Symposium on Energy Geotechnics
Accelerating the energy transition
3-5 October 2023, Delft, the Netherlands

Peer-reviewed Conference Contribution

Incorporating phase change materials in geothermal energy piles for thermal energy storage

Abubakar Kawuwa Sani[1,*] and Rao Martand Singh[2]

[1] Depart. of Civil and Env. Eng., Faculty of Eng. and Physical Sciences, University of Surrey, Guildford GU2 7XH, UK
[2] Depart. of Civil & Env. Eng., Norwegian University of Science & Technology (NTNU), Trondheim 7034, Norway
* Corresponding author: as0139@surrey.ac.uk

Introduction

Geothermal energy piles (GEPs) are foundation elements that are installed in the ground to support the weight of the building to a competent strata. Energy loops are installed into the piles to allow heat rejection or extraction via the circulation of fluid through the loops. In winter, low-grade heat is extracted from the ground (source) and transferred to the building (sink) to achieve space heating. Conversely, in summer, heat is removed from the building and rejected into the ground to achieve space cooling. The system relies on the temperature gradient between the ground and the ambient air temperature; where in winter, the ground temperature is higher than the air temperature, while in summer, the opposite is true. Thus, the system can sustainably and continuously supply the heating and/or cooling demand of a building once the temperature gradient between the ambient air and the ground is maintained. To improve the sustainability and performance of the system, the heat energy rejected into the ground can be stored and used at a later time when space heating is required [1]. Energy storage substances such as phase change materials (PCMs) can be incorporated into energy piles to store the heat that is rejected into the ground to improve the performance of the GEP system [2]. PCMs are materials that stores or releases heat energy during phase transition. Many researchers including [3,4] have reported using PCMs in buildings to improve thermal comfort and minimise the energy demand during heating and cooling periods, however, not much work has been done with regard to incorporating them into pile foundations to improve the performance of GEP systems.

Thus, this study carried out a laboratory experiment to investigate the effect of the addition salt hydrate PCM on the energy performance of geothermal energy piles.

Laboratory test and procedure

In this study, lab-scaled models of energy piles were constructed, with and without PCM. The piles are characterised by a length and a diameter of 300 mm and 100 mm, respectively. In order to add PCM into the piles, the PCM was encased and sealed in a PVC tube with an inner and an outer diameter of 6mm and 8mm, respectively. The same size of PVC tube was used for the energy loops. The energy loop (U-shape), and the encased PCM incorporated tubes are attached together and placed in the mould prior to concreting, for the pile model with PCM (see Figure 1a). Whereas only the energy loop was installed in the control sample.

In the test setup, a layer of sand (220mm thick) was placed and compacted in an insulated wooden box (520mm × 520mm × 520mm). Afterwards, the pile was then installed at the center of the box and then filled with sand, in layers and compacted. An insulation sheet was used to cover the top of the box to prevent heat loss and the ambient air temperature influencing the tests' results. Water at a temperature of 32°C, was circulated through the pile continuously for a duration of 4 days (96 hours). Instrumentations were installed in the pile and soil to monitor and record the changes in temperature during the tests (see Figure 1b).

Results and discussion

Figure 1c shows the results comparing the average energy rejected, and stored, in the ground for the piles with and without PCM. The maximum heat energy stored at the beginning of the test was found to be about 460W and 360W for the control and PCM piles. However, at the end of the tests, the energy stored was 230W and 430W for the control and PCM pile, with an average

DOI: https://doi.org/10.59490/seg23.2023.573

energy stored as shown in Table 1. The addition of salt hydrate PCM absorbs the heat rejected into the pile, consequently improving its thermal performance by about 22% in comparison to the control pile. Similarly, the magnitude of temperature developed in the pile and surrounding soil were observed to be lower in the pile with PCM. This can ultimately reduce the induced stresses and strains induced in a pile due to heat energy extraction or rejection.

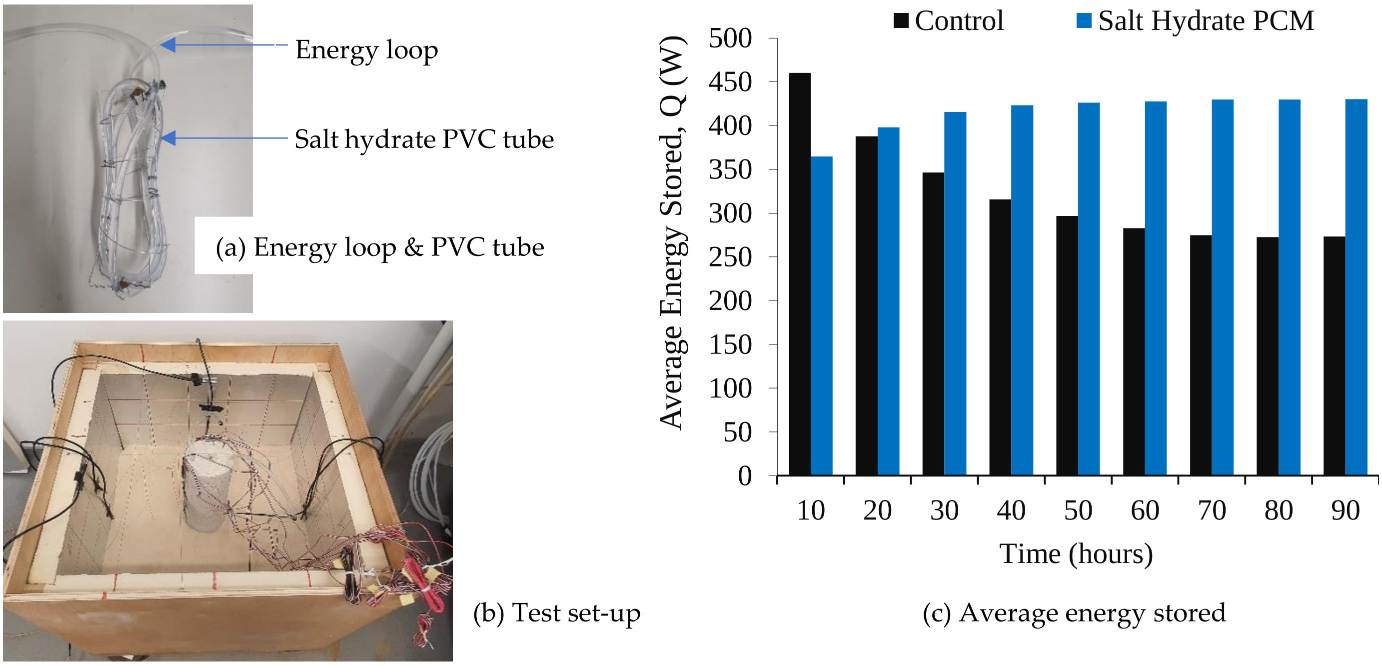

Figure 1: Test set-up and results for the heating tests

Table 1: Results of average heat energy stored for heating test

Pile model	**Average heat energy stored (W)**	**%age Increase (%)**
Control pile	323	-
Salt hydrate PCM pile	416	≈22

Conclusion

This paper investigated the feasibility of using salt hydrate PCM in energy piles for heat storage. It was found that the energy rejected in a pile with PCM increases by up to 22% compared to a non-PCM pile.

Contributor statement

The idea was conceived by both authors. Abubakar Kawuwa Sani: conceptualization, writing, and reviewing. Rao Martand Singh: feedback.

Acknowledgments

We would like to acknowledge EPSRC (research grant number EP/S037349/1) for providing the research funds to conduct these lab studies. In addition, the contributions of our project partners including PCM limited, Keller, MIKE WYE, LYTAG, TARMAC and Gi-energy are duly noted.

References

[1] A.K. Sani, R.M. Singh, T. Amis, I. Cavarretta, A review on the performance of geothermal energy pile foundation, its design process and applications, Renew. Sustain. Energy Rev. 106 (2019) 54–78. https://doi.org/10.1016/j.rser.2019.02.008.

[2] A.K. Sani, I.O. Olawoore, R.M. Singh, Assessment of impregnating phase change materials into lightweight aggregates for development of thermal energy storage aggregate composites, Constr. Build. Mater. 305 (2021) 124683. https://doi.org/10.1016/j.conbuildmat.2021.124683.

[3] L.F. Cabeza, C. Castellón, M. Nogués, M. Medrano, R. Leppers, O. Zubillaga, Use of microencapsulated PCM in concrete walls for energy savings, Energy Build. 39 (2007) 113–119. https://doi.org/10.1016/j.enbuild.2006.03.030.

[4] S.A. Memon, H.Z. Cui, H. Zhang, F. Xing, Utilization of macro encapsulated phase change materials for the development of thermal energy storage and structural lightweight aggregate concrete, Appl. Energy. 139 (2015) 43–55. https://doi.org/10.1016/j.apenergy.2014.11.022.