Analysis of shallow subsurface geological structure and result of thermal response test in the Karatsu Plain, Saga Prefecture, Japan

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1 Introduction

A ground-source heat pump system is a renewable energy system that uses underground layers (about 100 m depth) as a heat source for heating, cooling, and snow melting. A typical system is one in which a borehole heat exchanger is buried underground to exchange heat with the ground, and this system can be installed throughout Japan. Although this system is expected to have high energy-saving performance, the high cost of installation is one of the factors inhibiting its widespread use. In particular, reducing the cost of installing the heat exchanger is an issue.

In order to design an appropriate system (especially the required length of heat exchanger), it is important to understand the apparent thermal conductivity (λ value; the effective thermal conductivity of the underground including the effect of heat transfer diffusion by groundwater flow) of the ground. The most effective method is to conduct a thermal response test in the field, but this test is also very expensive, so it is desirable to have a cheaper and simpler method to determine the λ value. With the above background, AIST has been conducting geological and thermophysical investigations in the Karatsu Plain, the northern part of Saga Prefecture.

2. Shallow subsurface geological structure of the Karatsu Plain

All-core drilling was conducted at Saga Prefectural Karatsu Higashi Junior and Senior High School (Loc.1) in the central part of the Karatsu Plain. The shallow subsurface geological structure was examined from about 2100 borehole column data collected around the Karatsu Plain. The foundation of the Karatsu Plain is Cretaceous granites. The depths of the basement are 20-25 m along the Matsuura River and 5-15 m in the Karatsu urban areas, respectively. These basements are covered by unconsolidated sediments (gravel, sand, and mud). A 14C date of about 7900 years ago was obtained from a core sample at a depth of 9.6 m at Hamasaki Elementary School in the eastern part of the Karatsu Plain, being considerable that these sediments are the Holocene.

3.Thermal response test results in the Karatsu Plain

3-1. Thermal response test results of the hot water circulation system

A heat exchanger (double U-tube) was buried in a borehole drilled up to 100 m from Loc.1, and a thermal response test was conducted. The estimated λ value was 2.32 W/(m K). The effective thermal conductivity of the Holocene of the core samples was also measured using KD2Pro (Decagon Inc.) at approximately 1 m depth.The average effective thermal conductivity is about 1.55 W/(m K). In the future, the thermal conductivity of the granite will be measured and compared with the λ value estimated from the thermal response test.

3-2. Results of the cable method thermal response test

Another boreholes (non-core) were drilled to a depth of 50 m at the Niji-no-Matsubara School (Loc.2) in the eastern part of the Karatsu Plain and at the Taisei Community Center (Loc.3) in Karatsu City in the western part of the plain. The geology of Loc.2 is composed of the Holocene from 0.2 to 12 m depth and granite from 12 to 50 m depth. The geology of Loc.3 is the Holocene at depths of 0.5 to 20.5 m, and granite at depths below that. The λ-values estimated from the cable method thermal response tests at both locations (averages of 50 m depth) are 1.97 W/(m-K) at Loc.2 and 2.91 W/(m-K) at Loc.3.

The λ values of the Holocene are mostly around 1.2~2 W/(m K). The λ-values of the granites tend to

increase with depth, and the values range from 1.2 to 14.8 W/(m-K), Particularly the λ values are very high at the depth of 42-50 m in Loc.3, ranging from 5 to 14.8 W/(m-K), suggesting the possibility of groundwater flow. On the other hand, the upper part of the granite tends to be weathered. The λ-values in these sections were often below 3 W/(m K).

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