Geothermal System Study Case near Bucharest

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Abstract. The article shows a study case of a geothermal system near Bucharest. In the paper it is shown that for a good efficiency of a geothermal system for heating and air conditioning, it is important to follow a few steps. One step is a very accurate calculation of the heat and cold load. In the next step it is important to use a specific equipment to obtain the Thermal Response Test (TRT) of geological formations crossed by the borehole. TRT is helpful in providing information related to the evolution of the soil temperature while introducing a thermal load. All information that can be obtained or calculated from the TRT will provide how the climate system will function in time and its efficiency. Furthermore, the effective thermal conductivity and thermal resistance of the well will be determined, extremely important parameters in designing the correct length of the geoheat exchanger. The article used specific software to simulate the evolution of parameters in time, for soil and heat pump. Earth Energy Design offer information for the number of needed boreholes, the depth and the yearly evolution of the soil's temperature in time for the system etc. Following all these main steps, finally a very efficient system can be designed, that can ensure the heating and produce hot water for the consumption of a house, office building or of other destination buildings.

1 Introduction

Heat pumps are a friendly alternative, thus in the context of a growing concern about energy savings, it was a go to option for heritage buildings. Even it is used the correct insulation for the walls it is very difficult to find the best solution for heating and cooling the building. Thus, when the rehabilitation of the Minovici Museum's building commenced, the solution with geothermal heat pumps was taken into account . [1]

Fig. 1. Vila Minovici

The building in this study case is The Folk Art Museum "Prof. Dr. Nicolae Minovici ". Its architecture's charm is specific to the sub-Carpathian area of the Romanian Country.

It was built in 1905, under the plans of the architect Cristofi Cerchez and was designated from the beginning to be open to public even though it also served as a personal household. It has been open to the public since 1914.

The museum is located in Dr. Nicolae Minovici Street no. 1, near the Miorita Fountain, in the Băneasa neighborhood.

Because of the flowers that cover the building it is also known as the "Villa with the Bells".

2 Steps of correct design of the system

2.1 Calculate the load

The building is located in the Nth part of Bucharest, near the outskirts of the city. It is located between other buildings with maximum 3-4 levels, in an area with houses and old villas, so this is a windy area and with a cooler temperature in the winter and warmly in the summer.

The museum has, in fact 4 building but in this study case we refer only to the main building. The principal data of this building are:

$Ac = 236 \text{ m}^2$.

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H_{total} = 18.40 m, and takes place on 4 levels, namely: S (partial) + P + E + M.

For a correct design we have to take into consideration all the data.

The foundations is a continuous type of concrete, and the structure is made of brick-built brick masonry that is not in a good condition.

The floors are made of wooden tiles at the first floor and the ceramic tiles for the ground floor and the roof are made with a ceramic tile cover.

Because the main exhibits of the museum are popular costumes and have considerable age, it is important to ensure optimal exposure conditions that require an accurate temperature and humidity, which obviously implies a very precisely calculation of the thermal loads: 30 kWth for heating and 29 kWth for cooling;

2.2 Response test

The thermal response, test is a way to determine ground thermal properties that are very important for design the system with ground source heat pumps. The test concern in injecting a constant known heat power into a borehole of the geoheat exchanger and then measuring the temperature response. [2, 3]

A good test provide the right undisturbed formation ground temperature and that permit calculate the thermal conductivity and the borehole thermal resistance and estimate of the thermal diffusivity.

These values, are indispensable for the optimal design of a geothermal system. All this values will be used in a geothermal design program to design for optimize the cost of the system. Earth Energy designer software for example can estimate the cost of the geoheat exchanger.

For the response test of this study case was use un American equipment named GeoCube and the results are:
Thermal Conductivity (W/(m*K)) : 2.10
Thermal Diffusivity (est.) (m^2/day) : 0.089
Average Heat Flux (W/m) : 59.9
Thermal Resist (BTR) (m*K/W) : 0.13
Average Flow Rate (L/s) : 0.36
Test Duration (hr) : 72
Calculation Interval : 6.0 - 46.0 Hours
Borehole Input Parameters
Undisturbed Ground Temperature (°C) : 13.6
Depth (m) : 70.0
Borehole Diameter (mm) : 140.0
Pipe Size: 1" (32x3mm)
Grout Thermal Conductivity (W/(m*K)) : 1.70
Drilling Method : Standard
Drilling Time (hr) : 5.0
Diffusivity Input Parameters
Soil/Rock Specific Heat - Dry (kJ/(K*kg)) : N/A
Soil/Rock Density - Dry (kg/m^3) : N/A
Moisture (0-100) (%) : N/A
Flow Rate Input Parameters
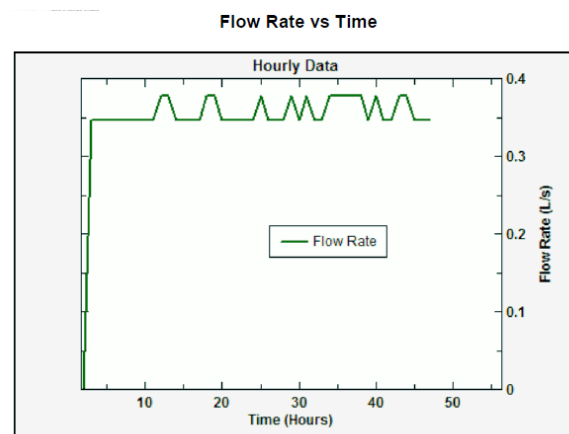TC Unit Model Name: GeoCube Standard
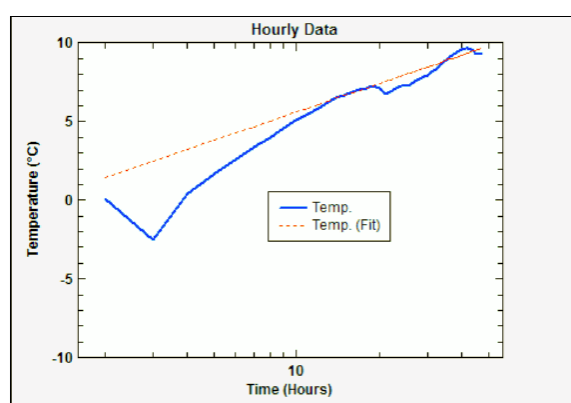

Fig. 2. Flow rate vs time

Fig. 3. Flow rate vs time

2.3 The results of the response test

From all the data, the most important parameter is thermal conductivity because is taken into account for the correct sizing of the GHE.

The expected value of thermal conductivity in this case was 2.08 W / m * K and the value resulting from calculation is 2.10 W / m * K. Percentage means: less than 1%. This is an insignificant difference.

Nor is thermal diffusivity much different than expected. The project was 0.094 m^2 / day, and the thermal conductivity test resulted in 0.089 m^2 / day. This means in percent: less than 6%. This value also falls within the margin of error.

2.4 Using specialized software

Data from the Thermal Response test along with other calculated data is usually used in a specialized software to determine both the length of the heat exchanger and its time behaviour. Earth Energy Designer is one of that used especially in Europe. It's an easy-to-use software with a friendly interface. [4, 5]

EED simulates the behaviour of the geothermal heat exchanger - GHE - over time, more precisely the evolution over time of the temperature of the rocks crossed by the exchanger. [6, 7]

Table 1. Value of data for the borehole.

| Size	U.M	Values
Borehole deep	m	75
Distance between boreholes	m	5
Borehole diameter	mm	140
Pipe U diameter	mm	32
Thickness of the U-pipe wall	mm	3
The thermal conductivity of the U-pipe	W/(m·K)	0.42
The distance between the pipe axes	mm	108
Thermal conductivity of cement	W/(m·K)	1.7
Pipe / fill contact resistance	(m·K)/W	0

Table 2. Value of data for the carrier fluid - water.

Size	U.M	Values
Thermal conductivity	W/(m·K)	0.59
Heat specific mass	J/(Kg·K)	4186
Density	Kg/m³	999.2
Viscozity	Kg/(m·s)	0.0011
The freezing point	°C	0
Flow through the well	l/s	0.19

Table 3. The value of the basic parameters.

Size	U.M	Values
Annual domestic hot water demand	MWh	8.26
Annual heating load	MWh	63
Annual cooling load	MWh	50
Seasonal Performance Factor (ACM)	-	3.1
Seasonal Performance Factor (FPS Heating)	-	4.5
Seasonal performance factor (FPS cooling)	-	6
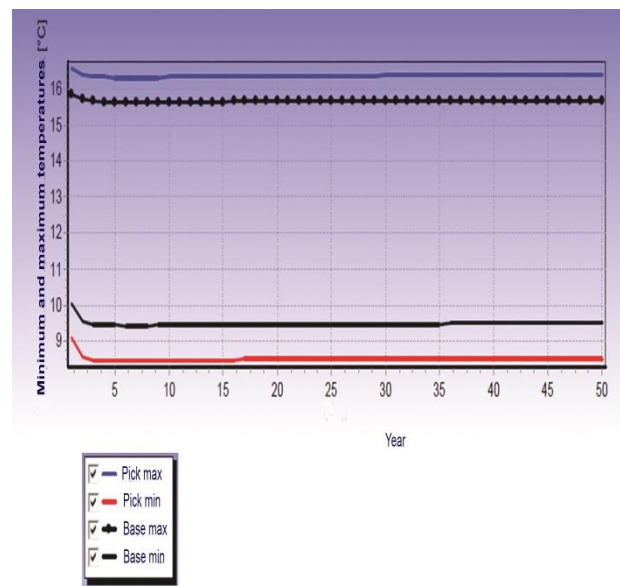
Fig. 4. The evolution of fluid temperature over the 50 years
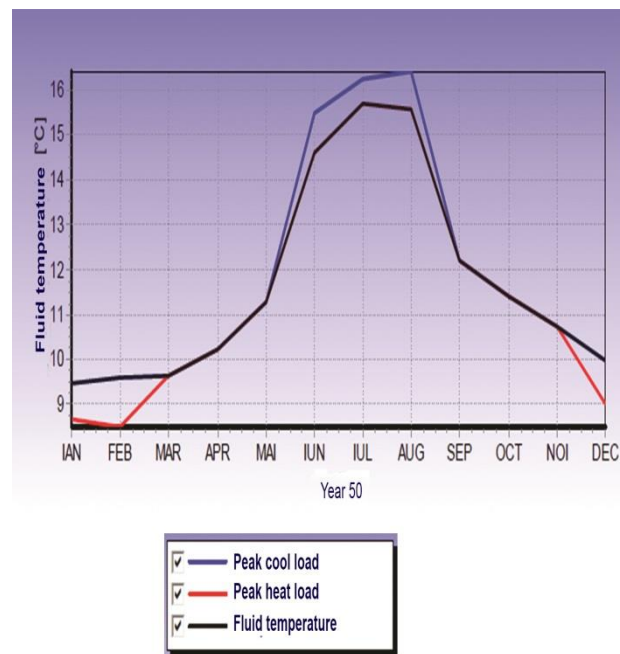
Fig. 5. The evolution of fluid temperature for the year 50

Number of boreholes: 32

Drilling depth : 75 m

Total drilling length : 2400 m

3 Conclusions

This paper presented a study case of a geothermal system near Bucharest for a museum building.

Calculating the heat requirement it is imperative for the simulation to be as close as possible to the real situation and in this work the error was under 6%.

The use of specialized software EED facilitates a modeling work and offers a lot of very useful data for making an efficient geoheat exchanger for old buildings.

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