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# Lateral bearing capacity of piles in soft saturated clay by two optimization algorithms

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**Abstract**

Determining the lateral bearing capacity of piles is one of the important issues that due to factors such as heterogeneity of soil environment in the pile and its geometric characteristics, the correct estimation of lateral bearing capacity of a pile is a problem. Although pile loading testing can be used as a reliable method at various stages of design despite its high accuracy, it incurs high costs and long execution times for construction and mining projects. In this paper, in order to apply new intelligent methods to estimate the lateral bearing capacity of piles in soft clay soils, two bee colony optimization and invasive weed optimization algorithms have been used. In these modelling, pile diameter (D), buried pile length (L), eccentricity of load (e) and non-drained shear strength of soil (Su) have been used as input parameters. Finally, in order to evaluate the accuracy of the models, the indices of square correlation coefficient ($R^2$), variance inclusion (VAF), mean absolute error percentage (MAPE), root mean square error (RMSE) and mean square error (MSE) were used. The evaluation results showed that for the bee colony algorithm, the estimation accuracy using $R^2$ and VAF indices was about 0.98-0.99 and using MAPE, RMSE and MSE indices between 0.000032-0.0056 and also for the algorithm. For invasive weed optimization algorithm, estimation accuracy using $R^2$ and VAF indices was about 0.97-0.98 and using MAPE, RMSE and MSE indices was between 0.0005-0.023. In addition, the results of sensitivity analysis showed that the non-drained shear strength of soil (Su), among other input parameters, has the greatest impact on the lateral bearing capacity of piles and change in it will have the greatest impact on the output of models.

***Keywords:*** *Lateral bearing capacity of piles, Soft saturated clay soils, Bee colony algorithm, Invasive weed optimization algorithm, Sensitivity analysis*

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## Extended Abstract:

### 1. Introduction

When designing structures, one of the most important parts that should be given special importance is the design of piles related to the structure. Piles are members of relatively tall structures or underground columns that are used to transfer structural loads through low-load soil layers to hard, solid soils with high load-bearing capacity at greater depths or on bedrock, so that the incoming load can be applied. And reduce the settling of surface structures to the permissible level. Otherwise, due to soil rupture under the foundation or excessive and heterogeneous subsidence, the destruction of the structure is inevitable. The behaviour of a pile under lateral loading is much more complex than a pile under a vertical load and also depends on the type of pile. In this case, the rupture may be due to rotation, bending (buckling and bending rupture) or displacement of the pile (shear rupture) or there may be several meters distance between the back of the pile and the soil. There is no bending in short candles, but there is the possibility of rotation and displacement, which is called rigid candles. In tall and thin candles, bending occurs and the probability of destruction of the candle structures is high, which is called flexible candles. In addition to the type of pile, another important factor in the bearing capacity of such piles is its geotechnical criterion so that if the load exceeds the capacity and strength characteristics of the soil, the product will lead to large horizontal displacement of the pile and ultimately lead to deep foundation failure. Therefore, due to the complexities of geotechnical behaviour, choosing the type of piles and the interaction of soil and piles, modelling and correctly predicting the behaviour of piles is very difficult and in some cases impossible. For this purpose, estimating the lateral bearing capacity of the pile using laboratory methods, due to time-consuming and costly experiments, theoretical methods due to high error and variable properties for each region, the researchers resorted to using computer methods. However, calculating the load capacity of a pile under lateral load with the help of finite element or finite difference computer programs requires advanced computers with temporary memory and high processing speed. In recent years, soft computing methods have been used as new intelligent methods to model complex relationships in various geotechnical fields, including piles, which have different values predicted by these methods than theoretical (analytical and experimental) methods, numerical and statistical Probabilities are closer to the actual values.

### 2. Materials and methods

As mentioned earlier, determining the lateral bearing capacity of a pile is difficult, costly and time consuming due to the complexity of soil behaviour. Therefore, mapping a mathematical relation by considering all the parameters accurately, so that in other cases it is possible to predict the lateral load capacity of the spark plugs, seems difficult and even impossible. Therefore, in order to consider all the parameters affecting the lateral bearing capacity of the piles and the prediction value is close to the real value, the use of intelligent methods is a very good alternative to methods such as experimental and regression methods and the ability to expand to determine bearing capacity. It also has side candles with different characteristics and various parameters. For this purpose, in this paper, the bee colony algorithm and invasive weed optimization algorithm are used to predict the lateral bearing capacity of piles in soft saturated clay soils. The data include 38 lateral load pile loading tests located on small-scale soft saturated clay soils, with parameters such as pile diameter (D), pile buried length (L), eccentricity of load (e), and non-drained shear strength of soil

(Su). ) Is used as the model input and the candle lateral resistance (Qm) is used as the model output. In this modelling, in order to accurately estimate the lateral bearing capacity of piles in soft saturated clay soils, the data were randomly divided into two parts: training and test data. For this purpose, out of 38 data, 80% of it (30 data) was used as training data (model construction) and the remaining 20% as test data (model evaluation).

## 3. Results and discussion

In this paper, out of 38 pile-scale lateral load tests with pile diameter input parameters (D), buried pile length (L), eccentricity of load (e) and untrained shear strength (Su) to estimate bearing capacity The side of the candles in soft saturated clay was exploited by two intelligent algorithms (bee colony optimization and invasive weed optimization algorithms). In the modelling stage, 80% of the data were randomly used in the training stage to build the model and the remaining 20% in the test stage was used to validate and evaluate the models. After constructing the model by algorithms and coding in MATLAB software to evaluate and validate the model created from the statistical indices of square correlation ($R^2$), variance inclusion (VAF), mean absolute error percentage (MAPE), root mean square error (RMSE) and mean square error (MSE) was used for each of the algorithms and training and test data. According to the validation and the obtained results, it was found that the model created by bee colony optimization and invasive weed optimization algorithms has a high accuracy and the actual value is very close to the predicted value. Due to the uncertainty in the values of geological parameters, the created limit state function can be generalized to any region, and by having the values of each of the model inputs, the lateral load-bearing capacity of piles in soils can be obtained at any point. Therefore, it can be concluded that this proposed model can be used for pile bearing capacity in a variety of soft clay soils. Finally, after validation of the model, @RISK software was used to evaluate the sensitivity analysis and the results showed that the Su parameter has the greatest effect on the lateral bearing capacity of piles in soils compared to other input parameters of the model. The results of this paper show that two bee colony optimization and invasive weed optimization algorithms for indirect estimation of lateral bearing capacity of piles are highly efficient and are used to solve complex problems of geotechnical engineering and rock mechanics.

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