huang et al., 2009; Yang and Huang, 2009). Most of these studies show that increases in pore-water pressures due to rainfall have high impact on reducing shear strength of soil and causing slope failures.

However, knowledge of pore-water pressure variation due to rainfall is needed for studies related to seepage analyses, slope stability analyses, engineered slope design, and evaluating slope responses to rainfall (Rahardjo et al., 2007, 2008). Pore-water pressure information needed for such purposes is usually obtained through field instrumentation program which is often time consuming and resource intensive. Therefore, it would be an advantage if pore-water pressure could be predicted from knowledge of rainfall and antecedent pore-water pressures or other associated variables which are easily obtainable.

Different types of Artificial Neural Networks (ANNs) have been applied successfully in the prediction of various geotechnical parameters such as, soil permeability (Sinha and Wang, 2008; Erzin et al., 2009), bearing capacity of shallow foundation (Shahin et al., 2002; Padmini et al., 2008), settlement of rockfill dams (Kim and Kim, 2008), deflection of diaphragm walls (Kung et al., 2007), and pullout capacity of marquee ground anchors (Shahin and Jaksa, 2005). ANN has also been applied in site characterization (Basheer et al., 1996), tunneling performance evaluation (Yoo and Kim, 2007) and slope stability evaluation (Ni et al., 1996; Mayoraz and Vulliet, 2002; Goh and Kulhawy, 2003; Wang et al., 2005; Fernentinou and Sakellariou, 2007; Zhao, 2008).

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