Iranian Journal of Engineering Geology
Summer 2023, Vol.16, No.2

Investigating the Effects of Thermal Loading on Geothermal Pile in Layered Soils

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Abstract

Energy pile is dual purpose foundation that transfers structural loads and also transforms energy. They act as heat exchanger in addition to transferring loads to underneath earth layers. To investigate the effects of soils on energy pile, in present study a two dimensional (2D), axisymmetric numerical model for the energy piles has been created using finite element method base on the field test by COMSOL. The main purpose of this study is investigating energy pile response in various soils. This was performed by considering some different hypothetical layers with the bedrock under them and their results which included displacement, strain and stresses induced by thermal load compared with four layered soil experimental data. The results showed that soil properties have important effect on the response of energy pile. Also temperature affects pile reactions. Conclusions specified that in all result graphs the response of layered soil is between single layer responses.

Keywords: *Geothermal, Pile, Renewable Energy, Finite Element*

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Extended Abstract:

1. Introduction

Because of increasing demand for energy resources due to population growth and the consequent overexploitation of fossil fuels, to mitigate greenhouse gas emissions, it is important to transition from conventional energy sources to renewable ones. Geothermal energy is environmentally friendly option that can contribute to sustainable development. The use of geothermal energy in building heating and cooling systems, specifically through geothermal piles or energy foundations, is explored. Several research studies are demonstrated the thermo-mechanical behaviour and performance of energy piles under different conditions. The effects of thermal loads on displacement, stress, and strains are discussed, emphasizing the need to consider these factors in the design of energy piles. Current study focuses on analysing the thermal response of energy piles in various soil types using experimental data from a four-story building in Lausanne, Switzerland. Numerical calculations and comparisons with test results are conducted to validate the findings.

2. Materials and methods

In the current study, a Finite Element Method (FEM) was used for investigating the thermo-mechanical behavior of energy piles. COMSOL 5.3 Multiphysics software used to model the thermo-hydro-mechanical (THM) behavior of the piles.
In this study, the pile geometry was considered axially symmetrical due to its circular cross-section and the uniform characteristics of the stratigraphy. The pile had a radius of 0.5 m and a length of 26 m.
For the mechanical boundary conditions, the right vertical boundary was allowed to move only in the vertical direction, while the bottom boundary was fixed and unable to move. The model was free at the top, and the left border was treated as the axis of symmetry. The contact surface between the pile and the soil was assumed to be hard and uneven, indicating no relative movement between them. Drainage was permitted from the upper and right borders.
Thermal loading was applied to the pile by implementing temperature changes listed in Table 1. The model allowed heat exchange with the external boundary. Positive displacement was defined as upward, and negative axial stress and strain values represented compression. A compressive axial force was assumed as negative, so heating the pile caused a positive change.

Table 1: Temperature values applied to the pile

Temperature(^{0}c)	Time(day)
0	0
2	5
21	12
10	15
3	28

3. Tests results

In the present research, an investigation into the thermal behavior of a pile using both numerical modeling and experimental results conducted. A heating-cooling cycle aplied to the pile over a specific time period, consisting of a 12-day heating period followed by a 16-day cooling period.

Data collected on the change in location, strain, and stress of the heat exchanger pile at various depths. The obtained results from the numerical model were then compared to the values obtained from the experimental study.

In the graphs provided, the vertical displacement is depicted in a positive direction for upward movement, and tensile stress is considered positive. This convention helps in visualizing the behavior of the pile under thermal loading.

The study not only focused on analyzing the thermal behavior of the pile in three different types of single and homogeneous layers but also included the consideration of a multi-layer state. This allowed for a comprehensive understanding of the pile's response under varying conditions.

By comparing the numerical model results with the experimental data, the researchers aimed to validate the accuracy and reliability of their simulation approach. This analysis can provide valuable insights into the thermal performance and structural behavior of heat exchanger piles, aiding in their design and optimization.

4. Conclusion

This study focused on investigating the behavior of geothermal piles under thermal loading in different soil conditions using numerical modeling. Two scenarios were considered: one with a non-homogeneous and layered soil profile, and another with a homogeneous soil layer on bedrock. The analysis compared the strains and stresses in these scenarios. The results showed that the response of thermal energy piles varied depending on the type of soil, soil characteristics, and load on the pile. Heat caused changes in stress and strain, increasing vertical stress with depth. The presence of different soil layers led to variations in strain and stress compared to a homogeneous soil condition. Notably, the response of multi-layered soil at the surface closely resembled that of loose soil. The modulus of elasticity affected displacement, compressive stress, and vertical strain. The study emphasized the significant influence of soil type and layering on geothermal pile behavior and stressed the importance of considering real-world soil conditions for accurate analysis and design.

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