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Investigation of the effect of groundwater flow velocity on energy efficiency in energy pile groups positioned parallel to the groundwater flow direction

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ABSTRACT

In recent years, many studies have been carried out on energy piles based on the principle of utilizing the heat potential of shallow soils. The thermal energy obtained from energy piles is affected by various factors. One of important factors can be considered as groundwater flow. In this study, the effect of groundwater flow velocity on the thermal energy obtained from energy pile groups positioned parallel to the groundwater flow direction was investigated using GeoStudio TEMP/W and SEEP/W Finite Element Method Software. Analyses results indicate that the energy obtained from the piles may increase with the increase in the groundwater flow velocity.

Introduction

In recent years the geothermal heat potential of the ground has interested by researchers as an important renewable energy source. Since it is not possible to transfer geothermal energy to the ground surface in terms of application and economy, the heat potential of shallow soils is an important alternative that should be evaluated.

The energy pile mechanism is an environmental technology that facilitates the use of renewable energy sources for efficient space heating and cooling. In this system, the piles that are already required for structural support are equipped with geothermal loops for performing heat exchange operations to exploit the near surface geothermal energy [1].

Material and Method

Energy piles are actually traditional deep foundation piles with embedded fluid pipes that work as ground heat exchangers. The basic schema of energy piles foundation seen in Fig. 1.

Heat transfer in energy pile foundations is governed by the dynamics of the thermal requirements of the building, the thermal properties of the soil, concrete and heat carrier fluid, the aspect ratio and spacing between the energy piles, the thermal influence of the ground surface and the presence of groundwater flow.

Soil conditions, soil thermal properties, heat exchanger pipe configurations, foundation geometry and presence of groundwater are the main factors affecting the thermal efficiency of energy piles. The presence and movements of groundwater flow in shallow soil complicate the heat transfer mechanism. Generally, groundwater conditions are advantageous for the thermal performance of energy piles. Model geometry designed in TEMP/W and SEEP/W is shown in Fig. 2, heat transfer model with groundwater flow is shown in Fig. 3.

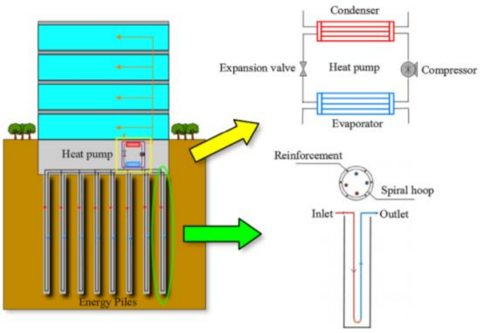

Figure 1. The schematic diagram of Energy Pile foundation [2]

In this study, the effect of the groundwater flow rate in the shallow soil on the efficiency of group energy piles were investigated with numerical analyses. The analyses were performed by TEMP/W and SEEP/W Finite Element Method Software [3-4].

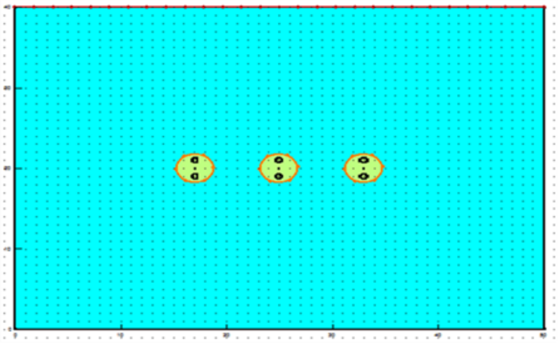

Figure 2. Model geometry (TEMP/W, SEEP/W)

Results and Discussion

In the energy pile groups positioned parallel to the groundwater flow direction in the aquifer, the predicted thermal energy which can be extracted increase as the velocity of the groundwater flow increases. It is seen in Table 1 that the ultimate rate of heat gain is achieved in the first pile in the groundwater flow direction, while the lowest heat gain can be reached in the last pile in the group.

Table 1. Energy values obtained for pile groups positioned parallel to the groundwater flow direction at different groundwater flow rates (plan analysis) [5]

Time	First Pile			Second Pile			Third Pile		
	v= 0,16 m/gün	v= 0,8 m/gün	v= 1,6 m/gün	v= 0,16 m/gün	v= 0,8 m/gün	v= 1,6 m/gün	v= 0,16 m/gün	v= 0,8 m/gün	v= 1,6 m/gün
0	169,39	261,357	346,80	153,63	181,52	211,43	154,29	175,37	197,43
30	107,35	219,121	309,60	75,751	109,87	145,98	75,474	95,059	122,29
60	98,922	215,277	306,01	56,987	100,02	139,28	54,928	81,434	113,31
90	96,931	214,518	305,26	49,472	98,364	138,28	45,378	78,677	111,96
180	96,200	214,314	305,06	44,406	98,036	138,06	36,259	78,052	111,69
360	96,178	214,311	305,06	44,027	98,034	138,05	34,722	78,049	111,69

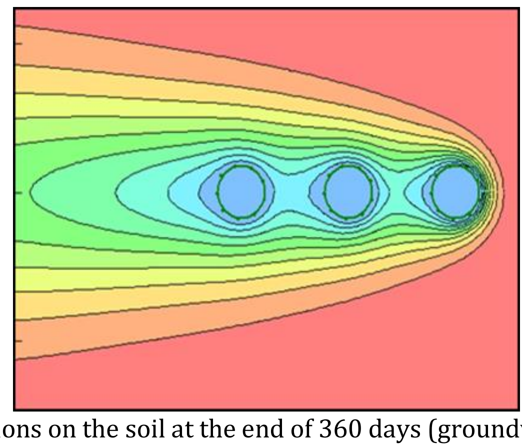

Figure 3. Temperature distributions on the soil at the end of 360 days (groundwater flow available) (TEMP/W, SEEP/W)

In the group formed with three energy piles positioned parallel to the flow direction, the effect of groundwater on the heat energy that can be obtained was formulated using the nonlinear regression technique, taking into account the results of the plan analysis.The quantity of energy (E, Watt) that can be obtained depending on the time (t, day) and the groundwater flow rate in the aquifer (v, m/day) is respectively, starting from the first energy pile in the flow direction:

$$E\ (\text{Watt}) = -0{,}3753\sqrt{t} + 249{,}4\sqrt{v} \qquad R^2 = 0{,}98 \qquad (1)$$

$$E = -31{,}39\ \sqrt[5]{t} + 190\sqrt[4]{v} \qquad R^2 = 0{,}98 \qquad (2)$$

$$E = -39{,}45\sqrt[5]{t} + 145{,}2\ \sqrt[4]{v}\ + 0{,}07376t + 42{,}72 \qquad R^2 = 0{,}98 \qquad (3)$$

Conclusion

The presence of groundwater flow positively affects thermal energy extraction efficiency in the energy pile groups. In the two-dimensional analyses performed with TEMP/W and SEEP/W it was observed that the maximum energy efficiency in the groups positioned parallel to the groundwater flow direction is in the first pile, while the heat transfer between the pile-ground decreases significantly due to the thermal interaction in the second and third piles, hence it should be considered in the design of energy pile systems.

Additionally, it is understood that the energy obtained from the piles increases significantly with increasing groundwater flow velocity.

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Fatma DÜLGER CANOĞULLARI: Investigation, Writing-draft preparation, Software **Özgür Lütfi ERTUĞRUL:** Data curation, Validation, Writing-Reviewing and Editing.

Conflicts of interest:

The authors declare no conflicts of interest.

References

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