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Global Sensitivity Analysis in the Surface Settlement Prediction Caused by Mechanized Tunneling

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ABSTRACT: Global sensitivity analysis is one of the beneficial and useful tools to identify the uncertainty of input variables that has been extremely investigated in different science such as simulations. Sensitivity analysis is an essential step in the production of a meta-model, which by identifying effective parameters in tunneling, reduces the time and computations required. In this paper, sensitivity analysis was carried out on geotechnical and operational parameters of EPB mechanized tunneling in soft soil. So, the tunneling processes were modeled using a finite difference method in FLAC 3D software, and the numerical model was validated by the monitoring data obtained from the East-West route of the Tehran metro 7 line. The sensitivity analysis by using the elementary effect Morris method was performed on the 6 input parameters and three parameters (face pressure, specific gravity and cohesion of the soil layer in which the tunnel was excavated) were selected as effective and sensitive parameters in the maximum surface settlement. Then to construct the meta-model, 100 samples were generated from effective parameters using the Latin Hypercube method. After numerical simulation for each sample, the simulation results were used for surface settlement prediction by using an artificial neural network. The results showed that the prediction of the meta-model based on the artificial neural network and the numerical model for the data in the design phase corresponded about 98%.

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1- Introduction

For complex nonlinear problems such as mechanized tunneling, numerical simulation is very time-consuming and requires a lot of computation. So, sensitivity analysis is a useful and effective strategy to reduce the number of effective parameters and also decrease the uncertainty in the model response due to the uncertainties of the model inputs. In general, sensitivity analysis is separated into two main concepts, local and global [1-5]. Global sensitivity analysis is one of the approaches of sensitivity analyses that search the variations of model response by changing all parameters at the same time [6].

2- Methodology

In this paper, Morris elementary effect sensitivity analysis method was used to identify the important parameters in predicting the maximum surface settlement caused by tunneling process using earth pressure balance boring machine. Therefore, the finite difference method and the well-known software FLAC3D were used for numerical simulation, and subsequently the detection of sensitive parameters, 100 numerical simulations was performed for the prediction of the settlement using artificial neural network and the results were compared by the settlement simulation with initial geotechnical parameters.

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3- Results and Discussion

Among the geotechnical parameters, the specific gravity of the first and second layers, the cohesion of the first, second and third layers and also the face pressure as an operating parameter gauge for sensitivity analysis were selected. Their input values were based on the results of in situ and laboratory tests of soil samples for different depths of the selected section. The results of each simulation were collected by considering vertical displacement as the final result and the parameters related to the sensitivity analysis, including absolute mean value and standard deviation, were calculated. As can be seen from Figures 1 and 2, face pressure and cohesion of the second layer have the highest absolute mean value and standard deviation, indicating the high interaction of these two parameters with the rest of the parameters along with their high impact. To select the third parameter, the final result of the settlement after 30 steps of excavation was used, which this parameter is the specific weight of the second layer.

In order to create a meta-model, 100 samples using the Latin hypercube random data generation method were generated and then three-dimensional numerical simulations were performed for them. Using simulation results for every sample, 1500 data were prepared to predict the neural network. The results of the artificial neural network for all three types of training, testing, and validation data are presented in Table 1.

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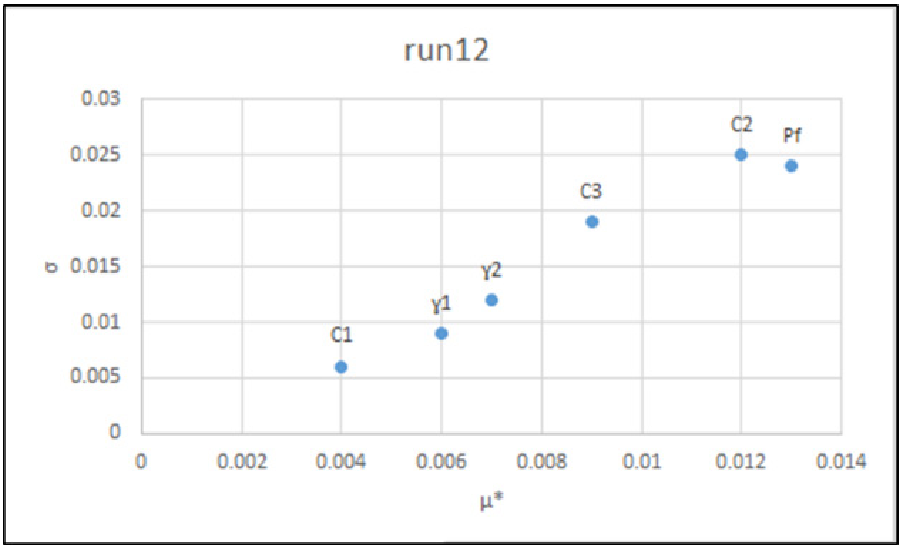

Fig. 1. Absolute mean values and standard deviation for the 6 selected parameters after 12 excavation steps

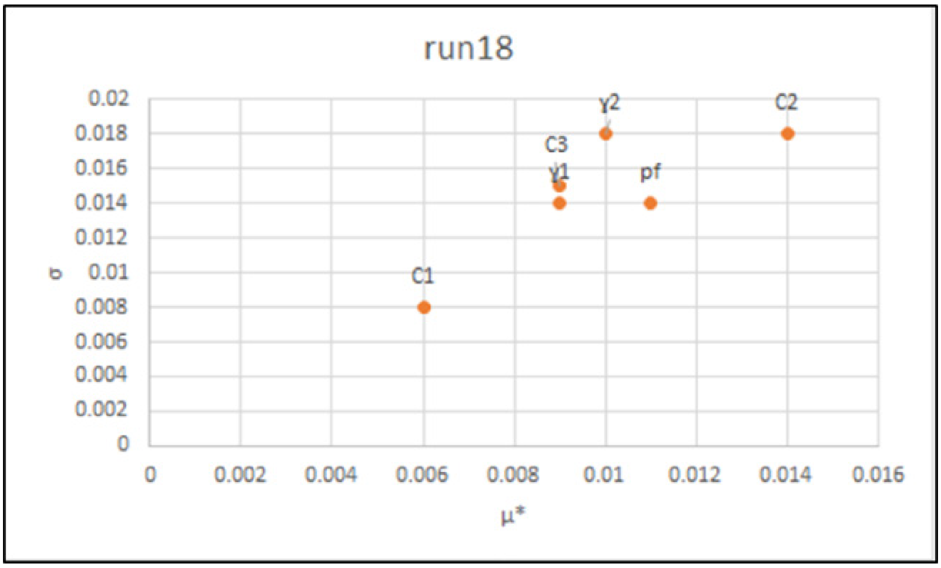

Fig. 2 Absolute mean values and standard deviation for the 6 selected parameters after 18 excavation steps

Table1. The results of ANN prediction

step	Regression factor	Mean square error	Number of samples
Training	0.9837	$4.93*10^{-4}$	1050
Test	0.9825	$6.26*10^{-4}$	225
Validation	0.9814	$6.61*10^{-4}$	225

4- Conclusions

The most important results of this paper are as follows:

The model constructed with initial geotechnical values with an error rate of about 10% showed acceptable concordance with the monitoring data and the validity of the numerical model was confirmed.

By Morris elementary effect sensitivity analysis method, three parameters of face pressure, specific gravity and cohesion of the second layer were selected as effective parameters in the maximum surface settlement.

The prediction results with the neural network showed 98% concordance with the 3D simulation results.

The time required to predict using a neural network is less than one minute. Therefore, due to this very low computational time, it is possible to apply these results in predicting the operational parameters to reduce the surface settlement by back analysis.

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