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Energy Pile Resistance Calculation Method using Genetic Algorithm

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1 INTRODUCTION

Current zero greenhouse gas emission policy requires the industry to develop energy-saving strategies in buildings what recently becomes a crucial international issue. This issue causes increasing interest in nearly zero energy buildings (NZEB) construction and has led to growing focus on geo-structures that utilize shallow geothermal energy for space cooling and heating of buildings. Energy piles are the most common application of these structures. One of the great advantages of this issue is the stable underground temperature to exchange heat with the ground. However, the widespread energy piles application faces challenges due to the interaction between thermal and geotechnical design [1].

Energy pile performance has been studied regarding thermo-mechanical behavior or in situ experiments, laboratory tests, and numerical analyses. However, there is a lack of research on the optimization of energy piles under pile thermal resistance. Genetic algorithm modelling can be applied to optimize the design of energy piles considering thermal resistance across pile perimeter [2].

2 METHODOLOGY

To calculate the resistance across the perimeter of the energy pile, we designed the pile numerical model in COMSOL software. The 72 design cases were analysed using one U-shaped pipe with different position configuration. For numerical model, pile diameter $r_p = 0.6\text{m}$, inflow temperature $T_i = 277.15\text{K}$, temperature outflow $T_{out} = 280.15\text{K}$, soil temperature $T_g = 286.15\text{K}$. The dimensionless parameters introduced here are as follows (1):

$$\lambda_1 = \frac{r_b}{r_p}, \lambda_2 = \alpha, \lambda_3 = \frac{r_b}{r_t} \quad (1)$$

Where r_p pipe radius, r_b pile radius, r_t distance between pile and pipe center; α – angle between pipes centers and pile center. Based on the numerical calculation results we performed genetic algorithm modelling to obtain the value of shape factor S_b for unit pile resistance R'_b calculation, where k_g is soil's coefficient of thermal conductivity (2).

$$R'_b = \frac{1}{S_b k_g} \quad (2)$$

3 RESULTS & DISCUSSIONS

Based on the genetic algorithm method, a type of machine learning algorithm, we developed a predictive model that fits the provided data through regression analysis. The procedure first initialises a population of potential models, represented as mathematical expressions. Each mathematical model consists of building blocks, such as mathematical operators and variables. The initial population is generated randomly, and each model is evaluated based on its ability to fit the data. Regression calculations are performed using the selected model, which is expressed as a mathematical equation that predicts the target variable based on the input variables. Equation (3) can be used to predict the target unit resistance of the energy pile:

$$R'_b = \frac{1}{S_b k_g} = \frac{1}{k_g} \cdot \frac{1}{\frac{\sqrt{\lambda_1 + k_1 \lambda_2}}{\lambda_1 + k_2} + \sqrt{\frac{1}{\lambda_3^4} + \frac{k_3 \lambda_2}{k_4 \lambda_1 + \lambda_2}}} \quad (3)$$

Where, the k_1 , k_2 , k_3 and k_4 are constants equal to 6.288, 3.735, 10.341 and 2.336.

The quality of deployed model can be presented by employment model quality quantification parameters to measure the performance and accuracy of a model in predicting the target variable. The most common model quality quantification parameters are presented in **Table 1**.

Table 1: Unit resistance model quality assessment with use of common parameters.

parameter	MSE	RMSE	RSE	RRSE	R ²
unit resistance model	0.0036	0.06	0.052	0.229	0.953

4 CONCLUSIONS

This paper describes the methodology used to calculate the unit resistance of an energy pile by developing a numerical model in COMSOL software and using genetic algorithm modelling to obtain the value of shape factor S_b for calculating the unit pile resistance. The results and discussion show that the predictive model developed using regression analysis, and equation (3) can be used to predict the target unit resistance of the energy pile. Based on the model quality parameters, it can be concluded that the model has high accuracy ($R^2=0.953$) and low error (RMSE=0.06) in predicting the target variable R'_b , allows to utilise it in practice.

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