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Reliability and Efficiency of Metamodel for Numerical Back Analysis of Tunnel Excavation

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Abstract: During tunnel construction, the ground properties, initially evaluated, are continuously assessed and verified through back analysis. This procedure generally requires many numerical analyses, so a metamodel based on artificial neural networks has been used to reduce the number of analyses. More datasets can be used to create more reliable metamodels. However, there are no established rules regarding the optimum number of datasets for a reliable metamodel. Metamodels predicting the vertical displacement of the tunnel crown using five ground parameters (unit weight (γ), uniaxial compressive strength (UCS), material constant m_i, geological strength index (GSI), and coefficient of lateral pressure (K)), with 3, 4, 6, 8, and 10 values per property, were created to confirm the reliability of the metamodel based on the number of datasets in this study. Metamodels using 6 and 8 values for each property showed 5% and 1% mean absolute percent errors, respectively. These numbers of each of the properties would be appropriate for developing the metamodel. Among the five parameters, only the results of the global sensitivity analyses of GSI and K are higher than 0.9. According to these results, it is verified that assessments based only on these parameters are sufficient in the back analysis.

Keywords: metamodel; artificial neural networks; back analysis; reliability; tunnel excavation

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1. Introduction

Tunnel engineers use numerical analysis methods, such as the finite element method, finite difference method, and distinct element method to predict the behaviours of underground and structures for support. However, it is difficult to obtain perfect information of ground due to its complexity and uncertainties. Additionally, it is impossible to conduct some experiments to obtain all of the ground properties due to costs and time. Back analysis has been employed to overcome the uncertain and limited information about the ground condition. Back analysis quantitatively assesses the ground properties via numerical analysis using measured displacements [1,2] and stresses [3]. It comprises inverse and direct methods, and the direct method is generally used for the convenience of calculation. In the direct method, numerical analysis is performed, and the displacements or stresses of the analysis are compared with measured displacements or stresses. Here, errors between predicted and measured values are calculated. The numerical analysis is repetitively performed by tuning the target parameters until the mean of the errors is minimised or falls below the target of mean of errors. The object properties of a back analysis can be obtained from the properties that derive results satisfying the tolerance. In this paper, back analysis means the direct method of a back analysis.

Back analysis has been widely used in geotechnical engineering. Gioda and Locatelli [4] conducted a back analysis to assess the elastic modulus and confirmed that the design must consider a lower elastic modulus than the ground investigation results. Fakhimi et al. [5] evaluated the coefficient of lateral pressure and cohesion of the ground