Thermal response test

Objective

Analysis of the data based on the measurements of a real thermal response test provided on the "Moodle of the Course".

Introduction

The town of Thonon-les-Bains is studying the construction of a new school. This building should be carried out within the framework of the sustainable development established and supported by the city. The buildings department envisaged for this building a construction based on a concept respectful of the environment, with use of geothermal system for energy needs. In this exercise, real TRT data from the Project is provided.

A geothermal borehole, 100 m in length and 132 mm in diameter, have been employed for TRT as a part of this project. The characteristics of borehole are given in the table below. Fig. 1 shows the illustration of one of the geothermal boreholes.

	Geothermal borehole
Drill length (m)	100
Drill diameter (mm)	132
Geothermal borehole length (m)	100
Arrangement of circulating tubes	Double-U
Type of circulating tubes	Polyethylene
External diameter of the tubes (mm)	32
Wall thickness of the tubes (mm)	2.9
Filling material of the borehole	Bentonite and cement
Circulating fluid type	Water
Flow rate during the test (liters/h)	480-720

During the thermal response test (i) heat carrier fluid is circulated without turning on the heating, (ii) after the first stage, the heat was injected into the geothermal borehole (Heat injection 49.7 W/m). The data measured during the TRT are provided on the Moodle.

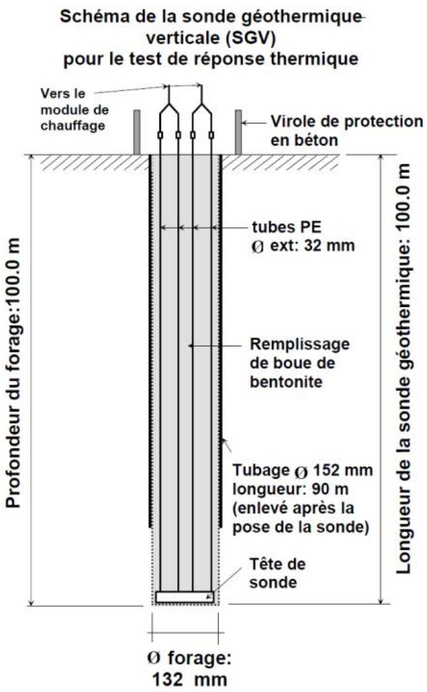


Fig. 1. Illustration of the geothermal boreholes used in the Project

As learned during the course, the measurements of in-situ thermal response test (TRT) can be employed to determine the following properties of the soils:

- undisturbed ground temperature (T_0): determined from the temperature data recorded before the heat injection
- effective thermal conductivity of the ground (λ)

Use the TRT data provided to:

1. Determine the undisturbed ground temperature. Comment briefly on the reason behind the difference between the actual ground temperature and the ones determined from the TRT data.
2. Illustrate the measured quantities during a TRT (i.e., T_{in}, T_{out}, internal temperature, external temperature, flow rate).
3. Compute the ground thermal conductivity. Briefly comment the accuracy of the method adopted for the defintion of the thermal conductivity.
4. Imagine the ground thermal conductivity value will be used for the design of an energy geostructure and the thermal conductivity value is calculated from a pile. Would you recommend it to be used? Briefly comment on your choice.

Content of the report

The report must contain a description of the experimental equipment and parts that constitute the mini-module. A description of how to install and run the test. The results elaborated by the test and a brief critical comment of the latter.

Solution

Description of the experimental equipment

The apparatus (EPFL mini-module, Figure 2-4 is compact and fits into a "flight case" (0.6m ´ 0.3m ´ 0.7m). The equipment includes a data transmission system whereby the test can be followed and certain functions controlled remotely using an internet connection. Figure 2-5 describes the pipe layout, locations and connection of the instruments.

The Heater

The heater (Figure 2-5) was manufactured by the French company GRETEL with a maximum power of 9kW adjustable in steps of 1kW. The circulation pump has a three step adjustable speed (2050, 1650 and 1200 rpm), where the maximum speed mounts to $8m^3/h$. The heater has a flow regulating valve to maintain constant flow. A security system (Pressiostat) disrupts the heater in case of shortage of water where the pressure falls below 1bar, caused by for example a breach in the tubes. High pressure (>3 bar), is released by a regulating valve. In order to protect the materials within the borehole heat exchanger, a thermostat (Aquastat) regulates the temperature by temporarily cutting the electrical power supply if the temperature exceeds 80°C. This is undesirable since it results in a variation in power level and often means that the test has to be restarted. In addition, the heater has a second thermal security system with an emergency switch-off at 95°C. After a switch-off, the system needs to be restarted manually.

The electrical network

The power supply of the mini-module is achieved by a three-phase current with a voltage of 400V and a maximum current of 15 A.

Instrumentation and hydraulic circuit

PVC pipes have been used for the hydraulic circuit for practical reasons and to limit the weight. Two automatic air valves are placed on high points of the tubes and taps are placed on the circuit to control and stop the flow. The measurement devices are mounted directly on the hydraulic circuit inside the module and comprise a flow meter, pressure meters and thermometers. Data is recorded every minute for the following eight parameters:
- Incoming and outgoing fluid temperatures
- Internal and external temperature of the test unit
- Pressure of the heat-conducting fluid (input and output) of the heat exchanger tubes
- Flow rate of the heat-conducting fluid
- Energy consumption

The test apparatus is also equipped with a remote data transmission system, whereby a modem installed inside the test unit transmits the information recorded by the data-logger to an internet-connected server. Thus the test performance can be followed in real time from any location. With the latest adaptation it is also possible to switch flow and power on and off as well as altering the power level by sending an SMS. Hence the test operator only needs to be on site for the installation and dismantling of the test apparatus, which enables great savings in time and cost.

Figure 2-4: The EPFL mini-module.

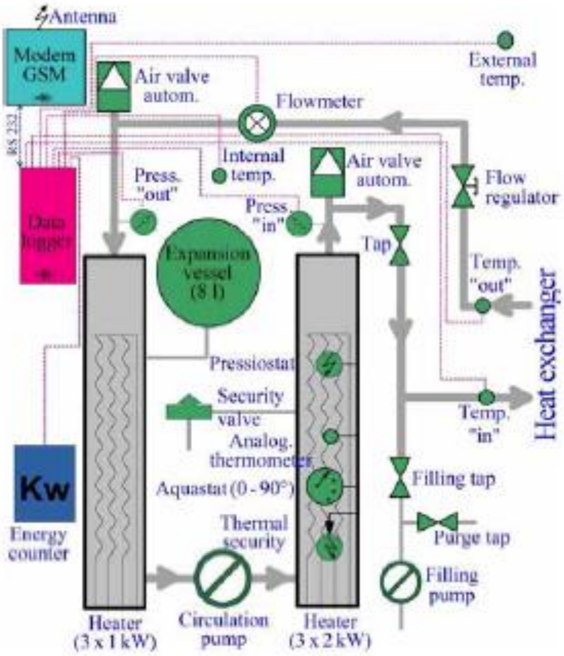


Figure 2-5: Schematic diagram of the EPFL mini-module.

Procedure

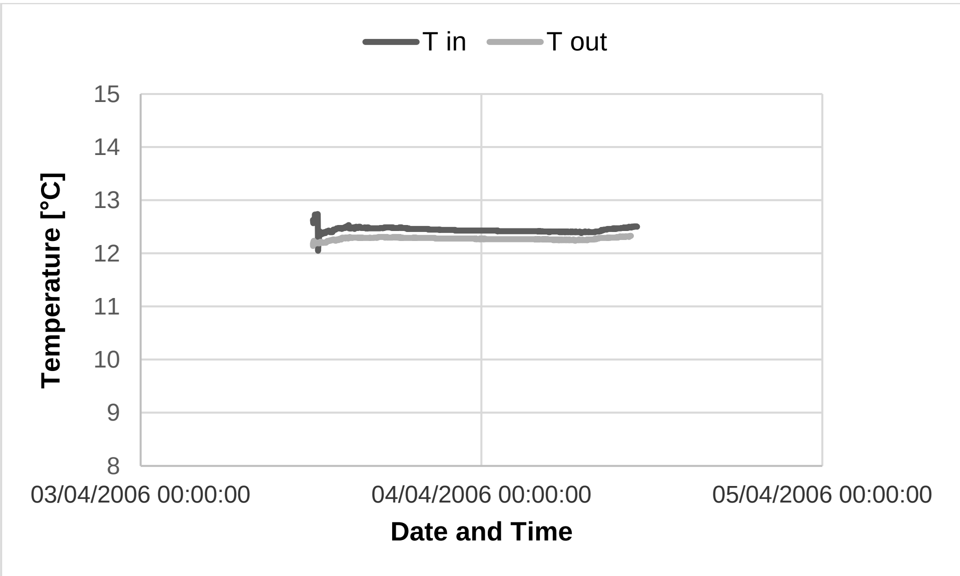
1. Installation of ground heat exchanger and grouting
2. Setting up equipment, calibration and testing of components
3. Setting the levels for flow rate and heat power
4. Activating data logger and remote data transmission system
5. Insulating tubes between equipment and heat exchanger
6. Determination of the undisturbed ground temperature
7. Switching on heating and monitoring (constant power)
8. Switching off, dismantling and cleaning of test equipment

Measured data

- Temperatures:
    - Inlet fluid temperature
    - Outlet fluid temperature
    - Temperature inside the module
    - Temperature outside the module
- Fluid pressure:
    - Inlet fluid pressure
    - Outlet fluid pressure
- Flow rate
- Power consumption

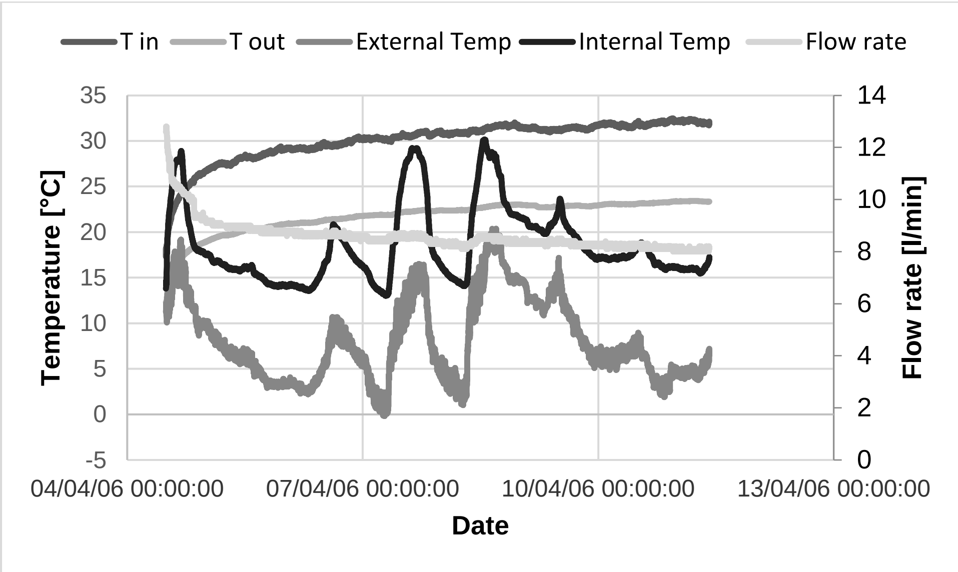
Test results

1. Determine the undisturbed ground temperature. Comment briefly on the reason behind the difference between the actual ground temperature and the ones determined from the TRT data.



The one obtained from the TRT data should be corrected to take into consideration the heating of the pump. The undisturbed ground temperature not corrected is 12.28 °C.

2. Illustrate the measured quantities during a TRT (i.e., T_{in}, T_{out}, internal temperature, external temperature, flow rate).



3. Compute the ground thermal conductivity. Briefly comment the accuracy of the method adopted for the defintion of the thermal conductivity.

$$T(t) = k\ln(t) + m$$

$$\lambda = \frac{q}{4\pi k} = \frac{49.7}{4\pi \cdot 1.9699} = 2.00\, W/m\,°C$$