Bulgarian Chemical Communications, Volume 48, Special Issue E (pp. 27 - 30) 2016

Iller bank-Atasehir-building ground source heat pump system and thermal response test - case study

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Turkey has a great geothermal energy capacity due to Alpin Orogenesis. There are a lot of young magmatic intrusions and geothermal areas that is waiting be exploited in terms of shallow geothermal energy. Turkey's implementation of renewable energy is increasing in recent years due to the new energy policy targets. Shallow geothermal energy systems in Turkey have been increasing since 2007. Installed capacity of these systems is approximately 42,3 MW. Iller Bank Inc. Com. is a Development and Investment Bank servicing financial and technical support to municipalities in Turkey. With the purpose of setting an example of shallow geothermal application in official buildings for municipalities, a ground source heat pump system has been implemented at Iller Bank headquarters building in Istanbul-Atasehir in 2015. The building is located on metasandstone belonging to Paleozoic aged Kocatongel Formation. Heating and cooling demands of the building are approximately 1160 and 1817 kWh respectively. The ground source heat pump system was designed to supply some portion of this demand. 24 borehole heat exchangers with depths varying between 60 and 153 meters were installed. Thermal Response Test (TRT) was carried at two different borehole heat exchangers and effective ground thermal conductivity, undisturbed ground temperature, and resistivity were obtained. Thermal conductivity data from the TRT test showed significant differences due to ground water flow effect in one of the boreholes. In this paper, an overview of shallow geothermal systems in Turkey with a special focus on geological parameters will be given. As a case study, Iller Bank Atasehir Ground Source Heat Pump System will be analyzed.

Keywords: shallow geothermal systems, thermal response test, Iller Bank Atasehir Building ground source heat pump system case study

INTRODUCTION

In Turkey, we see an increase in renewable energy implementations in recent years due to the concerns over increasing energy demand, energy security and global climate change. There are 16 million buildings in Turkey, which is the second largest energy consumer with a share of 35% following the industry (1). About 80% of this share is used to meet heating demand. Fossil fuels are mostly used for heating leading to increased greenhouse emissions.

Shallow geothermal systems increase energy efficiency and provide a beneficial alternative as a renewable energy source for heating and cooling demands. Shallow geothermal systems have two main groups of applications: "Ground Source Heat Pump (GSHP)" and "Underground Thermal Heat Storage". Although Heat Pump Systems are well known in Turkey, there are few applications of shallow geothermal systems reaching to an installed capacity of 42,3 MW (2).

Iller Bank. Inc. Comp. is a development and investment bank in Turkey that supports municipalities technically and financially. Recently, more focus on activities to supply renewable heating and electricity municipalities was given.

In order to set an example of shallow geothermal application in official buildings for municipalities, a ground source heat pump system has been implemented at Iller Bank headquarters building in Istanbul-Atasehir in 2015 (Fig.1 and Fig.2). In addition, photovoltaic and gray water systems are employed in this building. Project and installation was made between 2012 and 2015. The system was commissioned and started operation in 2015. In this paper, experiences from this project are given.

Fig.1. General view of Atasehir Building

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Fig.2. General view of BHE's area

GEOLOGY

Iller Bank Atasehir Building is located on a geological unit called Istanbul sequence (Fig.3). The rock formations in this area listed from older to younger are:

- Kocatongel Formation (QPkc) consisting of metasandstone and claystone, Paleozoic aged;
- Kurtkoy Formation (QPk) consisting of sandstone and conglomerate rocks, Paleozoic aged;
- Pelitli Formation (SDp) consisting of limestone, Devonien aged;
- Kartal member of Pendik (Dpkz) Formation consisting of shale, Devonien aged.

The building is located mainly on metasandstone, which is very fractured and covered with solid waste filling material of 10-15 meters in depth. Metasandstone has groundwater at three different layers.

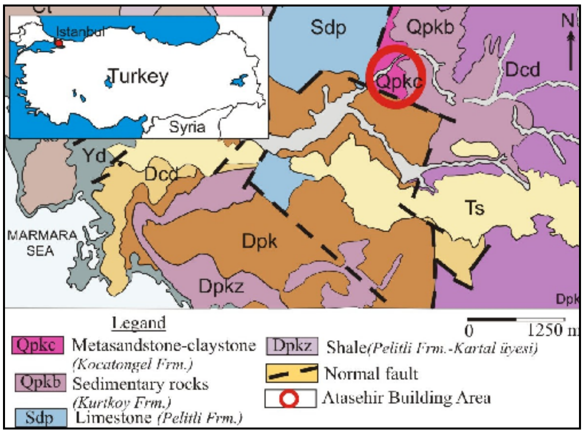

Fig.3. Simplified geological setting map of Atasehir Building [3]

GROUND SOURCE HEAT PUMP SYSTEM

150 kW of the building heating and cooling load was planned to be met with GSHP system with 24 boreholes each at 150 m. Two different drilling methods - rotary and pneumatic - were used depending on rock properties (Fig.4).

Fig.4. General view of drilling stage

Thickness of solid waste filling material on the top varied between 5 to 15 m. Greenish-gray Metasandstone units were seen throughout the depth after the top layer. Metasandstone had fractured levels at 40, 80 and 120 m depths. Secondary limestone was seen in fractured levels, which are related to the existence of groundwater (Fig.5). Thermal conductivity of solid waste filling material was measured at Ankara University Geological Department as 0,65 to 1,65 W/mK.

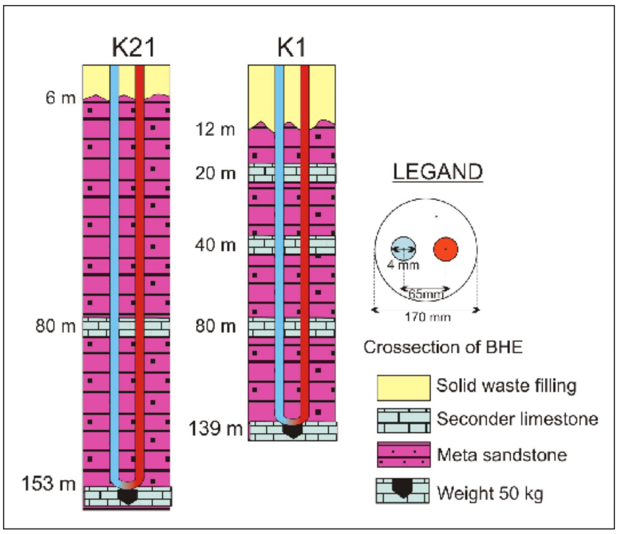

Fig.5. BHE's cross-section and geological layers

Fig.6 shows the location of the 24 boreholes used in the GSHP system. The depths vary from 60 to 153 m. Due to the difficulties of the sloped drilling area, it was not possible to have all the wells at the same depth. The distance between the boreholes was 6 m. BHE consisted of a single U pipe (HDPE) of 16 bar (PN16) and 0,04 m outer diameter, grouting material having 2,35 W/mK thermal conductivity and spacers were used at every 3 meters. Injection pipe having ¾" was used and grouting material mix was prepared on site. Grouting mix composition was 52% sand, 24% Portland cement and 24% water. Pressure test (2 hours at 6 bar) was carried out before and after inserting U pipes. While preparing vertical piping of BHE, horizontal piping was implemented at the same time in the construction area. For installation of horizontal pipes, pits were excavated at 1,5 meter depth and sand layer having 15 cm thick was placed both under and top of pipes for protecting from any damages. Heat transfer fluid used in U-Pipes was water.

Three collectors were used for linking to the mechanical room and each collector was linked to 8 BHEs.

Two heat pumps (one of them as backup) having 500 kW capacity were installed. The heat pump's COP is 4,82 for heating and EER is 4,67 for cooling.

First monitoring results show that 207 kW of the load was met with the installed GSHP system. This was higher than the expected design value of 150 kW.

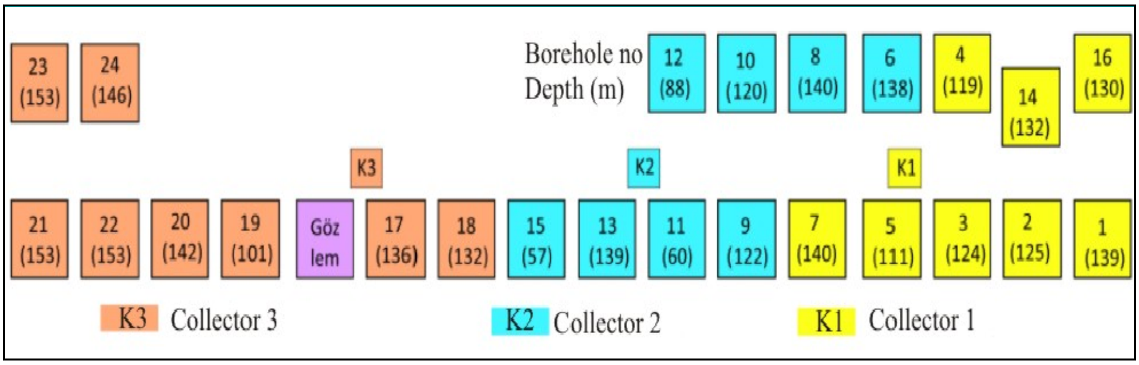

Fig.6. Schematic view of Borehole heat exchangers

THERMAL RESPONSE TEST

Thermal response test (TRT) is carried out to determine thermal properties of borehole heat exchanger such as undisturbed ground temperature, effective thermal conductivity (λeff) and borehole resistance (Rb). TRT was carried out at K1 and K21 boreholes shown in Fig.3 by Center for Environmental Research of Cukurova University (Fig.7) in a total duration of 6 days.

Fig.7. TRT test device of Center for Environmental Research of Cukurova University

For determining undisturbed ground temperature, temperature measurements without heat injection during the first hour were used. Heat injection rate has been selected as 9 kW based on the depth of the boreholes.

Undisturbed ground temperature was calculated as 17,6 ^{0}C (Fig.8). This value shows a 0,6 ^{0}C deviation from annual average air temperature which is expected to be 15 ±1-2 ^{0}C. It is estimated that this increase of soil temperature is caused by the intense building developments in the vicinity as shown in Fig.2.

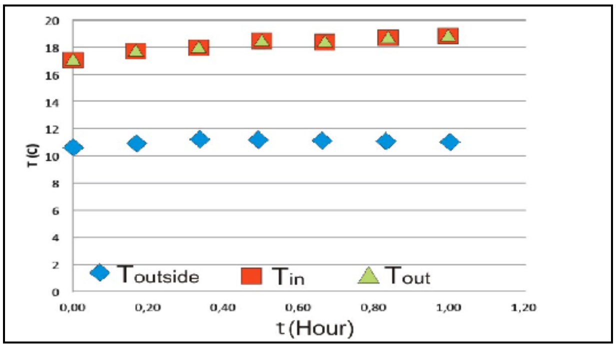

Fig.8. Temperature distribution during first hour of TRT without heat injection

Fig.9 and Fig.10 show temperature distributions of ambient, inlet and outlet fluid temperatures during TRT tests for K1 and K21 borehole heat exchangers, respectively. Measured data was evaluated using line source approximation method to determine λ_{eff} and R_b. For K1, R_b was 0,12 K/(W/m) and λ_{eff} was 4,5 W/mK and for K21 R_b was 0,04 K/(W/m) and λ_{eff} was 2,8 W/mK [4].

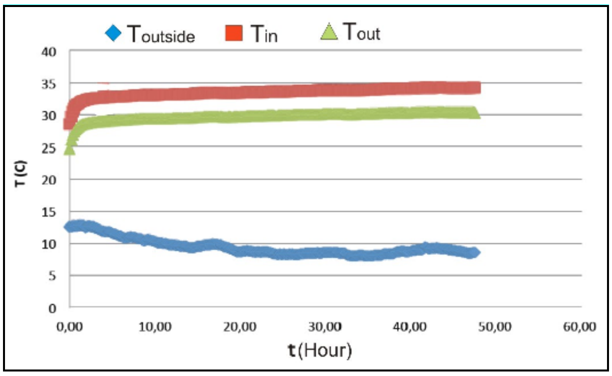

Fig.9. Temperatures distributions during TRT at K1 borehole [4]

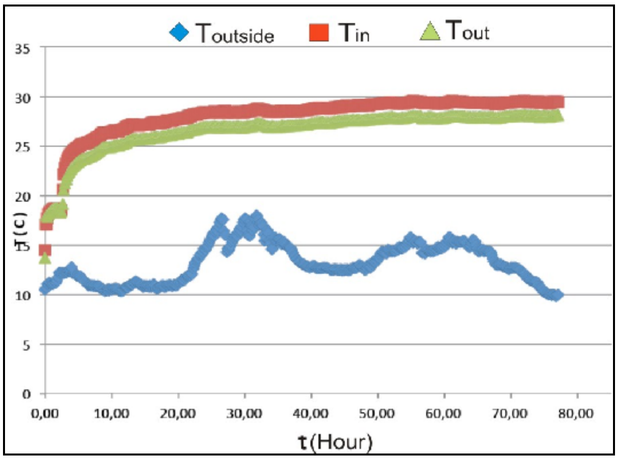

Fig.10. Temperature distributions during TRT at K21 borehole [4]

The differences of thermal conductivity and borehole resistance between K1 and K21 boreholes are caused by increased amount of groundwater due to the fractured zones in K1 (Fig.11).

CONCLUSION

Iller Bank In. Com. constructed its headquarters in Ataşehir as an energy efficient building with GSHP, solar photovoltaic and waste water systems in order to set an example to the municipalities. This building is also considered to be a pioneer among the official buildings in Turkey.

GSHP system with a capacity of 207 kW has 24 BHEs, at various depths from 60 to 153 m. Total length of single U-pipe installed in the BHEs was 3000 m. Geological layers consisted of solid waste filling material (10-15 meter) and metasandstone onwards. Thermal conductivity values of solid waste filling material varied between 0,65 W/mK and 1,15 W/mK.

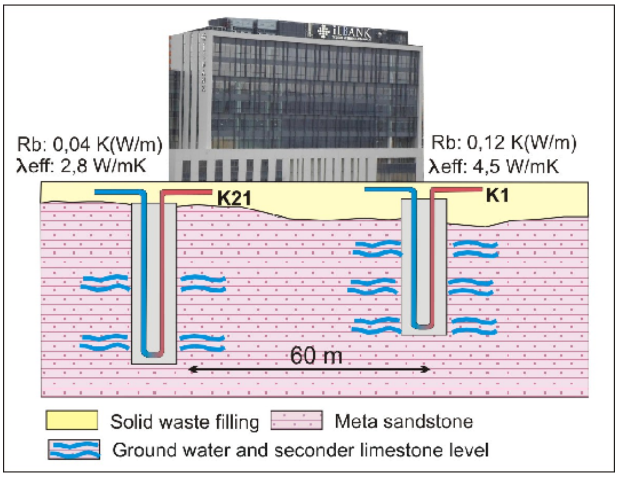

Fig.11. Schematic view of thermal properties BHE's

TRT results from two different BHEs show that effective thermal conductivity values were 2,5 W/mK and 4,5 W/mK and borehole resistance values were 0,04 and 0,12 K/(W/m). The undisturbed ground temperature was determined 17,6 ^{0}C. Differences between effective thermal conductivity values can be explained by increased amount of groundwater due to the fractured zones around K1 borehole.

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