

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Effect of Derating Factor on the Thermal Performance of Earth Air Tunnel Heat Exchanger: A Review

Ankit Goyal¹, Chandral Pal Singh Inda¹, Sunil Kumar Bhati¹, Dr. Jai Gopal Gupta²

Guest Faculty, Department of Mechanical Engineering, Government Women Engineering College Ajmer, India¹

Head of Department, Department of Mechanical Engineering, Government Women Engineering College Ajmer, India²

ABSTRACT: For the transient operating conditions derating factor is used to evaluate deterioration of Earth Air Tunnel Heat Exchanger's thermal performance. Derating factor depends upon soil's thermal conductivity, duration of continuous operation and the pipe length. Collection/rejection of heat from pipe to nearby sub soil is one the major problem in operating earth air tunnel heat exchanger because it alters the soil temperature which have adverse effect on the thermal performance of EATHE system with time. Hence the efficiency of EATHE system greatly depends upon extent of thermal saturation and the time required for self-recovery of soil around the buried pipe. Problem of derating factor are more severe with the soil having poor thermal conductivity.

KEYWORDS: Derating factor, Transient operation, Continuous operation, Thermal saturation

I. INTRODUCTION

Earth air tunnel heat exchanger used underground soil as heat source/sink and air as heat transfer medium. Earth can be considered as huge energy collector and storage medium. Ground has high heat capacity and have a large insulation potential. Hence soil temperature up to a depth of about 3-4 m remain constant throughout the year. Air after passing through underground tunnel exchange heat with surrounding soil and thus outlet air temperature higher in winter and lower in summer. Several researchers studied the EATHE system such as Ghosal et al. [10] investigate the performance of EATHE integrated with green house. Svec et al. [14] presented numerical model for steady-state, transient and cyclic behaviour of several configurations, and it was shown that substantially reduced heat flows were obtained when plastic pipe was used. Sodha et al. [11] also investigated the effect of length, radius of pipe and air mass flow rate on the seasonal cooling potential of an underground air pipe system. Sensitivity analysis based on system parameters such as inlet air temperature, air velocity, pipe length, pipe radius and the pipe depth for evaluating the performance of earth-to-air heat exchangers was carried out by Tzaferis et al. [12] using eight different algorithms. Hakan et al. [13] investigated the performance of Ground Heat Exchangers (GHE) system consisted of pipes buried in the soil, which was used for transferring heat between the soil and the heat exchanger pipes of the Ground Source Heat Pump (GSHP) using a software developed in MATLAB environment. Bansal et al. [7] have studied the effect of three different types of soils with thermal conductivities of 0.52, 2, 4 ($\text{W m}^{-1} \text{K}^{-1}$). It was found that maximum performance deterioration with prolonged operation takes place with soil having lowest thermal conductivity. It has been clearly seen through the literature review that thermal performance of EATHE system deteriorates upon its continuous operation, especially in case of lower soil thermal conductivity. Various researcher works on intermittent operation of EATHE to solve the system deterioration problem. Mathur et al. [2] investigated the transient conditions for three different soil conditions considering three operating modes. In first mode EATHE system works continuously for 12 h, in mode-2 it works for 60 min then turn off for 20 min. and in the mode-3 EATHE runs for 60 min and remain off for 40 min. The 3-different soil used i.e. soil-1, soil-2, soil-3 having thermal conductivity 0.52, 1.00, 1.28 ($\text{W m}^{-1} \text{K}^{-1}$) respectively.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

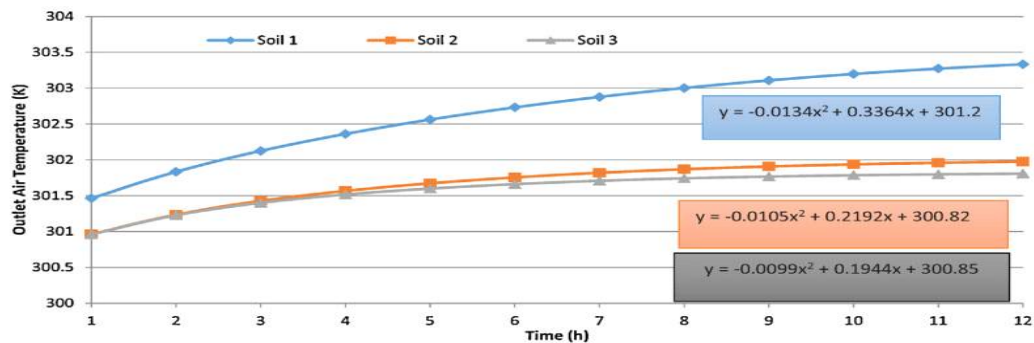


Fig. 1 Variation in air outlet temperature in continuous operation mode

From fig. 1 it is observed that the outlet air temperature increase with time due to the saturation of adjacent soil. The EATHE outlet air temperature increase was maximum 1.87 K for soil-1, 1.01 K for soil-2, 0.85 K for soil-3 after 12 h of continuous operation. The performance of system gets deteriorated due to saturation of subsoil surrounding the EATHE pipe during continuous running. Soil having highest conductivity i.e. soil-3 experience least deterioration in term of outlet air temperature. The comparison of mode 2, mode 3 performance for soil-1 is shown in fig. 2 and fig. 3 respectively. It was observed that the thermal performance of EATHE system improved in mode-2 as compared to mode-1 because during OFF period of EATHE system, surrounding soil dissipates the stored heat to the next sub soil region and also regains its heat absorbing capacity which was not possible in mode-1.

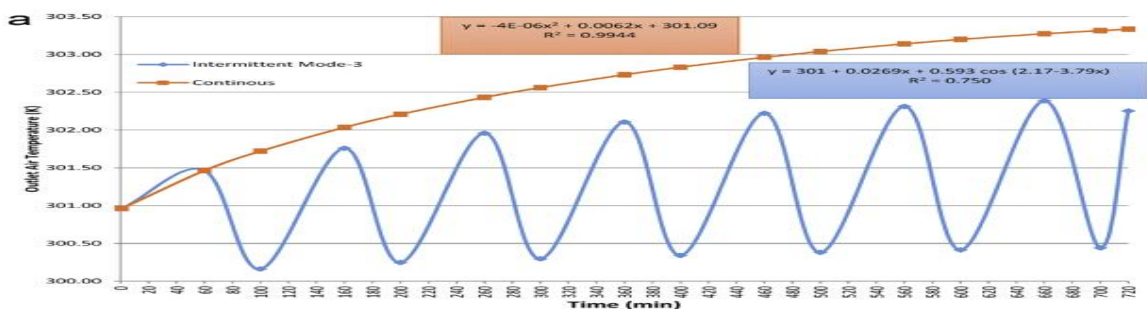


Fig. 2 EATHE outlet air temperature in intermittent (mode 2) and continuous operation with soil-1

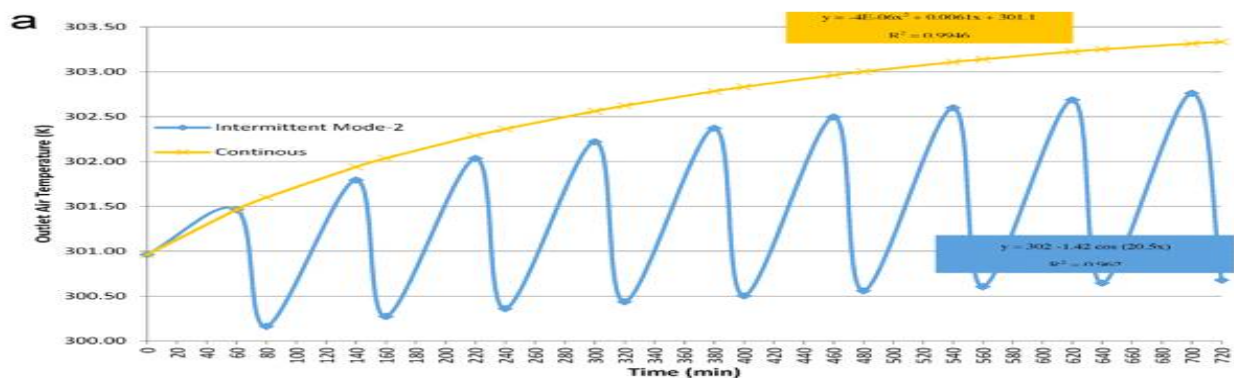


Fig. 3 EATHE outlet air temperature in intermittent (mode 3) and continuous operation with soil-1

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Mishra et al. [1] determine the derating factor for EATHE using transient analysis in summer season. Misra et al study shows that the transient thermal performance of EATHE is significantly dependent on thermal conductivity of the soil and duration of its continuous operation. He simulated the soil layers surrounding the pipe to study the transient effect of thermal conductivity of soil on the thermal performance of Earth to Air heat exchanger by using 3 different types of soil SL1, SL2, SL3 having thermal conductivity 0.52, 2 and 4 respectively.

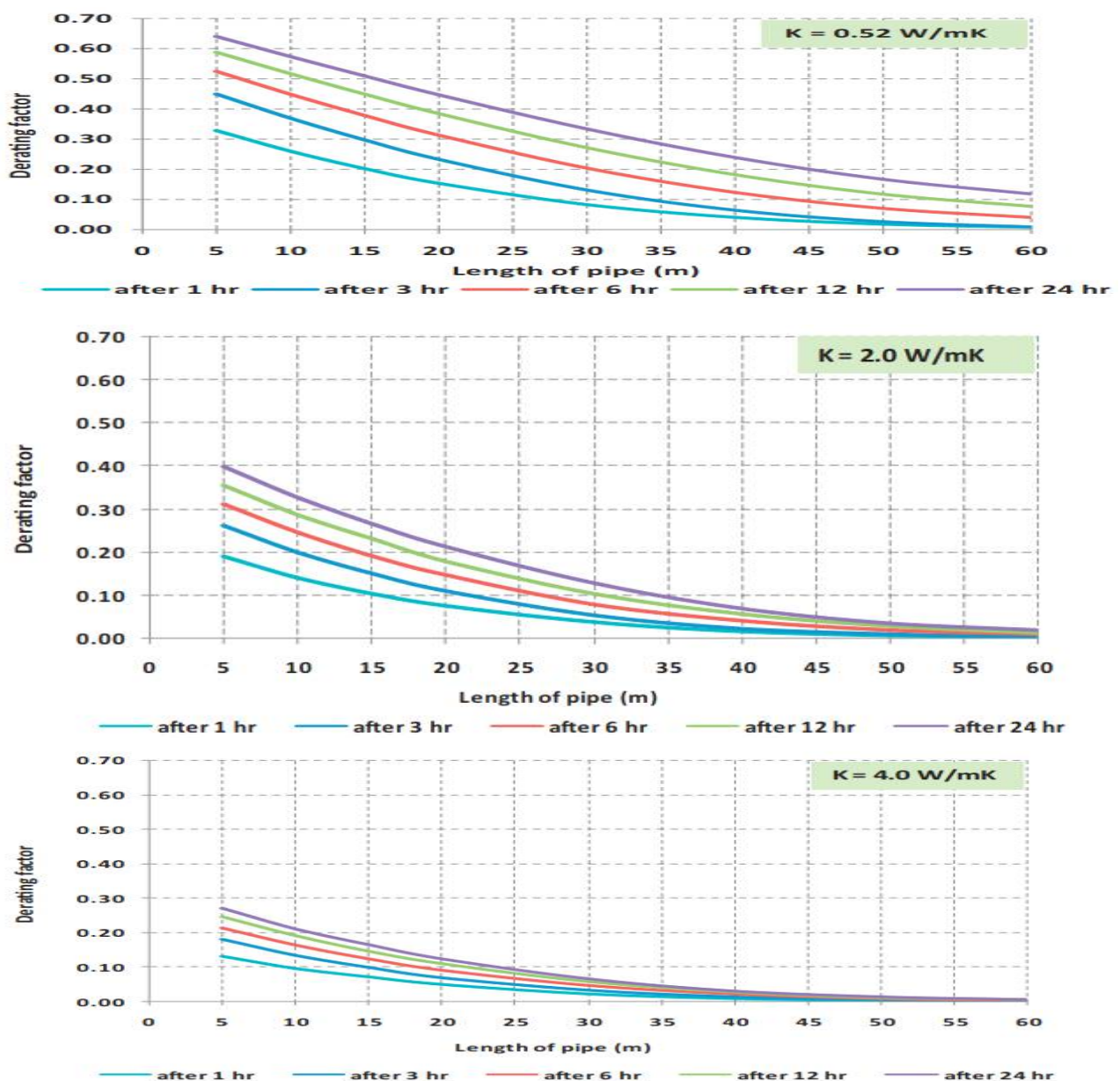


Fig 4 Hourly variation in derating factor along the length of pipe for soil SL1, SL2, SL3 under transient condition.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

As shown in fig. 4, slope of derating factor decreases as the thermal conductivity of soil increases. Curves for SL1 derating factor are much steeper than the curves for SL2 and SL3. It is also observed that soil SL1 have more derating factor than SL2 and SL3 as the separation between the derating curves for different operating hours under transient condition for soil SL1 is more than soil SL2 and SL3.

II. CONCLUSION

- Derating factor is used to compare the thermal performance of EATHE system operating under transient and steady state. It was also observed from the studies that derating factor is a function of thermal conductivity of soil, duration of continuous use and length of pipe. Zero derating factor at a location in a pipe signifies that thermal performance of EATHE in transient and steady mode will be the same. Larger the value of derating factor greater the deterioration in thermal performance of EATHE system operating under transient mode.
- In continuous operation heat, will not dissipate away and stored in the soil. Therefore, temperature of the soil near to the pipe increase continuously hence resulting in decrease the temperature drop from EATHE inlet and outlet. Studies also showed that soil with high thermal conductivity can be operated continuously while soil having lower thermal conductivity must be used in intermittent mode as soil with lower thermal conductivity will saturate at a faster rate than soil with higher thermal conductivity.

REFERENCES

- [1] Mishra R., Bansal V., Agrawal G.D., Mathur J., Aseri T., Transient analysis based determination of derating factor for earth air tunnel heat exchanger in summer, Energy and buildings 58(2013) 103-110.
- [2] Mathur A., Srivastava A., Agrawal G.D., Mathur S., Mathur J., CFD analysis of EATHE system under transient conditions for intermittent operation, Energy and Buildings 87(2015) 37-44.
- [3] Niu F., Yu Y., Yu D., Li H., Investigation on Soil Thermal Saturation and Recovery of an Earth to Air Heat Exchanger under Different Operation Strategies, Applied thermal Engineering 77(2015) 90-100.
- [4] Mathur A., Surana A. K., Verma P., Agrawal G.D., Mathur S., Mathur J., Investigation of soil thermal saturation and recovery under intermittent and continuous operation of EATHE, Energy and Building 109(2015) 291-303.
- [5] Mathure A., Surana A. K., Mathure S., Numerical investigation of the performance and soil temperature recovery of an EATHE system under intermittent operation, Renewable Energy 95(2016) 510-521.
- [6] Mishra R., Bansal V., Agrawal G.D., Mathur J., Aseri T., CFD analysis based parametric study of determination of derating factor for Earth air tunnel heat exchanger, Applied Energy 103(2013) 266-277.
- [7] Bansal V., Mishra R Agrawal G.D., Mathur J., 'Derating Factor' new concept for evaluating thermal performance of earth air tunnel heat exchanger: A transient CFD analysis, Applied Energy 102(2013) 418-426.
- [8] Mathur A., Srivastava A., Agrawal G.D., Mathur S., Mathur J., Transient effect of soil thermal diffusivity on performance of EATHE system, Energy Reports 1(2015) 17-21.
- [9] Bisoniya T. S., Kumar A., Baredar P., Cooling Potential Evaluation of Earth-Air Heat Exchanger System for Summer Season, International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, 2(2014)
- [10] Ghosal, M.K., Tiwari, G.N., Srivastava, N.S.L., 2004. Thermal modelling of a greenhouse with an integrated earth to air heat exchanger: an experimental validation. Energy Build. 36, 219–227.
- [11] Sodha M.S., Sharma A.K., Singh S.P., Bansal N.K., Kumar A., Evaluation of an earth-air-tunnel system for cooling/heating of a hospital complex. Building and Environment 77(1984) 115–22.
- [12] Tzaferis A, LiParakis D, Santamouris M, Argiriou A. Analysis of the accuracy and sensitivity of eight models to predict the performance of earth to air heat exchanger. Energy and Buildings 18(1992) 35–43.
- [13] Hakan D, Ahmet K, Galip T., Heat transfer of horizontal parallel pipe ground heat exchanger and experimental verification. Appl. Thermal Eng. 29(2009) 224–33.
- [14] Svec OJ, Goodrich LE, Palmer JHL. Heat transfer characteristics of in-ground heat exchangers. Energy Res 7(1983) 265–78.
- [15] Saini D., Sharma L. M., Agarwal G.D., Mishra R., "a critical analysis of design of earth air tunnel heat exchanger", innovative trends in science, engineering and management 2015-978-81.