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EXTENDED ABSTRACTS

Using Two Intelligent Optimization Algorithms to Estimate the Effective Stress of Unsaturated Soils

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1. Introduction

Compacted soils, which are commonly used in geotechnical engineering projects, such as earth dams, highways, embankments, and airport runways, are mostly unsaturated. To achieve a safe design in all these projects, the stress state variable in soil plays a significant role. Any proposed model for the stress state variable should express its independence from the soil properties. In saturated soils, the e effective stress is taken into account as the stress state variable. Some researchers have attempted to find the stress state variable for unsaturated soils the same as that for saturated soils with only one variable; however, they have noticed that the soil properties have been involved in the proposed models (Bishop, 1959; Escario and Saez, 1986; Khalili and Khabbaz, 1998; Lu and Likos, 2004; Rahnema et al., 2019). The purpose of this paper is to apply new intelligent methods to accurately estimate the effective stress parameter, using two gray wolf optimization (GWO) and sine-cosine (SCA) optimization algorithms.

2. Methodology

2.1. Database

In this paper, the datasets used to develop two models were derived from 120 collected data from the literature (Bishop and Blight, 1963; Khalili et al., 2004; Lee et al., 2005; Miao et al., 2002; Rahardjo et al., 2004; Rampino et al., 2000; Russell and Khalili, 2006; Russell and Khalili, 2004; Thu et al., 2006). These data were associated with the results of triaxial, shear, pressure plate, and filter paper tests. These datasets consist of seven characteristics of unsaturated soils: suction (S), bubbling pressure (h_b), net confining pressure (P), residual water content (θ_r), saturated volumetric water content (θ_s), soil-water characteristic curve fitting parameter (λ), and effective stress parameter (χ). S, h_b, P, θ_r, and Θ_s characteristics of data became dimensionless as follows: P/P_0 is the dimensionless confining pressure parameter P_0 =101.325 KPa, S/h_b is the dimensionless suction parameter, and θ_r/θ_s is the dimensionless volumetric water content parameter.

2.2. Methods

2.2.1. Gray wolf optimization (GWO) algorithm

The GWO algorithm inspired by grey wolves that is suggested by Mirjalili et al. (2014). This algorithm divides the population into four groups: delta, omega, beta and alpha (Fattahi and Hasanipanah, 2020). In addition, the three hunting stages are simulated: attacking prey, looking for prey and encircling prey. The GWO algorithm needs a parameter number to be set, which includes initialize alpha, the stopping criteria, the sites selected

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number for neighborhood search, the search agents number, delta, the maximum iterations number and beta. A detailed explanation of the GWO could be discovered in (Mirjalili et al., 2014; Mirjalili et al., 2016). Many research have highlighted the potential of using the GWO algorithm. Xu et al. (2020) used the GWO algorithm for optimizing the SVR in predicting the UCS and shear strength. Gao et al. (2020) used the GWO algorithm to estimate the peak shear strength. Yu et al. (2020) studied the implementation of the GWO algorithm as well. They used the GWO algorithm to optimize the SVR parameters for assessing rock displacement caused by mine blasting. Shariati et al. (2020) recently estimated the concrete compressive strength using a combination of the GWO algorithm and the intense learning machine. The studies described above verified that the GWO algorithm can be utilized as an efficient algorithm for goal optimization.

2.2.2. Sine-cosine algorithm (SCA)

A newly proposed technique by (Mirjalili, 2016) called SCA simply based on Sine and Cosine function is applied for exploitation and exploration phases in global optimization functions. The SCA creates different initial random agent solutions and requires them to fluctuate outwards or towards the best possible solution using a mathematical model based on sine and cosine functions. Basic principles of SCA is represent in Fig. 1.

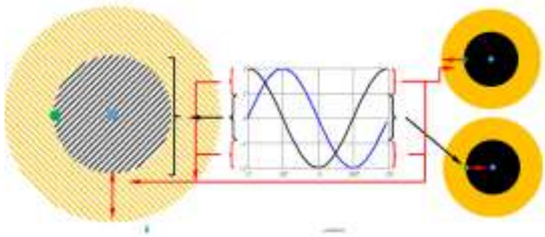


Fig. 1. Basic principle of SCA (Singh and Singh, 2017)

3. Results and discussion

In this paper, GWO and SCA models are suggested to estimate effective stress parameter. Comparative experiments (square correlation coefficient (R^2), mean absolute error percentage (MAPE), variance inclusion (VAF), mean square error (RMSE) and mean square error (MSE)) for two hybrid intelligence models is showed in Table 1. From Table 1, it can be found that the GWO algorithm is more reliable than SCA algorithm for predicting effective stress parameter.

Also, Figs. 2 and 3 show a comparison between estimated values of effective stress parameter by the GWO and SCA models and actual values for all 120 data points.

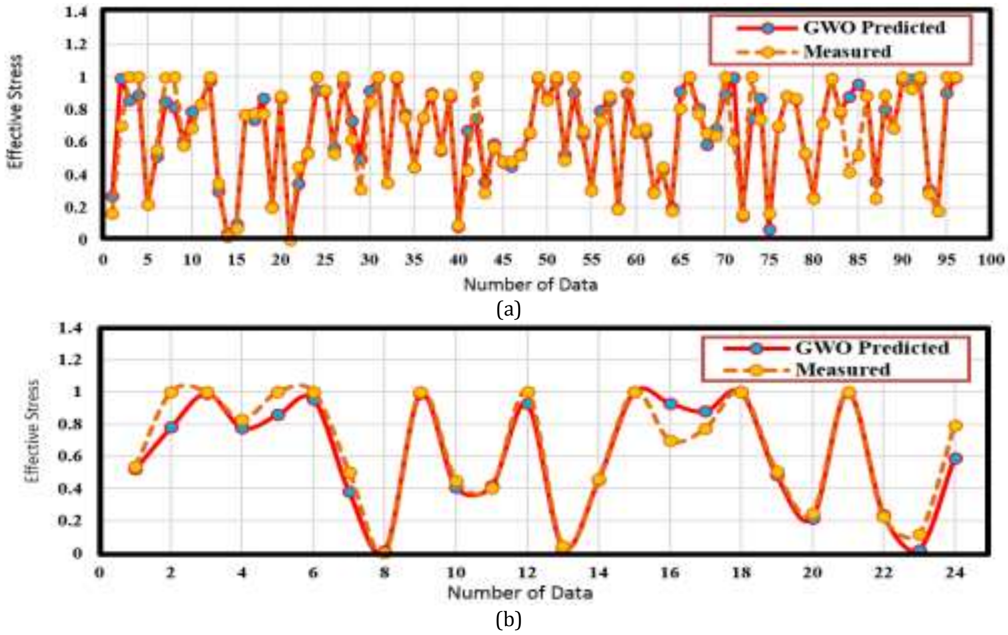
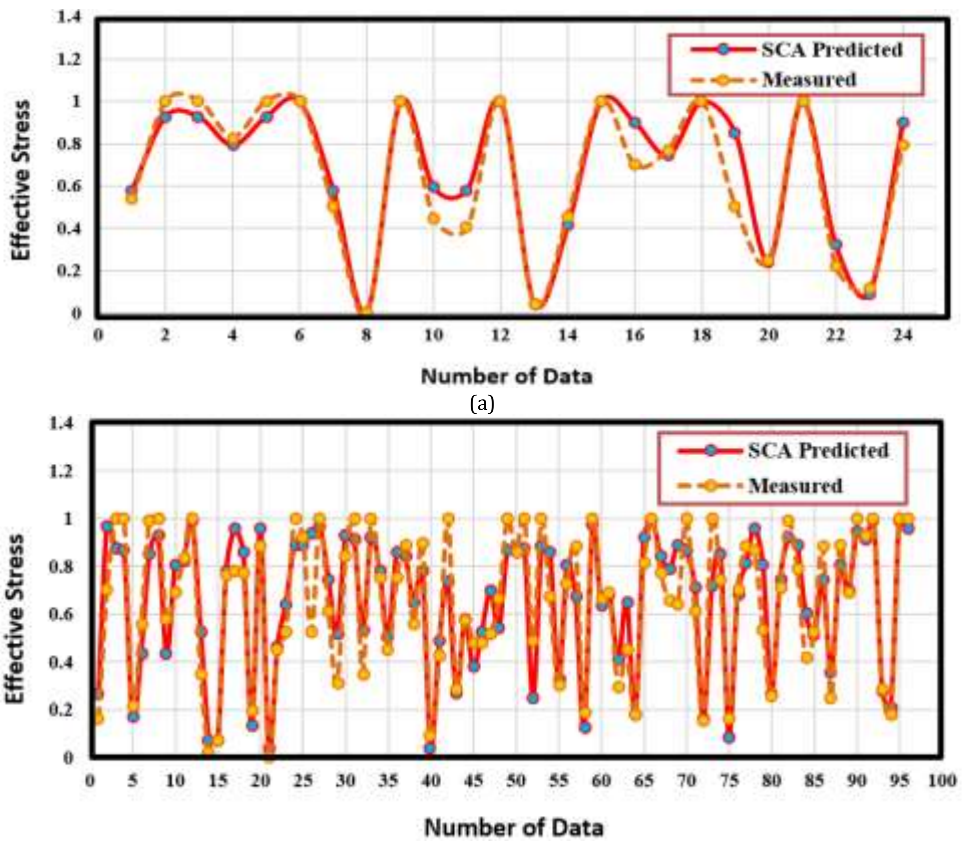


Fig. 2. Demonstrating the errors of effective stress parameter prediction by GWO algorithm for: a) training datasets, b) testing datasets



(a)

(b)

Fig. 3. Demonstrating the errors of effective stress parameter prediction by SCA algorithm for: a) training datasets, b) testing datasets

Table 1. Performance indices for two artificial intelligence methods

Model	MSE (Train)	MSE (Test)	RMSE (Train)	RMSE (Test)	MAPE (Train)	MAPE (Test)	VAF (Train)	VAF (Test)	R^2 (Train)	R^2 (Test)
GWO	0.009676	0.005529	0.0983	0.0743	0.01	0.0075	0.9134	0.9553	0.8632	0.9325
SCA	0.015029	0.007084	0.1225	0.0841	0.0125	0.0085	0.8867	0.9260	0.8306	0.9171

4. Conclusions

Unsaturated soils cover about 40% of the earth's surface soils and are found in most geotechnical engineering projects. Determining the shear strength of unsaturated soils based on the principle of effective stress for use in such projects requires relatively time-consuming, costly and complex tests. On the other hand, due to changes in soil properties of each region, the use of experimental methods to estimate the effective stress of unsaturated soils is less accurate and is associated with errors. In order to accurately estimate the shear strength of unsaturated soils, the purpose of this paper is to apply new intelligent methods to accurately estimate the effective stress parameter, using two GWO and SCA algorithms. In these models, parameters such as: the air entry value, the volumetric water content at residual and saturated conditions, the slope of soil water characteristic curve, the net confining stress and suction are used as input parameters and effective stress parameter is used as output. Finally, RMSE, VAF, MAPE, MSE and R^2 were used to evaluate the accuracy of the prediction models. The modeling results show that the use of two new algorithms, gray wolf and sine-cosine, has acceptable accuracy and efficiency in estimating the effective stress parameter for unsaturated soils.

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