Long-term Effects of Ground Source Heat Pumps on Underground Temperature

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Abstract

Ground Source Heat Pumps (GSHPs) have received much attention in recent years because of their energy efficiency. Most studies are interested in the performance of GSHPs. However, little research has been done on the underground temperature distribution and change affected by GSHPs. This study set up a numerical model in COMSOL Multiphysics® and simulated the underground temperature over 100 years.

In this study, a single pile (borehole) was investigated and models were built in COMSOL. The ground was assumed to be an isotropic and homogeneous solid with the heat capacity of C_p=1000[J/(kg*K)] and the thermal conductivity of k=2.4[W/(m*K)] and without considering the groundwater movement. A 2D axisymmetric model in the polar coordinates was set up first to verify the boundary conditions, and then thermal load conditions were added to the proper boundaries of the model to simulate the long-term effects on the underground temperature from the GSHP heat exchanger. The lower boundary condition was set to be a fixed heat flux q_0=0.075 W/m². The lateral boundary was assumed to be adiabatic.

The temperature values for 200 years at the depth of -15 m, -25 m, -40 m, and -60 m are shown in Figure 3. The temperature of the ground is considered to be constant before heat loads were added and the parameters and boundary conditions are considered suitable for this simulation.

The data in Table 1 shows the temperature changes in different distances and depths of the ground near the energy pile under three different heat compensation conditions. The temperature before heat loading and the average values of the underground temperature for the first five years and last five years of the 100-year simulation are presented.

According to the simulation results, the underground temperature did not decrease under the thermal load with full heat compensation; the temperature decreased under the other two thermal loads, and the decrease processes were finished in the first five years. The area where the temperature decreased the most was at the depth of -15 m and was 0.5 m from the pile boundary.

Reference

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Figures used in the abstract

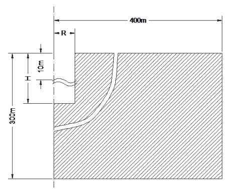

Figure 1: Computational domain for 2D models of the ground temperature.

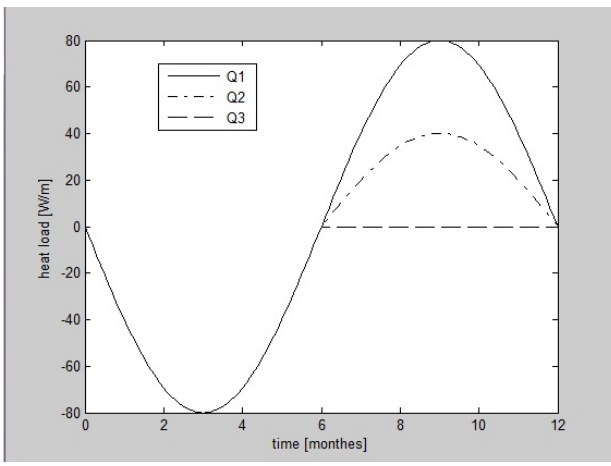

Figure 2: Thermal load curves for full compensation (Q1), half compensation (Q2), and no compensation (Q3). The injective heat loads are different, but the extractive heat loads are the same.

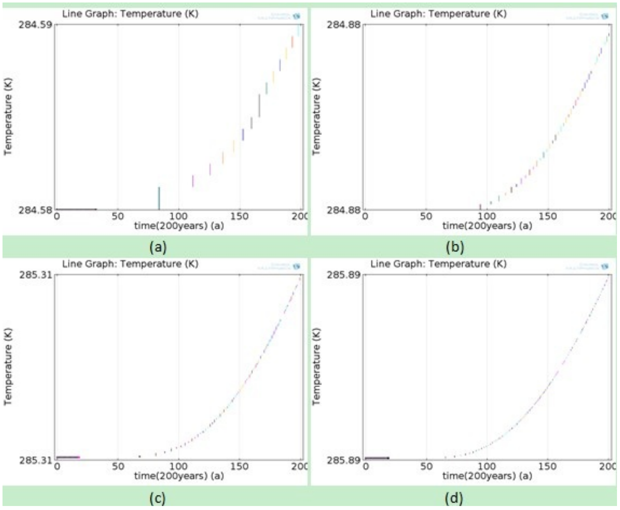

Figure 3: Temperature at the depth of -15 m (a), -25 m (b), -40 m (c), and -60 m (d) in the 200-year span.

Table 1. Underground temperature with different heat compensations

distance(m) temperature(K) depth (m)		0.5			5.5			10.5		
		before loading	first five years	last five years	before loading	first five years	last five years	before loading	first five years	last five years
full compensation	-15	284.59	285.21	284.48	284.59	284.79	284.57	284.59	284.6	284.58
	-25	284.88	285.38	284.8	284.88	285.1	284.86	284.88	284.9	284.87
	-40	285.31	285.35	285.3	285.31	285.35	285.3	285.31	284.32	285.3
	-60	285.89	285.89	285.89	285.89	285.89	285.89	285.89	285.89	285.89
half compensation	-15	284.59	282.82	283.02	284.59	284.18	284.24	284.59	284.45	284.44
	-25	284.88	283.47	283.56	284.88	284.45	284.45	284.88	284.69	284.65
	-40	285.31	285.25	285.18	285.31	285.26	285.19	285.31	285.28	285.21
	-60	285.89	285.89	285.85	285.89	285.89	285.85	285.89	285.89	285.85
no compensation	-15	284.59	281.68	281.61	284.59	284.01	283.93	284.59	284.38	284.31
	-25	284.88	282.55	282.36	284.88	284.26	284.07	284.88	284.61	284.45
	-40	285.31	285.23	285.06	285.31	285.24	285.08	285.31	285.26	285.12
	-60	285.89	285.89	285.81	285.89	285.89	285.81	285.89	285.89	285.82

Figure 4: Table 1. Underground temperature with different heat compensations.