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Modelling and Analytical Proofing of Low Energy Temperature Control using Earth/Ground Water Heat Exchanger

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Abstract

For given condition of (temperature and humidity) of suction air, the delivery air condition depends on the system parameters (depth, radius, length and air mass flow rate), thermo physical properties of the surrounding earth (thermal conductivity and specific thermal capacity) and earth surface environment (ambient temperature, ambient humidity and solar irradiance)[1,3].Sensitivity analysis of system performance is essential for understanding the relative importance of different parameters of design of a optimum system [2,5]. For the steady state periodic input air condition and the performance of the system can be measured in terms of heating potential during the winter period and cooling potential during the summer period. Sensitivity of the system performance parameters (heating potential in winter and cooling potential in summer) to the changes in system parameters or thermo physical properties of the surrounding earth has been analysed and the result is present is in this paper.

Keywords: *Solar temperature, low energy temperature control using earth/ground water heat exchanger, cooling potential, heating potential and sensitivity.*

1. INTRODUCTION:

The temperature of the surface of the ground is governed by the ambient temperature and absorbed solar radiation i.e., Solar temperature of the earth surface. Temporal fluctuations of the solar temperature pump a thermal wave into the ground with, daily period of 24 hours and seasonal fluctuation of 365 days. The amplitude of thermal waves as it travels the ground is damped. For daily fluctuation the skin depth is around 15-20 cm, while the seasonal fluctuation it is 4-5 m. Hence at the depth beyond 4-5 m both daily and seasonal fluctuations die down and the temperature of the ground at these depths is almost constant and is equal to the annual average of solar temperature of the earth surface. For the tropical climates of the sub range regions, the annual average of the solar temperature of the earth surface temperature will be around 28-30^0 C, which is very good for human thermal comfort. For a given climate (like Perinaickenpalayam or Coimbatore) this temperature is not in the desired range, it can be modified to the desired range by suitable treatment of the earth surface, (*i.e.,* the solar temperature of the earth surface), the earth surface can be blackened/glazed while for decreasing the solar temperature of the earth surface, the earth surface can be shaded, painted white and wetted with spray water. For the large thermal storage capacity of the ground, temperature at these depths is very stable. The effect of withdrawing heat or supplying heat on the earth temperature at these depths is not significant. This very stable thermal environment can be coupled to the above grade building by the system to create human thermal conditions inside the building. The simplest system would be a pipe of appropriate dimensions of about 4m in the ground if the pipe is of adequate length, the ambient air passing through it in summer and in winter will acquire the temperature equal to the annual average of the solar temperature of the earth surface.

The following assumptions are made for analysis:

1. Thermo physical properties of the ground are uniform and dependent of temperature.
2. Surface temperature of the ground is uniform.
3. Air mass flow rate in the pipe is constant.
4. Temperature gradient in the soil in the direction of air flow in the pipe is much smaller than the temperature gradient in the vertical direction.

The effective solar temperature of the earth surface for different earth surface conditions is given by (Bhardwaj and Bansal, 1981)

$$T_s^g = \frac{1}{h_{eff}}\left\{ h_c(1+0.013\, R_1\, Rh)\, T_{amb} + \alpha_g S - \varepsilon\Delta R - 0.013\, R_2 h_c\, (1-Rh)\right\} \quad (1)$$

$$\text{where} \quad h_{eff} = (1+0.013\, R_1)$$

Different parameters used in calculation for different surface conditions\

S. No	Surface treatment	R_1	R_2	α_g	h_c	S
1	Dry sunlit	0	0	0.6	14.0	S_G
2	Dry shaded	0	0	0.6	14.0	S_D
3	Wet sunlit	+249	-3013	0.6	14.0	S_G
4	Wet shaded	+249	-3013	0.6	14.0	S_D
5	Blackened sunlit	0	0	0.9	14.0	S_G
6	Blackened glazed	0	0	0.8	6.5	S_G

The different parameters used in calculation for different surface conditions are given in the Table 1. Since the environmental parameters namely solar irradiance, ambient temperature and relative humidity for each month are periodic in nature (with a periodicity of 24 hours), these parameters can be Fourier analysed as

$$f(t) = \sum_{n=0}^{\infty} \left\{ f_{cn} \cos(n\omega t) + f_{sn} \sin(n\omega t) \right\}$$

(2)

where $\omega = \dfrac{2\pi}{24 \text{ x } 3600}$

The Fourier coefficients f_{cn} and f_{sn} vary from month to month and have a periodicity of one year. These coefficients can be further Fourier analysed as

$$f_{cn} = \sum_{m=0}^{\infty} \left\{ f_{cn}^{cm} \cos(m\Omega t) + f_{cn}^{sm} \sin(m\Omega t) \right\} \tag{3}$$

and

$$f_{sn} = \sum_{m=0}^{\infty} \left\{ f_{sn}^{cm} \cos(m\Omega t) + f_{sn}^{sm} \sin(m\Omega t) \right\} \tag{4}$$

where $\Omega = \dfrac{2\pi}{365 \text{ x } 24 \text{ x } 3600}$

By substituting the values of f_{cn} and f_{sn} in Eq. (5.2), gives

$$f = \mathrm{Re} \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \left[f_n^{+m} \exp\{i(n\omega + m\Omega)t\} + f_n^{-m} \exp\{i(n\omega - m\Omega)t\} \right] \tag{5}$$

where $$f_n^{\pm m} = \frac{f_{cn}^{cm} - i f_{sn}^{cm}}{2} \pm \frac{f_{sn}^{sm} - i f_{cn}^{sm}}{2}$$

Considering an underground air-pipe air-conditioning system of radius r buried in the ground at a depth D with an axial heat source $\dot{q}$ of the type

$$\dot{q} = \dot{q}_0 + \mathrm{Re} \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \left[\dot{q}_n^{+m} \exp\{ i(n\omega + m\Omega)t \} + \dot{q}_n^{-m} \exp\{ i(n\omega - m\Omega)t \} \right] \tag{6}$$

and earth surface solair temperature T_s^g of type

$$T_s^g = T_{s0}^g + \mathrm{Re} \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \left[T_{sn}^{+mg} \exp\{ i(n\omega + m\Omega)t \} + T_{sn}^{-mg} \exp\{ i(n\omega - m\Omega)t \} \right] \tag{7}$$

The surface temperature of the air-pipe is given by (following Claesson and Dunand 1983 and assuming r << D)

$$\begin{aligned}
T_r(t) &= \frac{-\dot{q}}{2\pi k_g} \ln\left(\frac{2D}{r}\right) + T_{s0}^g \\
&+ \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} T_{sn}^{+mg} \exp\left(\frac{-D(1+i)}{d'^{+m}_n} \right) \exp\{ i(n\omega + m\Omega)t \} \\
&- \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \frac{\dot{q}_n^{+m}}{2\pi k_g} \left[\frac{iK_0\{\exp\left(\frac{i\pi}{4}\right) R_n'^{+m}\}}{R_n'^{+m} K_1\{\exp\left(\frac{i\pi}{4}\right) R_n'^{+m}\}} \exp\left(\frac{-3i\pi}{4}\right) - K_0(D_n'^{+m}) \exp\left(\frac{i\pi}{4}\right) \right] \mathrm{x} \\
&\qquad \exp\{ i(n\omega + m\Omega)t \} \\
&+ \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} T_{sn}^{-mg} \exp\left(\frac{-D(1+i)}{d'^{-m}_n} \right) \exp\{ i(n\omega + m\Omega)t \} \\
&- \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \frac{\dot{q}_n^{-m}}{2\pi k_g} \left[\frac{iK_0\{\exp\left(\frac{i\pi}{4}\right) R_n'^{-m}\}}{R_n'^{-m} K_1\{\exp\left(\frac{i\pi}{4}\right) R_n'^{-m}\}} \exp\left(\frac{-3i\pi}{4}\right) - K_0(D_n'^{-m}) \exp\left(\frac{i\pi}{4}\right) \right] \mathrm{x} \\
&\qquad \exp\{ i(n\omega - m\Omega)t \}
\end{aligned} \tag{8}$$

where K_0 and K_1 are modified Bessel functions of second kind of zero and first order respectively

$$R'^{\pm m}_n = \frac{r\sqrt{2}}{d'^{\pm m}_n},$$

$$D'^{\pm m}_n = \frac{D \sqrt[2]{2}}{d'^{\pm m}_n},$$

$$d'^{\pm m}_{n} = \sqrt{\frac{2k_g}{(n\omega \pm m\Omega)\rho_g C_g}}$$

In the double summation, the terms m=0 and n=0 are to be omitted.
For air flowing through the system, the energy balance equation can be written as

$$\dot{m}_f C_f \frac{\partial T_f}{\partial y}\Delta y + \rho_f C_f \pi r^2 \frac{\partial T_f}{\partial t}\Delta y = \dot{q}\Delta y \qquad (9)$$

$$\text{where} \quad \dot{q} = 2\pi r h_i \left(T_f - T_r\right) \qquad (10)$$

Assuming the suction air temperature T_i to be periodic, one can write,

$$T_f = T_{f0} + \mathrm{Re} \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \left[T_{fn}^{+m} \exp\{i(n\omega + m\Omega)t\} + T_{fn}^{-m} \exp\{i(n\omega - m\Omega)t\}\right] \qquad (11a)$$

$$T_r = T_{r0}\, \mathrm{Re} \sum_{n=0}^{\infty} \sum_{m=0}^{\infty} \left[T_{rn}^{+m} \exp\{i(n\omega + m\Omega)t\} + T_{rn}^{-m} \exp\{i(n\omega - m\Omega)t\}\right] \qquad (11b)$$

Substituting the value of T_r and T_f in Eq. 5.8 and 5.9, using Eq. 5.10 and comparing the
coefficients of exp $\{i(n \pm m\Omega)t\}$ on both sides of the resulting equation, one obtains two coupled equations for each of the temperature $T_{r0}, T_{f0}, T_{rn}^{+m}$ and T_{fn}^{+m} and T_{rn}^{-m} and T_{fn}^{-m} i.e.

$$T_{r0} = \frac{T_{f0} \dfrac{rh_i}{k_g} \ln\left(\dfrac{2D}{r}\right) + T_{s0}^{g}}{1 + \dfrac{rh_i}{k_g} \ln\left(\dfrac{2D}{r}\right)} \qquad (12a) \qquad \text{(from Eq. 8)}$$

$$T_{r0} = \frac{\dot{m}_f \, . \, c_f \dfrac{\partial T_{f0}}{\partial y} + 2\pi r h_i T_{fo}}{2\pi r h_i} \qquad (12b) \qquad \text{(from Eq. 9)}$$

$$T_{rn}^{+m} = \frac{T_{sn}^{+mg} \; . \; \exp\left\{\dfrac{-D(1+i)}{d_n'^{+m}}\right\} + \dfrac{rh_i}{k_g} \; . \; \lambda_n^{+m} \; m \, . \; T_{fn}^{+m}}{\left(1 + \dfrac{rh_i}{k_g} \; . \; \lambda_n^{+m}\right)} \qquad (13a) \quad \text{(from Eq. 8)}$$

$$T_{rn}^{+m} = \frac{\dfrac{\partial T_{fn}^{+m}}{\partial y} + \dfrac{2\pi r h_i}{\dot{m}_f\, c_f}\left\{1+\dfrac{\rho_f\, c_f\, r\,(in\omega + im\Omega)}{2h_i}\right\} T_{fn}^{+m}}{\dfrac{2\pi h_i}{\dot{m}_f\, c_f}}$$ (13b) (from Eq. 9)

$$T_{rn}^{-m} = \frac{T_{sn}^{-mg}\ .\ \exp\left\{\dfrac{-D(1+i)}{d_n'^{\,-m}}\right\} + \dfrac{rh_i}{k_g}\ .\ \lambda_n^{-m}\ .\ m\,.\ T_{fn}^{-m}}{\left(1+\dfrac{rh_i}{k_g}\ .\ \lambda_n^{-m}\right)}$$ (14 a) (from Eq. 8)

and

$$T_{rn}^{-m} = \frac{\dfrac{\partial T_{fn}^{-m}}{\partial y} + \dfrac{2\pi r h_i}{\dot{m}_f\, c_f}\left\{1+\dfrac{\rho_f\, c_f\, r\,(in\omega - im\Omega)}{2h_i}\right\} T_{fn}^{-m}}{\dfrac{2\pi h_i}{\dot{m}_f\, c_f}}$$ (14b) (from Eq. 9)

where

$$\lambda_n^{\pm m} = \frac{iK_0\left\{\exp\left(\dfrac{i\pi}{4}\right) R_n'^{-m}\right\}}{R_n'^{-m}\, K_1\left\{\exp\left(\dfrac{i\pi}{4}\right) R_n'^{-m}\right\}}\quad \exp\left(\frac{-3i\pi}{4}\right) - K_0\,(D_n'^{-m})\,\exp\left(\frac{i\pi}{4}\right)$$

On eliminating T_r terms from each set of the coupled Eqs. (12), (13) and (14), we obtain the following equations for T_{f0}, T_{fn}^{+m}, T_{fn}^{-m}

$$\frac{\partial T_{fn}^{-m}}{\partial y} = \beta_0\left(T_{s0}^{g} - T_{f0}\right) \tag{15}$$

$$\frac{\partial T_{fn}^{+m}}{\partial y} = \frac{\mu}{\beta_n^{+m}}\left[T_{sn}^{+mg}\ .\exp\left\{\frac{-D(1+i)}{d_n'^{\,+m}}\right\} - T_{fn}^{+m}\,.\,\tau_n^{+m}\right] \tag{16}$$

and

$$\frac{\partial T_{fn}^{-m}}{\partial y} = \frac{\mu}{\beta_n^{-m}}\left[T_{sn}^{-mg}\ .\exp\left\{\frac{-D(1+i)}{d_n'^{\,-m}}\right\} - T_{fn}^{-m}\,.\,\tau_n^{-m}\right] \tag{17}$$

where

$$\beta_0 = \frac{2\pi r h_i}{\dot{m}_f \,.\, c_f \,.\left\{1 + \frac{r h_i}{k_g} \,.\, \ln\left(\frac{2d}{r}\right)\right\}}$$

$$\mu = \frac{2\pi r h_i}{m_f \,.\, c_f}$$

$$\beta_n^{\pm m} = 1 + \left(\frac{r h_i}{k_g}\right) . \, \lambda_n^{\pm m}$$

and

$$\tau_n^{\pm m} = 1 + \left\{\frac{\rho_f \,.\, c_f \,.\, r(in\omega \pm im\Omega)\beta_n^{\pm m}}{2h_i}\right\}$$

Integrating Eqs. (5.15), (5.16), (5.17) and applying the boundary conditions that the inlet air temperature to the underground air-pipe air-conditioning system is equal to T_{fi} and outlet temperature at y=L is equal to $T_{fo,}$ i.e.

$$T_{f0}\big|_{y=0} = T_{fi0o}, \quad T_{fn}^{+m}\big|_{y=0} = T_{fin}^{+m}, \quad T_{fn}^{-m}\big|_{y=0} = T_{fin}^{-m} \tag{18a}$$

$$T_{f0}\big|_{y=L} = T_{fo0}, \quad T_{fn}^{+m}\big|_{y=L} = T_{fon}^{+m}, \quad T_{fn}^{-m}\big|_{y=L} = T_{fon}^{-m} \tag{18b}$$

We get the following solutions for T_{fo0} , T_{fon}^{+m}, T_{fon}^{-m}

$$T_{fo0} = T_{s0}^{g}\{1 - \exp(-\beta_0 L)\} + T_{fi0} \,.\, \exp(-\beta_0 L) \tag{19}$$

$$T_{fon}^{+m} = \frac{T_{sn}^{+mg} \exp\left\{\frac{-D\,(1+i)}{d'^{\,+m}_n}\right\}\left\{1 - \exp\left(\frac{\mu L \tau_n^{+m}}{\beta_n^{+m}}\right)\right\}}{\tau_n^{-m}} + \frac{T_{fin}\,\tau_n^{+m}\exp\left(\frac{-\mu L \tau_n^{+m}}{\beta_n^{+m}}\right)}{\tau_n^{+m}} \tag{20}$$

$$T_{fon}^{-m} = \frac{T_{sn}^{-mg} \exp\left\{\frac{-D\,(1+i)}{d'^{\,-m}_n}\right\}\left\{1 - \exp\left(\frac{\mu L \tau_n^{-m}}{\beta_n^{-m}}\right)\right\}}{\tau_n^{-m}} + \frac{T_{fin}\,\tau_n^{-m}\exp\left(\frac{-\mu L \tau_n^{-m}}{\beta_n^{-m}}\right)}{\tau_n^{-m}} \tag{21}$$

Knowing the values of T_{fo0}, T_{fon}^{+m} and T_{fon}^{-m}, the hourly values of the delivery air temperature can then be obtained from the equation

$$T_{fo} = T_{fo0} + \sum_{n=o}^{6}\sum_{m=o}^{6}\left[T_{fon}^{+m}\exp\{i(n\omega + m\Omega)t\} + T_{fon}^{-m}\exp\{i(n\omega - m\Omega)t\}\right] \tag{22}$$

Since for the variation of ambient temperature and solair temperature of the earth's surface, the Fourier series converges for terms upto n=6 and m=6, only terms upto n=6 and m=6 are considered in Fourier series expansion.

The heating potential (Q_{hp}) of the underground air-pipe air-conditioning system is defined as total amount of heat gained by the cold air passing through the system in one heating season and can be calculated from the relation

$$Q_{hp} = \sum_{mo} \sum_{hr} \frac{\dot{m}_f . \dot{c}_f \left(T_{fo} - T_{fi}\right)^+ n_d}{1000} \qquad (23)$$

Similarly the cooling potential Q_{cp} of the underground air-pipe air-conditioning system is defined as the total amount of the heat lost by the hot air passing through the system in one cooling season and can be calculated from the relation

$$Q_{cp} = \sum_{mo} \sum_{hr} \frac{\dot{m}_f . \dot{c}_f \left(T_{fi} - T_{fo}\right)^+ n_d}{1000} \qquad (24)$$

where $\sum_{hr}$ represents the summation over hours of average day of the month and $\sum_{mo}$ represents summation over the months of the season. The + sign over the brackets signify that only positive value of the bracketed terms are included in the summation. This implies that in summer period if for certain hours of the day T_{fo} is greater than $T_{fi,}$ the hot air from the underground air-pipe air-conditioning system is not used. In winter period if for certain hours of the day T_{fo} is less than T_{fi}, the cold air from the pipe is not used.

2. SENSITIVITY ANALYSES:

As the thermal performance of the underground air-pipe air conditioning system depends on a variety of input parameters, it is often useful to know of these parameters, what is the relative importance of the parameters in determining the thermal performance of the system. This allows one to concentrate one's effort and resources on the parameter having larger influence on the performance of the system. In our case, the heating / cooling potential (Q_{hp} / Q_{cp}) depends on the system design parameters: diameter of the pipe (r), length of the pipe (L), depth of the pipe (D), velocity of the working fluid (v) and surrounding earth parameters: thermal conductivity of the ground (k_g).

i.e. HP (CP) = f (r, D, L, v, k_g)

$$Y = f(x_1, x_2, x_3, x_4, x_5) \qquad (25)$$

If the independent variable x_i is changed by $\pm$ U(x_i) ie. $x_i \rightarrow x_i \pm U[x_i]$, then the dependent variable, Y is consequently changes by some amount U[Y]. The change in dependent variable Y is then related to the change in dependent variable x_i by

$$U[Y] = \frac{\partial Y}{\partial x_i} U[x_i] \qquad (26)$$

It is often useful to express the change in any variable as a fraction or equivalently, a percentage, that is

$$U\%[Y] = \frac{U[Y]}{Y} \quad (27)$$

The relation (5.26) can then be written as

$$\frac{U[Y]}{Y} = \frac{x_i}{y} \cdot \frac{\partial y}{\partial x} \cdot \frac{U[x_i]}{x_i} \quad (28)$$

or $$U\%[Y] = I[y,x_i]\ U\%[x_i] \quad (29)$$

where the influence coefficient $I[y,x_i]$ is the logarithmic derivative of Y with respect to x_i, ie.

$$I\,[y,x_i] = \frac{\partial y / y}{\partial x_i / x_i} = \frac{\partial[\ln Y]}{\partial[\ln x_i]} \quad (30)$$

The influence coefficient is the measure of the sensitivity of the dependent variable Y on the independent variable x_i and for the relation of the form $Y = x_i^n$, is equal to the value of the exponent n, ie.

$$I[y,x_i] = n \quad (31)$$

Obviously $I[y,x_i]$ equal to +1 means a proportional relationship and $I[y,x_i]$ equal to –1 means an inverse relationship. $I[y,x_i]$ equal to 0 of course implies no relationship. The value of $I[y,x_i]$ thus calculated is a 'local' one, meaning that for a different set of parameters, the numerical value of $I[y,x_i]$ might be different. Further, if a maximum or minimum in Y has been found for a value of $X_i = X_{i0}$, then $I[y,X_{i0}]$ is necessarily zero. This also implies the greatest care in determining the uncertainties of the independent variable should be employed for those variables that have the largest influence coefficients at the condition of interest because these particular variables can contribute the largest uncertainty in the dependent variable Y.

3. Numerical determinations of the Influence Coefficient and percentage change in the dependent variable:

For the very complex nature of the expression of Q_{hp} (Q_{cp}), it is easier to determine the influence coefficient and percentage change in the Q_{hp} (Q_{cp}) numerically then analytically. A logical procedure would be arrange the independent variable in such a way as to make it possible to vary each x_i by a small fraction $\in$ ie. Change in x_i to $x_i\,(1\pm \in)$ and determine the percentage change in the dependent variable Y. The influence coefficient and the percentage change in the dependent variable Y can be numerically estimated from the relations

$$I[y, x_i] = \frac{(1+\epsilon/2)}{\epsilon} \cdot \frac{Y[x_i(1+\epsilon)] - Y[x_i]}{Y[x_i(1+\epsilon/2)]} \tag{32}$$

and

$$U\%[Y] = (1+\epsilon/2) \cdot \frac{Y[x_i(1+\epsilon)] - Y[x_i]}{Y[x_i(1+\epsilon/2)]} \times 100 \tag{34}$$

where the square brackets denote a functional relationship whereas the parenthesis form an algebraic group.

The variation of the influence coefficient and percentage change in heating potential and cooling potential of the system with percentage variations in different system parameters (r, L, v and D) and surrounding earth parameter (k_g) has been numerically estimated for the three climatic conditions under dry sunlit conditions of the earth surface.

For estimating sensitivity of the various earth surface treatments, the effect of variation of the length of the pipe system on the influence coefficient and percentage change in heating and cooling potential has also been analysed for different earth surface treatments (dry sunlit, dry shaded, wet sunlit, wet shaded, blackened and blackened glazed) for the above four representative city climates. The thermophysical properties of the air, earth and pipe material used in the calculations are given in the Table 2.

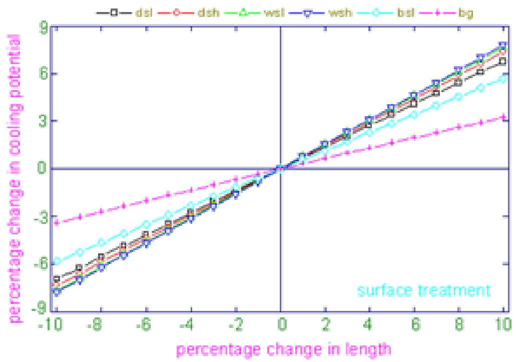
Table 2: Thermophysical properties of the air, earth and pipe material

S. No	Materials	Thermal conductivity W/m°C	Specific heat J/Kg°C	Density Kg/m^3
1	Air	0.0267	1000	1.2
2	Earth (dry)	0.50	2235	2460
3	Earth (wet)	1.50	2235	2460
4	Concrete (RCC)	1.36	886	2288

4. RESULTS AND DISCUSSION:

Modeling and sensitivity of the system has been done. The result shows that an increase in moisture content and decrease the soil content between day time and night time, which enables the soil to maintain an appropriate positive heat balance during night time. It is seen that system is more sensitive to change in length than to the change in other parameters. It is also sensitive to the velocity of the working fluid. Shading and intermittent wetting of the earth surface are two viable independent options for lowering temperature of the earth in the hot dry climates. For cold climates, blackening and glazing of earth surface surrounding the building is an interesting option to achieve an increase of temperature.

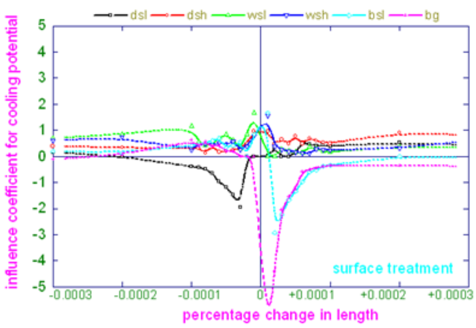
5. SIMULATIONS ATTAINED:



Percentage change in cooling potential with different surface treatments

6. CONCLUSION:

- The result shows that an increase in moisture content and decrease the soil content between day time and night time, which enables the soil to maintain an appropriate positive heat balance during night time.
- It is seen that system is more sensitive to change in length than to the change in other parameters.
- It is also sensitive to the velocity of the working fluid. Shading and intermittent wetting of the earth surface are two viable independent options for lowering temperature of the earth in the hot dry climates.
- For cold climates, blackening and glazing of earth surface surrounding the building is an interesting option to achieve an increase of temperature.



Variation of Influence coefficient for cooling potential with different surface treatments

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