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Investigating the engineering properties of fiber-reinforced ultra-high performance self-compacting concrete and predicting its rheological properties using a hybrid neural network and RBF

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ABSTRACT: This study investigates the rheological and mechanical properties of ultra-high performance fiber reinforced self-compacting concrete (UHPSCC) using garnet and basalt aggregates, microsilica, fly ash, nanosilica, and steel fibers. To reduce construction costs, two artificial neural networks (ANN-GA and RBF-NN) are used to predict UHPSCC properties and compared with laboratory results. The studied rheological properties include slump flow diameter, slump flow time, V-funnel test, and L-box test. The laboratory results show high compressive and tensile strength, and acceptable rheological properties within EFNARC acceptance range. Both neural networks demonstrate acceptable accuracy in predicting rheological properties, with ANN-GA having higher prediction accuracy. Understanding UHPSCC properties is essential for the construction industry, and the use of ANN-GA can save on costs while maintaining accuracy in predicting its properties.

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1- Introduction

To prevent excavation collapse and its possible negative consequences, structures called stabilization are used to contain the excavation. One of these methods is the use of anchors. An anchor is a structural element installed in soil or rock that is used to transfer the applied tensile load to the ground [1]. Nowadays, some excavations are abandoned during or at the end of the excavation process due to problems such as financial or management. In excavations stabilized with anchors, the load of the anchors usually changes over time and these changes in load may cause significant lateral displacements in the excavation wall and cause it to collapse. Few studies have been done regarding the long-term behavior of anchors, which have been used using various methods such as numerical modeling, field studies and measurements, and laboratory model tests [2-9]. These studies have the following shortcomings: (a) There are no studies that study different soils, especially coarse grains with cementation. (b) In previous researches soil creep parameters were obtained from laboratory tests and there is no verification based on field measurements of excavation. In this article, we try to solve the above deficiencies and study the long-term behavior of anchors in excavations. In this research, using field data regarding the long-term behavior of a project, numerical modeling was done with the definition of the Burger creep model. Also, by using back analysis, the input creep variables of the behavior model have been predicted and proposed for the coarse-grained soil of Tehran.

2- Methodology

In this research, numerical modeling has been done using FLAC 2D version 8.1 software. The data of the Atieh Gharb hospital project located in Gharb town of Tehran city have been used for numerical modeling. The depth of the excavation of this project is about 42 meters, and for its stabilization, a combination of concrete piles, anchors, and nails have been used. The soil of the project is coarse-grained soil with cementation. To model the soil in the software in a time-independent mode, the Plastic Hardening (PH) model is used. This model is a shear and volumetric hardening constitutive model for the simulation of soil behavior [10]. After modeling of the time-independent behavior of the excavation, the creep behavior should be modeled in a new phase. Based on the review of past researches, the Burger creep model has been used to model the creep behavior in this research. The model made in FLAC software is shown in Figure 1. For the meshing of the model, dimensions of the mesh in the soil environment in the areas close to the excavation wall are small, and to reduce the analysis time, the dimensions in the distance away from the excavation wall

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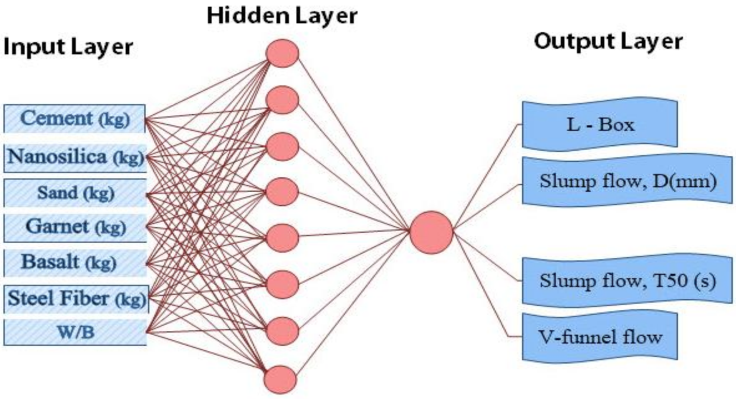

Fig. 1. Structures and input/output parameters of artificial neural networks

were gradually increased.

The determination of most variables in numerical modeling is based on classical modeling that has been presented in past researches. In this article, some specific points for the numerical modeling of the research subject are provided. The methodology of these points is summarized for the first time in this research and presented in this article. The FLAC software manual has presented how to determine the parameters based on the rock environment, and unfortunately, it does not mention how to determine and calculate the parameters of the cable element in the soil environment. Due to this lack of software guidance, some research [11] has been done by others to provide a practical method for soil containment modeling in FLAC software, which is summarized in this paper. Back analysis is a suitable method for determining model parameters using observational data collected from in-laboratory experiments [12] or field research [13]. In this research, because it was not possible to perform creep tests to obtain the parameters of the Burger creep model and the project was completed, the back analysis method was used to obtain the parameters of the Burger model. Four creep parameters of Burger model have been determined by the back analysis method and using the values of the prestressing force in the anchors over time as the output of the model.

In this research, data from two projects were used to verify numerical modeling: (a) Excavation of Atiye Hospital in Tehran; {b) nailed wall in Texas. The data of the prestressing force obtained from the loadcells and the displacements obtained from the survey in project (a) were compared with the numerical modeling results. In project (b), a nailed wall project on a road in Texas that was investigated in a study by the Texas Transportation Institute [4] was used.

3- Results and Discussion

The data obtained from the numerical analysis are presented and summarized in two parts including (a) the comparison of the changes in the prestressing force of anchors and (b) the horizontal displacement of the excavation wall over the time.

In the excavation of Atiyeh Gharb hospital, loadcells have been installed on two anchors and the load on these anchors has been monitored. Measurements were taken and recorded both during excavation and after the end of excavation (creep time). Accordingly, after the installation and prestressing of the 6th row anchor of 90 tons, the load in it until the end of the construction and excavation stages is equal to 86.3 tons, and 216 days after that it is equal to 83.7 tons. This means that during the period of 347 days after prestressing, the amount of load in this anchor has decreased by 7%. Also, after the installation and prestressing of the 11th row anchor of 90 tons, the load in it until the end of the construction and excavation stages is equal to 2.89 tons and 214 days after that it is equal to 1.87 tons. This means that during the period of 283 days after prestressing, the amount of load in this anchor has decreased by 3%. The results recorded by both loadcells are in good agreement with the results predicted by numerical modeling.

4- Conclusions

The numerical modeling method presented in this article can well model the time-dependent (creep) behavior of the anchors used in stabilization systems. Due to the fact that the creep variables of the Burger viscoplastic model for Tehran's coarse-grained soil had not been presented so far, in this research, these variables were obtained through the back analysis of the long-term behavior of achors. The long-term behavior of the stabilized excavation shows that over time due to creep, the horizontal deformation of the excavation wall increases, and the prestressing force in the anchors decreases. For the anchors installed in the upper levels of the excavation, i.e. in the upper depths and close to the ground level of the excavation, more load reduction occurs than other anchors during the creep time.

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