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Backfill thermal properties improvement using granular phase change materials and graphite

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Phase change materials (PCMs) are ideal for thermal energy storage due to latent heat release or absorption at target temperatures. Hence, adding PCMs into backfill materials of ground heat exchangers for example, can enhance the borehole thermal energy storage capacity and the corresponding shallow geothermal system performance. However, the heat transfer efficiency between the borehole and surrounding ground might be reduced because of the low thermal conductivity of PCMs. Incorporating additives with high thermal conductivity can reduce the lowering effect of PCMs on the overall thermal conductivity of the mixture while maintaining a desirable thermal capacity. This work mixes encapsulated PCMs (EPCMs), graphite and recycled glass fines, aiming to develop green backfill materials with excellent thermal properties. The heat capacity and thermal conductivity of the mixtures with different fractions of the components are measured in a laboratory. The measured data agree with simulated results. Better thermal properties can be achieved with specific fractions of components, and the findings could help geothermal systems design for better energy utilisation.

Geothermal energy is one of the promising renewable energy sources and its utilisation can be an alternative to fossil fuels. A geothermal system requires a ground source heat exchanger with pipes installed inside a borehole, and backfill materials filling the gap between the pipe heat exchanger and the ground. Thus, the thermal properties of backfill materials are essential to the geothermal energy extraction process and influence the corresponding shallow geothermal system performance [2]. PCMs are used to improve the thermal storage capacity of backfill materials because they can absorb and release heat at a relatively constant temperature [1]. To avoid problems of leakage and volume change of PCMs during a phase change, encapsulated PCMs (EPCMs) are better suited in backfill materials [5]. However, mixtures including PCMs may hinder heat transfer because of their low thermal conductivity. Therefore, other additives with high thermal conductivity can be used to resist the low heat transfer rate [3]. Even though the thermal properties of backfill materials are fundamental to the geothermal energy extraction process, their dependence on the amount of added PCMs and other additives has not been investigated yet. This work mixes EPCMs, graphite and recycled glass fines, aiming to develop green backfill materials with excellent thermal properties. The heat capacity (c_p), thermal conductivity (λ) and thermal diffusivity (α) of the mixtures with different fractions of the components are measured in a laboratory.

SEM images of materials used, recycled glass fines, EPCMs and graphite, are shown in **Figure 1(a)**. Cylindrical containers with a diameter of 44 mm and a height of 57 mm are used to prepare samples of mixtures. Each sample has the controlled volume fractions of components indicated by **Figure 1(b)** while keeping a constant overall porosity of 0.47. A decagon KD2 Pro thermal analyzer with a dual thermal needle measures the thermal properties of samples kept at 4 °C when EPCMs are in the solid phase and 45 °C when EPCMs are in the liquid phase. The geometrical mean model is used for theoretical estimations of values for comparison against experimental results [4].

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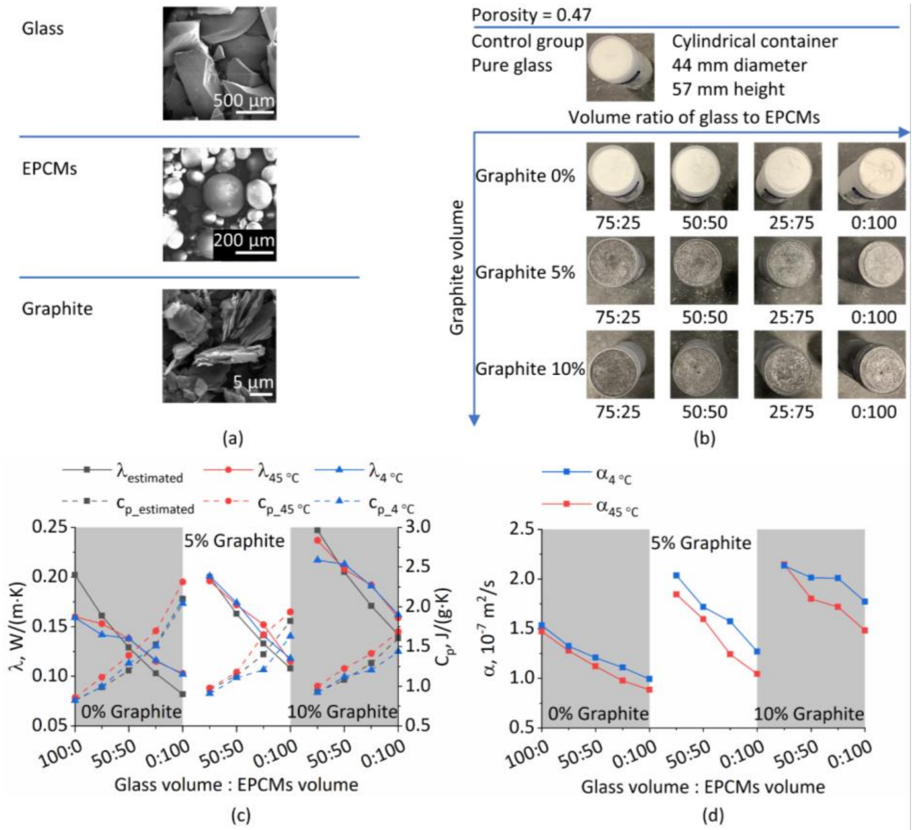

Figure 1: (a) Granular materials, (b) Experiment samples, (c) Thermal conductivities and capacities, (d) Thermal diffusivities.

The thermal conductivity (λ) of the mixtures increases with increasing graphite volume while decreasing with increasing EPCMs volume, as shown in **Figure 1(c)**. The difference between λ under solid EPCMs and liquid EPCMs is limited. The heat capacity (c_p) rises with increasing EPCMs volume but declines with the increase of graphite volume, and it is higher when EPCMs are liquid than solid. It can be observed that a trade-off between the improvement of c_p and the reduction of λ exists. Hence, the thermal diffusivity (α), which depends on the ratio of λ to c_p, is also investigated as presented in **Figure 1(d)**. It decreases with the increase of EPCMs volume but grows with increasing graphite volume. Besides, it is higher under solid EPCMs than that under liquid EPCMs. This indicates the backfilling materials have a faster thermal response to the change of surrounding temperature under solid EPCMs.

Contributor statement

Conceptualization: Wenbin Fei, Guillermo A. Narsilio. Formal analysis: Tairu Chen. Resources: Tairu Chen, Wenbin Fei, Guillermo A. Narsilio. Visualization: Tairu Chen. Writing – Original Draft: Tairu Chen. Writing – Review & Editing: Wenbin Fei, Guillermo A. Narsilio. Funding acquisition: Wenbin Fei

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