Thermal Conductivities of Granitic Rocks from Mae Chan Geothermal Resource, Chiang Rai Province, Northern Thailand

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ABSTRACT

The interests in using geothermal energy as the power production have been increasing. The Mae Chan geothermal resources located in the northern Thailand is considered as one of the potential geothermal power plants. In this work, the thermal properties of the granitic rocks collected from the Mae Chan geothermal resources are extensively studied. Thermal conductivity of rocks is one of the most important parameters in thermal studies of geothermal features. It plays an important role in the planning of the geothermal utilization. The laboratory measurements of the rock samples show that the average value of thermal conductivity of granites is 2.69 W/m•K within the range of 2.0–3.8 W/m•K. Thermal diffusivity and specific heat capacity of the rock samples are in the range of 650 to 1550 J/kg•K and 1.06×10^{-6} to 1.72×10^{-6} m^2/s, respectively. The Archimedean Principle, EN993-1, is used to measure and calculate the porosity and density of the rocks. The density and porosity of the rock samples are in the range of 2.55 to 3.05 g/cm^3 and 0.5 to 15%, respectively. The relationships between the thermal parameters of the rocks are studied in details. The study shows the strong correlations between the thermal conductivity and the density and porosity of rock samples. The empirical equations of the thermal conductivity are determined as functions of the density and porosity. In addition, the results show that the heat capacity and thermal diffusivity are not strongly correlated to the thermal conductivity.

Keywords: Thermal conductivities, Mae Chan geothermal, Granite

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Introduction

In Thailand, there is only one geothermal power plant in Fang district with a small capacity of 0.3 MW since 1988 (Ramingwong *et al*, 2000). One potential geothermal power productions in Thailand is the Mae Chan geothermal resource located in Mae Chan valley, Chiang Rai province, northern Thailand. Country rock is granite porphyry Triassic age filled with Quaternary deposits. Permian-Triassic rhyolite, andesite, and ash flow tuff can be found in the northern part of Mae Chan geothermal area (Fig 1).

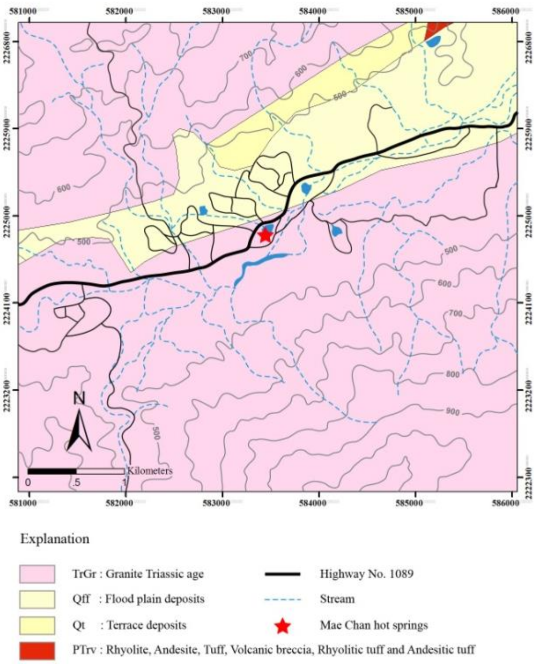


Figure 1 Geologic map of Mae Chan area (modified from Geologic map Amphoe Mae Chan 1:50000, Groundwater Resources Department, 2000)

Hot springs are fault-controlled, trending approximately NE-SW. (Ramingwong *et al*, 1978 and Kawada *et al*, 1987). Two wells were drilled, the temperature log of well number 1 was 122 °C at 100 m depth and well number 2 was 94 °C at 56 m depth (Ramingwong *et al*, 2000 and DEDE, 2005). In this work, the thermal properties of the rocks collected from Mea Chan valley will be studied extensively. These properties are important parameters in the planning of the geothermal utilization.

Objective of the study

The main objective of this study focuses on laboratory measurements and correlations of thermal properties of rocks in Mae Chan geothermal resource. Furthermore, the results will be used to define heat flow density and to determine the potential for geothermal power production in the study area.

Methodology/Experimental design

Rock samples were collected at the Mae Chan geothermal area, on outcrops and along the highway No. 1089. The field relationship of rocks and sample locations were finely examined. More than 20 rock samples of dimension approximately 5x5x2 cm^3 were prepared for laboratory measurement.

Density and Porosity

The density and porosity of the rock samples were determined by the Archimedean principle (in Accordance with European Standard EN 993-1).

The bulk density ρ_b in g/cm^3 was calculated as follows:

$$\rho_b = \frac{m_1}{m_3 - m_2} \cdot \rho_{fl} \qquad (1)$$

where; m_1 is the dry weight of the sample; m_2 is the weight of the saturated sample; m_3 is the underwater weight of the saturated sample and ρ_{fl} is the density of the saturation liquid depends on temperatures.

The total porosity ϕ_t was calculated as follows:

$$\phi_t = \frac{m_2 - m_1}{m_2 - m_3} \cdot 100 \qquad (2)$$

Thermal Properties

The thermal properties of rock samples were measured. The Hot Disk Thermal Constant Analyzer (Hot Disk AB) was used to study the following thermal parameters : the thermal conductivity λ, thermal diffusivity α and specific heat capacity c_p .The parameters were measured at room temperature. Inaccuracies of thermal conductivity, thermal diffusivity and specific heat capacity values are considered at $\pm$2%, $\pm$5% and $\pm$7%, respectively (Hot Disk AB, 2015).

Results and Discussion

Density and Porosity

The density and porosity of the rock samples determined by Eq.1 and 2 are in the range of 2.55 to 3.05 g/cm^3 and 0.5 to 15%, respectively (Fig. 2).

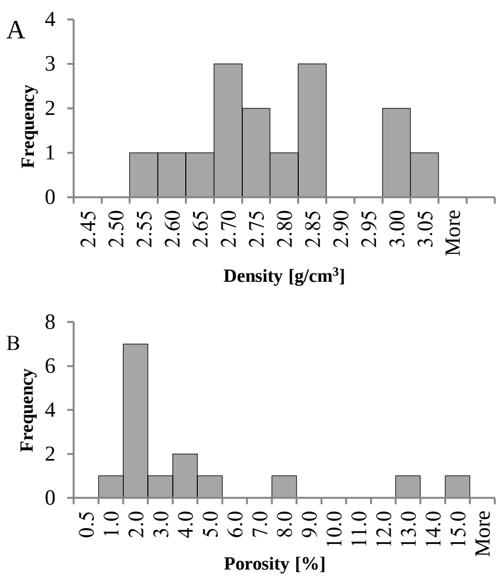


Figure 2 Histograms of the density (A) and porosity (B) of the Mae Chan granitic rock samples

Thermal Properties

The thermal conductivity, thermal diffusivity and specific heat capacity of the rock samples were measured. The result are in the range of 2.0 to 3.8 W/m$\cdot$K, 650 to 1550 J/kg$\cdot$K and 1.06x10^{-6} to 1.72x10^{-6} m^2/s, respectively (Fig. 3).

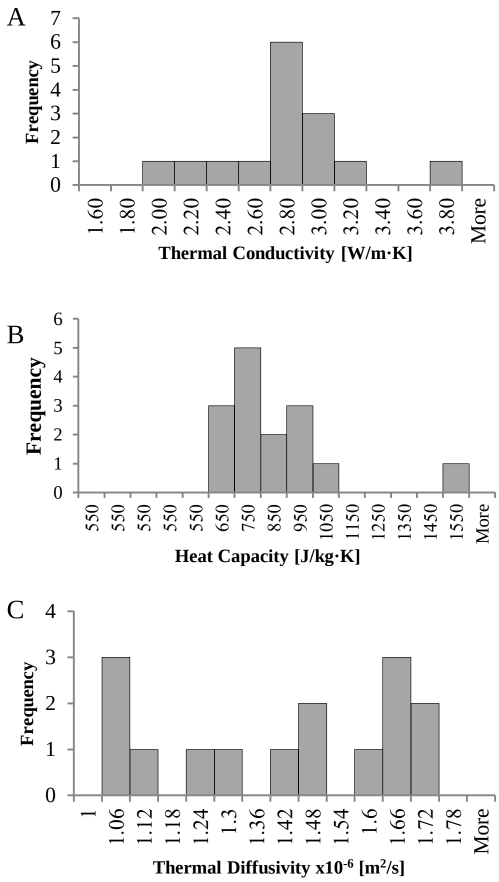
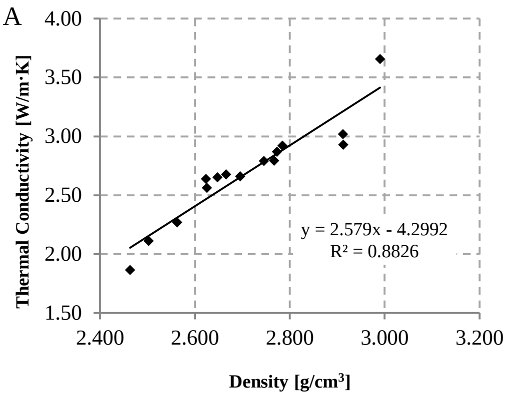
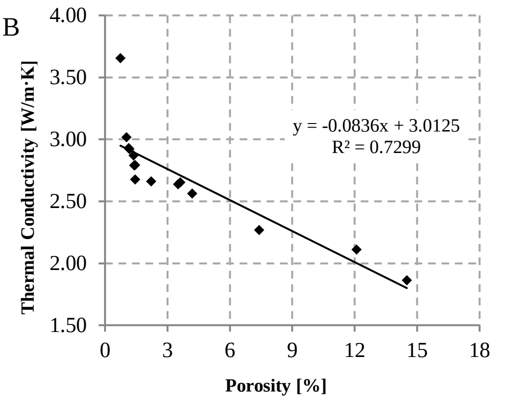


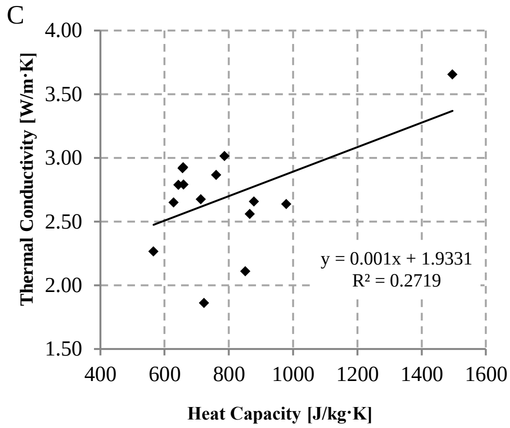
Figure 3 Histograms of the thermal conductivity (A), specific heat capacity (B) and thermal diffusivity (C) of the Mae Chan granitic rock samples

Relationships between the thermal properties

The relationship between thermal conductivity and density of the Mae Chan granitic rock samples is shown in Fig. 4A. The results show that thermal conductivity increases with increasing density. Linear relationship trend between thermal conductivity and density shows good correlation. Fig. 4B shows the strong linear relationship between the thermal conductivity and porosity. The thermal conductivity decreases linearly as porosity increases. Figs. 4C and 4D show the weak increasing trend of thermal conductivity with increasing specific heat capacity and thermal diffusivity, respectively. The good correlations ($R^2 > 0.6$) in Fig. 4A and 4B indicate that the density and porosity can be used to predict the thermal conductivity values.







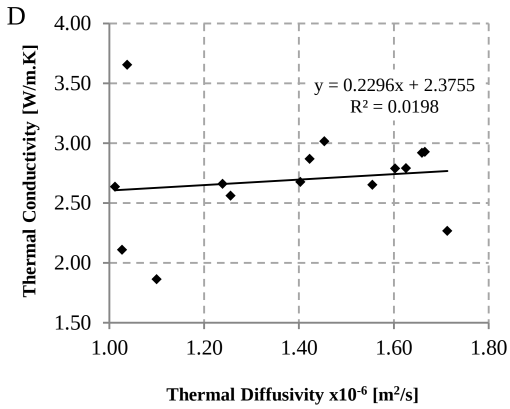


Figure 4 Thermal conductivity versus density (A), porosity (B), heat capacity (C) and thermal diffusivity (D) of the Mae Chan granitic rock samples

Comparisons between predicted and measured data

To check the prediction capabilities of the derived equations in Figs 4A and 4B, the data of density and porosity from measurements were plugged back into the derived equations to calculate the predicted thermal conductivity of the rock samples.

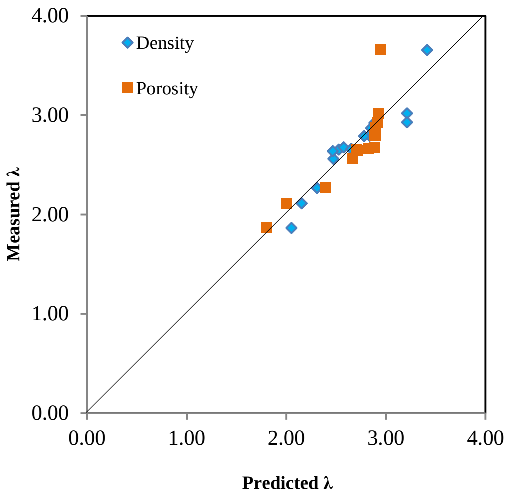


Figure 5 Predicted value and measured value of thermal conductivity from density and porosity of the Mae Chan granitic rock samples.

The predicted values were plotted against the measured values as shown in Fig. 5. A point lying on the diagonal line indicates an exact prediction. The results are shown the data point of density fall closer to diagonal line than porosity. This suggest that the ability to predict the thermal conductivity values using density values.

Conclusion

Mae Chan granitic rock samples were measured and analyzed. Laboratory measurements were carried out on the following thermal properties: thermal conductivity, thermal diffusivity, specific heat capacity, density and porosity. The results show that the average value of thermal conductivity of granites is 2.69 W/m∙K within the range of 2.0–3.8 W/m∙K. Thermal diffusivity and specific heat capacity of the rock samples are in the range of 650 to 1550 J/kg∙K and $1.06x10^{-6}$ to $1.72x10^{-6}$ m^2/s, respectively. The density and porosity of the rock samples are in the range of 2.55 to 3.05 g/cm^3 and 0.5 to 15%, respectively.

The study shows the strong correlations between the thermal conductivity and the density and porosity of rock samples. This suggests that the thermal conductivity can be determined from the density and porosity.

The next step of this study is to simulate of the heat transfer in Mae Chan geothermal resource using a simulator program and to estimate of the potential of geothermal resources.

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