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Research Article

TEMPERATURE MODELING IN SOIL DEPHT FOR THE REGION OF RABAT-EFFECT OF THE SOIL

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ABSTRACT

The demand on energy is increasing because of the industrial and socioeconomic development that known many countries in process of development such as Morocco. The conventional energies are pollutant and in addition to that they will disappear in few decades. So the best solution is to exploit the renewable energy because they are economic, not pollutant and permanent. One of these energies is the geothermic which consist to extract the calories stocked in the soil in sight of production of heating in the cold seasons and it can be used to cool in the hot seasons. In this paper, we study, under the meteorological conditions of the town of Rabat, the effect of the kind of soil on the temperature in depth of soil, and also on the depth of penetration and the dephasing. The resultants indicate that the depth of penetration and dephasing are significantly influenced by the kind of soil. But the average temperature of soil surface appears insensitive to the kind of soil.

Keywords: Geothermal, Penetration Depth, Phase, Soil Temperature, Nature of the Soil.

INTRODUCTION

Geothermal energy is the heat energy stored in the earth's surface. The depths of the earth contain huge amounts of natural heat, whose origin lies in the decay of radioactive elements[1,2].

According to current knowledge, temperatures rising to 6000 °C in the core and reach up to 1300 ° C in the upper mantle of the Earth. The flow of heat that reaches the Earth's surface exceeds 40 billion kW. Over 99% of our land mass is subjected to temperatures exceeding 100 °C. The remaining 0.1% of the mass is below 100°C. On average, the temperature increases from the surface to about 3°C per 100 m depth, this corresponds to a normal geothermal gradient[3].

Geothermal energy is a renewable energy. It consists in extracting the calories stored in the soil for the production of electricity (geothermal high temperature) or heat (geothermal low temperature).

Moreover, as the soil temperature from a given depth is almost constant throughout the year. This temperature therefore can have two different applications, according to whether it is higher or lower than the ambient temperature of the season concerned[4].

Indeed, using geo exchanger effective ventilation, the heat can be exploited for the production of heating during cold seasons and cold production during the warmer seasons. Thus, it can cover a large part of the energy needs of a residential heating and air conditioning[5,6].

The cost involved in the implementation of a geothermal facility that may appear large is compensated if we imagine that for a long time, it will heat and cool with a free energy and our electricity bill will be greatly reduced[7].

However, knowledge of the geothermal field is a factor necessary for the construction of geothermal installations. For this, it is important to assess in advance the geothermal potential of the area to be studied. Soil temperature depends on the depth to which this is measured temperature and weather conditions at the site such as solar radiation, ambient temperature and wind speed [8, 9]. It also depends on the nature of soil and the surrounding environment of the site such as for example the presence in the vicinity of a building.

Because of the unavailability of all the experimental data of the Rabat region in particular those concerning the nature of the soil, we conducted this study to examine the influence of this parameter on the temperature of the soil depth[10].

THEORETICAL MODELING

Temperature modelling in soil depth

The sol is treated as a homogeneous semi-infinite solid whose physical properties are constant and independant of the depth z, and which is subject to a signal sinusoidal (the temperature at the surface is denoted T_{surf}).

In this model, the temperature at the surface has the appearance of a given sinusoid as follows:

$$T_{surf}(t) = \overline{T}_{surf} + \sum_{j=1}^{N} A_{surf}(j) \times [\sin(\omega(j) \times t - \varphi_{surf}(j))] \quad (1)$$

N is the number of harmonics, and (j) is a positive integer from 1 to N.

Based on the model of semi-infinite solid, we deduce the temperature of the soil depth z and time t:

$$T_{soil}(z,t) = \overline{T}_{surf} + \sum_{j=1}^{N} A_{surf}(j) \times \exp\left(-\frac{z}{\delta[\omega(j)]}\right) \times \left(\sin(\omega(j) \times t - \varphi surf\ j - z\delta\ \omega j + geo \times z\right. \quad (2)$$

The depth of penetration of a temperature signal pulsation **ω(j)** is given function of the thermal diffusivity α_{soil} soil by the following relationship:

$$\delta[\omega(j)] = \sqrt{\frac{2 \times \alpha_{soil}}{\omega(j)}} \quad (3)$$

The pulsation ω (j) is calculated from the following reaction:

$$\omega(j) = \frac{2 \times \pi}{P} \times j \quad (4)$$

P, is the signal period expressed in seconds and extends over a year whole.

The geo coefficient is the temperature gradient due to heat flow. This flow is considered to be uniform at all points of the ground and directed vertically upward. The geothermal gradient is taken, by default, equal to 0.03 ° Cm^{-1}. However, if the depth is low, the effect of geothermal gradient can be neglected.

Modelling of the temperature at the surface

Fault experimental data on the temperature of the ground surface, it will use the model based on energy balance at the soil surface in order to derive an expression for its temperature. This report is prepared as follows:

The surface receives an amount of energy in the form of sunlight and as sensible convective heat exchange with the ambient air. It loses in turn a portion of its heat by radiation, conduction and convection form of latent heat exchange with the sky, soil and air respectively. This equation can be translated into the following equation:

$$Q_{cond} = (Q_{r-solar} - Q_{r-soil,sky}) + (Q_{conv-sensible} - Q_{conv-latente}) \quad (5)$$

Q_{cond} heat flow is transmitted by conduction in the soil.

She is determined by the following formula:

$$Q_{cond} = \lambda_{soil} \frac{dTsurf}{dt} \mid_{Z=0} \quad (6)$$

λ_{Soil} the parameter is the coefficient of thermal conduction of the ground.

$Q_{r-solar}$ is the amount of solar radiation absorbed by the surface. She is discharged according to the albedo of the soil by the following relationship:

$$Q_{r-solar} = (1 - \rho_{soil}) \times G \quad (7)$$

$Q_{r-soil,sky}$ is the heat flux exchanged by radiation between the surface and the costs heavenly; it is given by the following equation:

$$Q_{r-soil,sky} = \varepsilon_{soil} \times \sigma \times (T_{surf}^4 - T_{sky}^4) \quad (8)$$

Where ε_{soil} and σ are respectively the emissivity of soil and the Stefan-Boltzmann constant.

$Q_{conv-sensible}$ is the heat flux due to convection of the wind; it is estimated by the following relationship:

$$Q_{conv-sensible} = h_{wind} \times (T_a - T_{surf}) \quad (9)$$

With:

$$h_{wind} = 0.5 + 1.2 \times \sqrt{V_{wind}} \quad (10)$$

$Q_{conv-latent}$ flow is due to latent heat of evaporation at the surface soil is evaluated by the following empirical relationship:

$$Q_{conv-latent} = c_{lat} \times f \times h_{wind} \times [(a_{lat} \times T_{surf} + b_{lat}) - HR \times (a_{lat} \times T_a + b_{lat})] \quad (11)$$

HR is the relative humidity; the empirical constants are defined as follows:

$$a_{lat} = 103 \text{ Pa/K} \quad (12a)$$

$$b_{lat} = 609 \text{ Pa} \quad (12b)$$

$$c_{lat} = 0.0168 \text{ K/Pa} \quad (12c)$$

f empirically setting depends on the type of soil and soil humidity.

Table 1: Variation of the parameter f in terms of the nature of the soil

Nature of the soil	Parameter f
Arid	0.1-0.2
Dry	0.4 – 0.5
Wet	0.6 – 0.8
Saturated	1

A new exchange ratio equivalent designated by h_{eq} is introduced, which includes the heat flux lost by radiation exchange with the sky and the heat flux that the surface receives in exchange by convection with ambient air. This will make the linear heat balance equation with respect to the temperature T_{surf}.

$$Q_{conv-sensible} - Q_{r-soil,sky} = h_{eq} \times (T_a - T_{surf}) \quad (13)$$

Transformation Fourier series

Monthly average ambient temperatures as well as the monthly average of the horizontal global solar radiation in the city of Rabat are presented in Table 2.

These data are transformed into harmonic Fourier series as follows:

$$Ta(t) = \overline{Ta} + \sum_{j=1}^{N} A_T(j) \times [\sin(\omega(j) \times t - \varphi_T(j))] \quad (14)$$

$$G(t) = \overline{G} + \sum_{j=1}^{N} A_G(j) \times [\sin(\omega(j) \times t - \varphi_G(j))] \quad (15)$$

Ta and G denote the ambient temperature and solar radiation.N indicates the number of harmonics.

By injecting these last two terms in the energy balance and after the necessary simplifications, it resulted in the following:

$$T_{surf} = \frac{(1 - \rho_{soil}) \times \overline{G} + h_r \times \overline{T}_a + (h_r - he) \times (b_{lat}/a_{lat})}{he} \quad (16)$$

$$Tg\ \varphi_{surf}(j) = \frac{(h_{cond}(\omega(j)) + he) \times Y_2(J) - h_{cond}(\omega(j)) \times Y_1(j)}{-(h_{cond}(\omega(j)) + he) \times Y_1(j) - h_{cond}(\omega(j)) \times Y_2(j)} \quad (17a)$$

$$A_{surf}(j) = \frac{Y_1(j) \times \sin(\varphi_{surf}(j) + Y_2(j) \times \cos(\varphi_{surf(j)}))}{h_{cond}(j)} \quad (17b)$$

With:

$$h_e = h_{eq} + h_{wind} \times a_{lat} \times c_{lat} \times f \quad (18a)$$

$$h_r = h_{eq} ++ h_{wind} \times a_{lat} \times c_{lat} \times f \times HR \quad (18b)$$

$$h_{cond}((j)) = \frac{\lambda soil}{\delta[\omega(j)]} \quad (18c)$$

$$Y_1(j) = (1 - \rho_{soil}) \times A_G(j) \times \cos(\varphi_G(j)) + h_r \times A_T(j) \times \cos(\varphi_T(j)) \quad (18d)$$

$$Y_2(j) = -(1 - \rho_{soil}) \times A_G(j) \times \sin(\varphi_G(j)) - h_r \times A_T(j) \times \sin(\varphi_T(j)) \quad (18e)$$

RESULTS AND DISCUSSION

The city of Rabat is located northwest of Morocco. His site is characterized by an elevation of 50 m above the sea, longitude 6°45'W, latitude 34°2'N . Given the availability of hourly data of a whole year for the city of Rabat, we used monthly averages shown in Table 2.

As coastal cities, Rabat has a temperate climate. The winter is mild. Abundant rains fall in winter and spring. For the summer, the city is refreshed by breezes from the coast. Maximum temperatures rarely exceed 27 ° C. RABAT climate data were collected and summarized in Table 2. The degree days heating are 737 ° CJ while cooling degree days are more important 2640 ° CJ.

Table 2: Meteorological data of the city of Rabat

Month		Average air temperature	Relative humidity	Daily solar radiation - Horizontal	atmospheric pressure	Wind speed	Soil temperature	Degree days heating	Degree days cooling
		°C	%	kWh/m²/j	kPa	m/s	°C	°C-j	°C-j
January		12,6	82,9%	2,69	101,7	2,7	12,7	167	81
February		13,1	83,2%	3,58	101,5	2,7	14,5	137	87
March		14,2	79,7%	4,69	101,3	2,9	17,6	118	130
April		15,2	78,2%	6,17	101,1	3,2	20,0	84	156
May		17,4	77,6%	7,03	101,1	3,1	23,9	19	229
June		19,8	78,9%	7,25	101,2	3,0	28,5	0	294
July		22,2	79,0%	7,31	101,1	2,9	31,1	0	378
August		22,4	79,9%	6,81	101,1	2,8	29,9	0	384
September		21,5	80,5%	5,61	101,2	2,8	27,0	0	345
October		19,0	80,5%	4,28	101,2	2,8	22,7	0	279
November		15,9	81,5%	3,08	101,4	2,9	17,7	63	177
December.		13,2	83,2%	2,56	101,6	2,9	14,2	149	99
Annual		17,2	80,4%	5,10	101,3	2,9	21,7	737	2 640
Measured	m					10,0	0,0		

To investigate the influence of soil type and the period of the temperature signal and radiation penetration depth was taken as signal period: one day, one week, one month and one year. We chose three types of ground, as indicated in Table 3:

Table 3: Soil type and physical properties

Nature of the soil	Density (Kg/m^3)	Thermal diffusivity m^2/s)	Heat capacity (J.Kg/°C)
Clay	1500	9.69×10^{-7}	880
Silt-clay-sand	1800	6.22×10^{-7}	1340
Sand	1780	3.76×10^{-7}	1390

The results presented in Figure 1, we show two things.
First, we observe that the penetration depth associated with a one-year period exceeds three meters (3 m) for clay, but it is less than two meters (2 m) to the sand. This means that clay soil is very sensitive to the annual climate variations compared to a sandy soil. It follows that study of the soil is essential for determining the temperature of the soil in depth.
Second, for the three soils, the penetration depth corresponding to a monthly period is less than 1 m. This result leads us to say that as the monthly variations in climate are felt by a few layer deep crustal, we can use the monthly average of the ambient temperature and solar radiation to evaluate the soil temperature at a given depth without fear that it has great effects on the accuracy of our results.
Temperature modeling in soil depth for deep crustal Rabat region, one can use the average monthly ambient temperature and solar radiation to evaluate the soil temperature at
* data without fear that this has great effects on the accuracy of our results depth.

Furthermore, the soil does not seem to have an effect on the average temperature of the soil surface (Fig. 2), while it has a remarkable influence on the phase shift (Fig. 3). By way of example, to a depth of 3 m, the phase difference is 90 days for sand, while it is less than 60 days for the clay.
It should be also be noted that the phase shift is inversely proportional to the penetration depth of annual. In other words, it is more; the greater the phase shift is small.
As for the evolution of the phase shift depending on the depth, the results shown in Figure 3 indicate that the more you sink into the ground, the phase becomes more important. So that the results are independent of the nature of the soil, we took in Figure 4 as unit length the depth of annual penetration.
The evolution of the temperature of the soil in a year depending on the soil depth shows that the signal amplitude decreases when the temperature increases towards and beyond a distance equal to twice the depth of penetration, the soil temperature has more the shape of a sinusoid and stabilizes around a certain value.

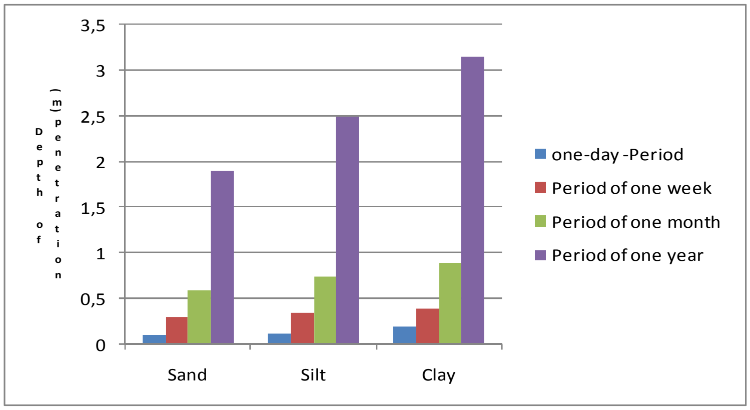

Figure 1: Thermal penetration depth according to the type of soil

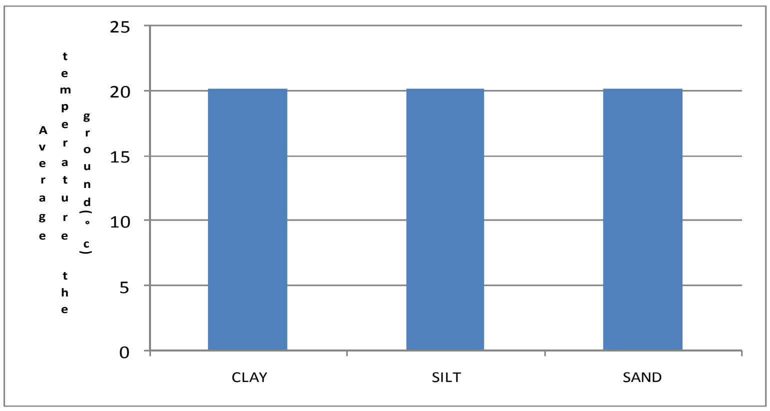

Figure 2: Average Temperature the ground surface depending on the nature of the soil

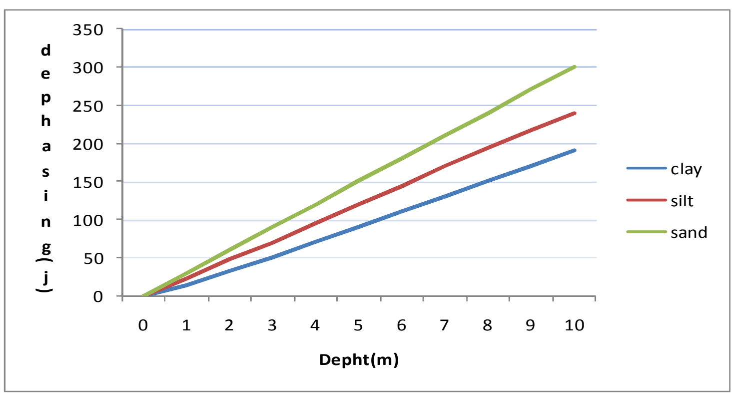

Figure 3: The phase variation as a function of the depth in soil

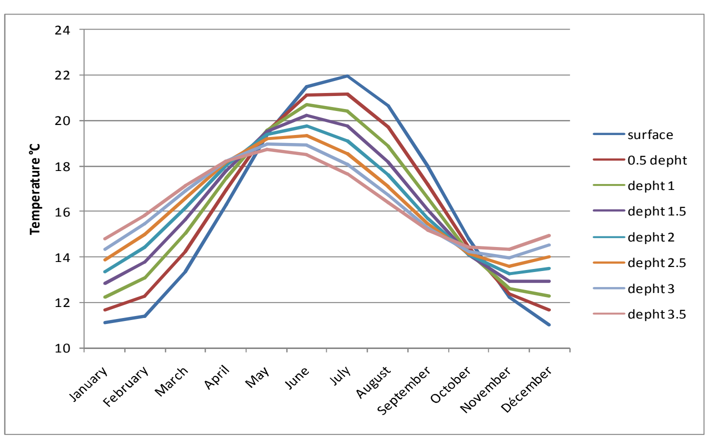

Figure 4: Annual evolution of the surface temperature and depth

CONCLUSION

Were studied in this work the influence of soil type on soil depth temperature for the city of Rabat.

The results indicate that this parameter is often taken by default greatly affects the depth of penetration and the annual dephasing.

For clay, it was found that the depth of penetration exceeds the annual three meters (3 m), while it is equal to just two meters (2 m) to the sand.

In addition, to a depth of 3 m, the phase is three months for sand, while it is less than two months to clay. It was also found that a temperature range between 17 ° C ground and 24 ° C is obtained for a deep $z=(3/2)\times\delta$.

This depth corresponds to a distance of 4.60 m in the sandy soil and 2.90 m in the clay soil, a difference of 1.7 m.

NOMENCLATURE

A: Amplitude

h: heat transfer coefficient, W / m^2K

P: Time, s

V: speed, m / s

z: Distance, m

G: global horizontal irradiance, W/m^2

RH: relative humidity

T: temperature, K

T: Time

geo: Geothermal Gradient, ° C / m

N: Number of harmonics m^2

$Q_{conv\ sensible:}$ Sensible heat flux exchanged by convection, W/ m^2.

$Q_{conv\_latente}$: Sensible heat flux exchanged by convection, W / m^2 the ground and the celestial vault

Qr_solar: solar radiation flux, W / m^2

Greeksymbols

ω: Pulse, rad/s

ε: Emissivity

σ: Stefan-Boltzmann constant

α:thermal diffusivity,m^2/s

φ: Initial Phase, rad

ρ: Albedo

δ penetration depth , m

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