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Numerical Investigation of Ground Cooling Potential for Malaysian Climate

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Abstract

Geographically, Malaysia located between 1° and 7° in North latitude and 100° and 120° in East longitude with the average daytime temperature about 31°C. However, temperature at 24°C is commonly applied for human comfort in commercial and residential building which is increasing the demand of electricity for cooling. This leads to the utilization of renewable energy and source of thermal storage such as ground [Shekerchian *et al*., 2012]. Ground has high thermal inertia in which about 46% energy from the sun is absorbed by the earth which makes temperature fluctuations at the ground surface attenuated deeper in the ground. At a sufficient depth, the ground temperature is lower than the outside temperature. When ambient air is drawn through buried pipe called ground heat exchanger (GHE), the air is cooled [Pfafferott, 2003]. This air can be used for human comfort by means of ventilation and can be used for other application. Towards of GHE implementation, this paper discusses underground temperature variation with considering different depth and thermal diffusivity based on mathematical model.

Mathematical model of ground has been developed in order to analyse ground temperature variation. The ground had treated as semi-infinite and homogeneous heat conducting medium. The basic one-dimensional heat conduction equation had used in developing the mathematical model. Based on the equation, temperature of ground at depth and time ($T_{z,t}$) can be expressed by Eq. (1).

$$T_{z,t} = 26.9 - 5.67\exp[-za]\cos\left[\frac{2\pi}{365}(t-365)-za\right] \qquad (1)$$

Analysis of underground temperature variation has been conducted up to 30 m depth and the thermal diffusivity was taken in the range of 0.04 to 0.10 m^2/day. Underground temperature has been obtained based on eq. (1) by using MATLAB software. Figure 1 presents the time-temperature graph at depth of 0 to 6 m, and thermal diffusivity of 0.04 m^2/day. Other finding in this study is that the variation of the amplitude gets attenuated relative to the depth of the ground for the range of the thermal diffusivity as shown in Figure 2. In the application of GHE, the amplitude of temperature should keep as small as possible so that the effect of cooling by the ground can be utilized at optimum condition. In addition, low thermal diffusivity is able to keep the GHE at low temperature.

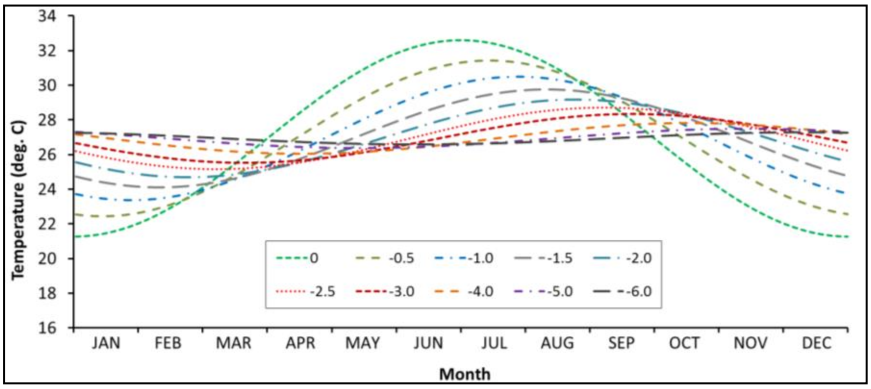

Figure 1: Time-temperature graph for thermal diffusivity of 0.04 m^2/day

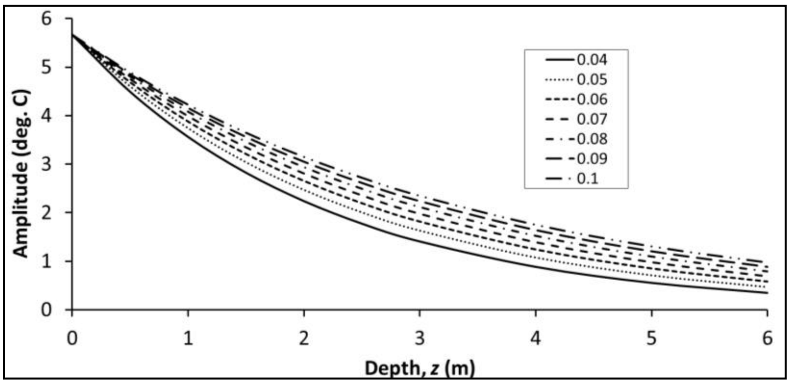

Figure 2: Amplitude of soil temperature as a function of depth

Correlation equations have been obtained from above figure which is for α = 0.04 until 0.06 m^2/day. Eq. (2) describes correlation equation for α = 0.04 m^2/day only.

$$A_s = -0.0268z^3 + 0.4188z^2 - 2.4322z + 5.6329, \qquad R^2 = 0.9998 \qquad (2)$$

Comparison of result has been performed with Sharan and Jadhav (2002), Al-Ajmi et al. (2006) and Derbel (2010). The present work shows good agreement with result obtained by Sharan and Al-Ajmi. However, comparison with Derbel showed that large difference has been obtained. This is due to different average annual temperature which is about 6°C.

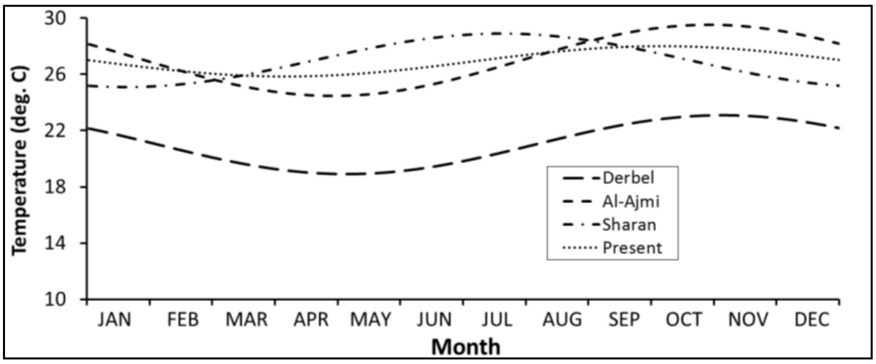

Figure 3: Comparison of present work with previous

From this analysis, it can be concluded that the underground temperature for Malaysian climate is able to produce passive cooling. The most significant cooling can be obtained from depth of 2.5 m and below with the maximum thermal diffusivity of 0.06 m^2/day. The temperature is ranging from 25°C to 29°C which is very significant for passive cooling in many applications.

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