

Peer-reviewed Conference Contribution

# Improving thermal storage of energy screw pile groups with phase change materials

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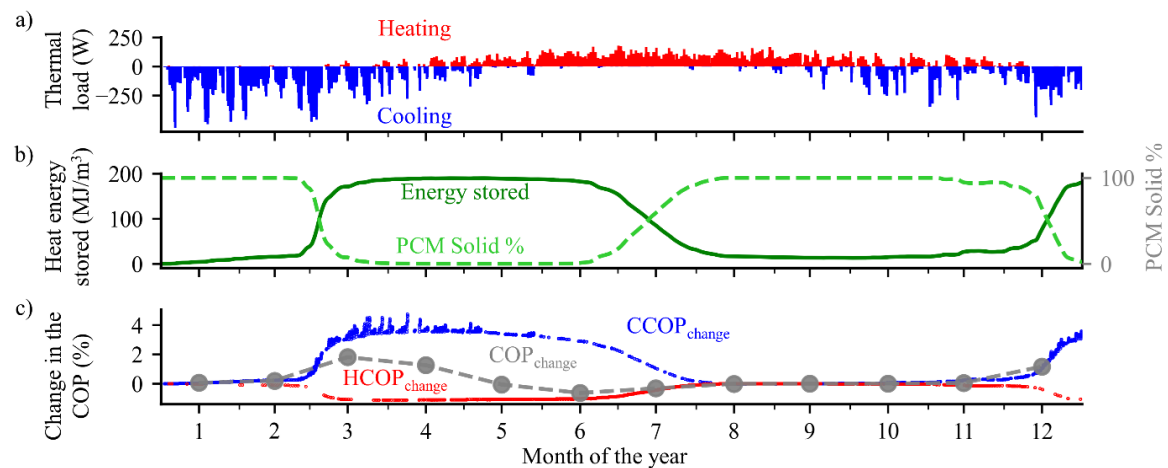
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To achieve affordable housing in a carbon-neutral society, new buildings require a dual-purpose approach that comprises efficient construction and a green energy supply. Energy screw piles [1, 7] meet this demand as they combine the agility of screw pile drilling with the capability of extracting clean shallow geothermal energy. Moreover, the screw piles can be filled with phase change materials (PCM) to provide latent thermal storage. Studies regarding the use of PCMs as borehole backfill in a ground source heat pump system (GSHP) conclude that PCM implementation can improve GSHP performance. However, most commercially available PCMs have low thermal conductivities ( $\lambda$ ) which undermine heat exchange rates [5, 10]. Besides, using PCMs as a composition of a concrete energy pile can reduce the pile structural performance since PCMs usually have a low mechanical capacity [2, 8]. The authors recently introduced PCM-sand mixtures as a core in the central hollow part of an energy screw pile, which does not impact the pile structural capacity [6]. The mixtures with a higher PCM content benefit the pile heat exchange through its latent heat, but only when the PCM does not reduce the mixture's  $\lambda$ . To overcome this problem, this work tests a new underground heat exchange system where instead of mixing the PCM in the energy screw pile filling material, regular screw piles (i.e., without the heat exchange tubes) are filled with pure PCM, acting as thermal storage piles. A numerical model built via COMSOL [4] is used to evaluate how this combination of screw piles performs thermally when supplying/rejecting heat for a GSHP system operating for a whole year.

This work uses a validated numerical model [3, 9] to simulate a grid of evenly distributed screw piles, where Energy Piles (EP) and Thermal Storage Piles (TSP) are positioned interspersed, evenly spaced 0.7 m apart. Inside the EPs, an U-loop pipe is inserted in the pile steel case and the remaining is filled with grout. In contrast, the steel case of the TSPs is filled with only PCM [11]. All other material properties and the screw pile geometry are based on [1]. The thermal load is based on the design of a building located in Melbourne, Australia (Figure 1(a)). The model considers the hourly operation of a GSHP for one year, calculating the GSHP Coefficient of performance (COP) at every time step and adjusting the ground thermal load. For comparison, two simulations (one where the TSPs are filled with PCM and a reference where they are filled with only air) are undertaken. Besides the energy stored, the COPs of both cases are compared as a relative increase/decrease percentage ( $COP_{\text{change}} = (COP_{\text{PCM}} / COP_{\text{Reference}}) - 1$ ).

Figure 1(b) presents the energy stored by the PCM and its corresponding percentage in a solid state over the simulation. As the EPs reject heat underground due to GSHP summer operation for cooling, the TSPs temperature rise and store sensible heat, until they reach their phase change temperature ( $T_{pc}$ ), when the PCM melts to store significantly more heat energy in a shorter time window due to latent heat. Conversely, the PCM solidifies when EPs extract more heat than reject due to GSHP winter operation (heating) for a certain period. The PCM melts again on the following summer, restarting the whole process. The peak energy stored in the TSPs is 190.3 MJ/m<sup>3</sup>. Even though the thermal load varies hourly, the PCM phase change process happens without immediate responses to the load variation. Figure 1(c) presents the resulting change in the hourly COP considering cooling (CCOP) and heating (HCOP) from implementing PCM in the TSPs, compared to the reference scenario (empty TSPs). The extra heat stored by the PCM lowers the circulating fluid temperature while the latent heat is engaged (months 2 to 7 and 12), which results in a higher CCOP and a lower HCOP. By plotting a monthly average of the  $COP_{\text{change}}$  (grey markers), it is clear that the impact of the PCM on the COP is

positive when cooling is dominant and slightly negative when heating becomes dominant while the latent heat is engaged. When the PCM is implemented in the EP [6, 10], the heat exchanged by the EP drops once the phase change process is over due to the low  $\lambda$  of the PCM, but by positioning it outside the EP the higher CCOP is sustained even after the phase change ends. However, lowering the fluid temperature increases CCOP while lowering HCOP at the same time, which can harm thermal performance if not designed properly. The results underlie the thermal storage potential available not only in screw piles, but also in any hollow pile foundation, by simply implementing PCM in the hollow case.



**Figure 1: Plots over time of the hourly thermal load input (a), resulting energy stored in the TSPs and PCM phase (b) and changes in the COP in comparison to the reference case (c).**

#### Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the authors upon reasonable request.

#### Contributor statement

Luis Bandeira Neto: Conceptualisation; Methodology; Software; Formal Analysis; Writing – original draft. Wenbin Fei: Conceptualisation; Fund Acquisition; Writing – review and editing. Guillermo Narsilio: Supervision; Fund Acquisition; Writing – review and editing.

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