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Experimental work over borehole filling material to reinforce characterization and model validation of Ground Heat Exchangers

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1. Introduction

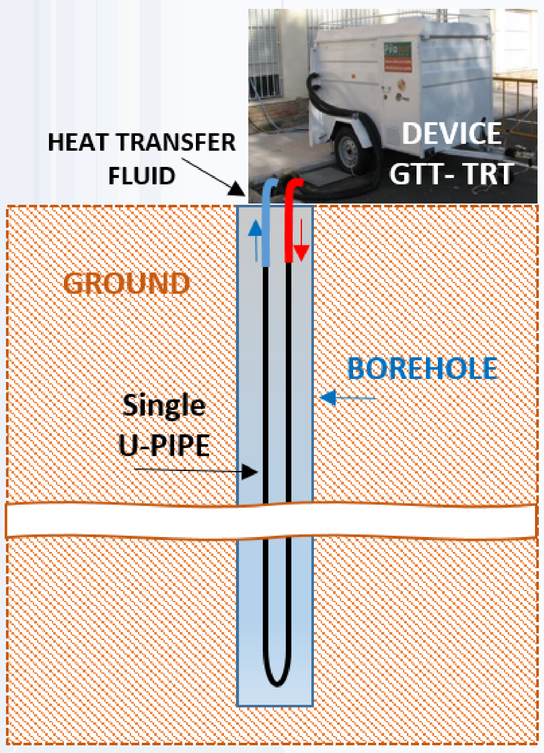
A Ground Source Heat Pump (GSHP) is a renewable efficient system applied to air conditioning in buildings. Unlike conventional systems, the external heat exchanger device interacts with the ground being called Ground Heat Exchanger (GHE).

Intermittent behaviour of GSHPs shows a high efficiency when injecting/rejecting heat flow in the form of pulses. As a result, it forces to account the borehole heat capacity C_b (MJ/m3.K) and thermal conductivity λ_b (W/m.K) in that transient behaviour, whose values cannot be provided accurately or there may be a lack of physical consistency by current methods.

The aim of this work is to demonstrate the convenience and effectiveness of adding easy experiments associated to the filling material of a vertical GHE to the previous characterization steps (GTT, TRT, ILS, …) of a GSHP design. At the same time, a GHE numerical model has been developed to obtain a first approximation in the process of parameters identification via Design of Experiments (DoE). Experimental results allow to discriminate the optimal range for this last process to select an effective set of thermal properties to tune the model.

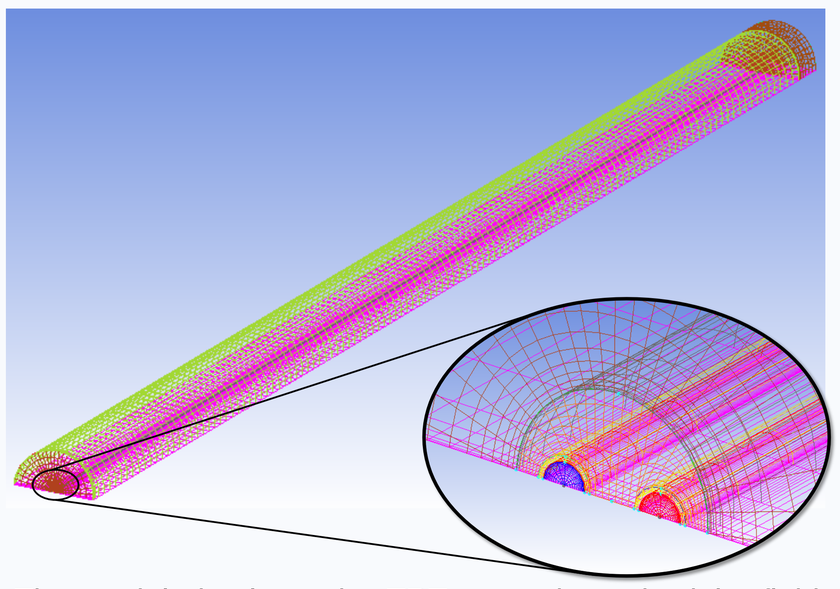
2. Materials and Methods

A) GHE tests and data



In-situ tests GTT and TRT records the undisturbed ground temperature over depth and the inlet and outlet fluid temperature along time, respectively.

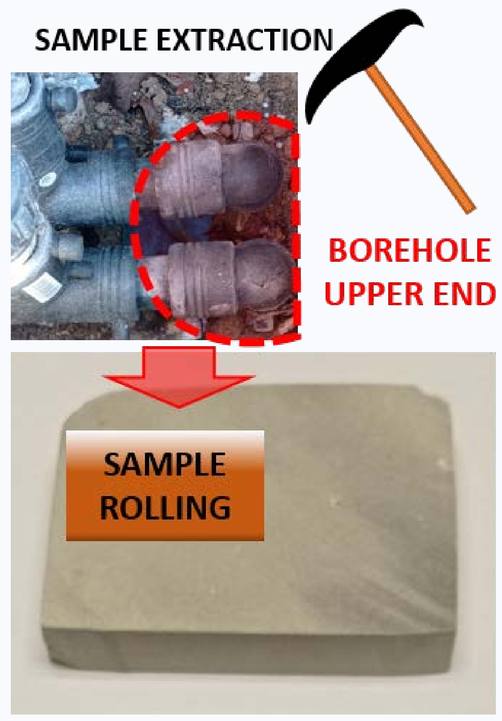
B) Numerical model and identification process



The model simulates the TRT test, where the inlet fluid and undisturbed ground temperatures are the boundary conditions. The outlet fluid temperature simulated is compared with that measured through the Root Mean Square Error (*RMSE*).

To identify the suitable value for the borehole characteristics, a two-factor Design of Experiments (DoE) has been applied, searching the minimum *RMSE*.

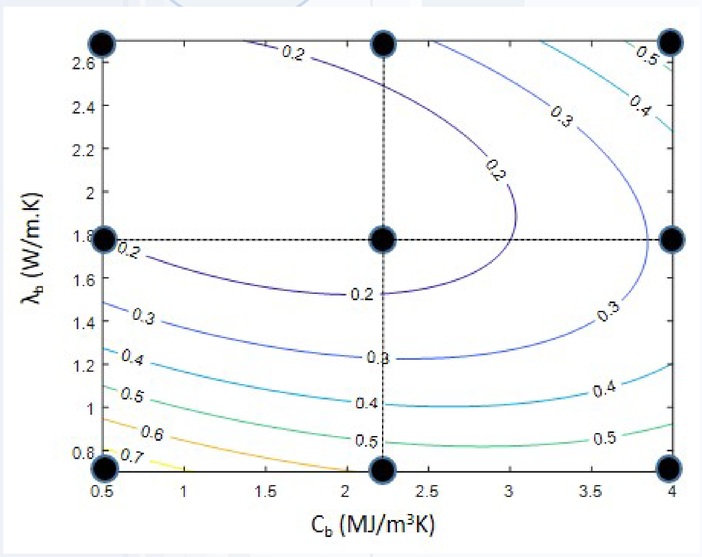
C) Experiments over borehole material



A thermal conductivity analysis over the filling material samples allowed to determine their thermal conductivity and specific heat. Density was obtained after weighing the samples, and so, the volumetric heat capacity.

3. Results

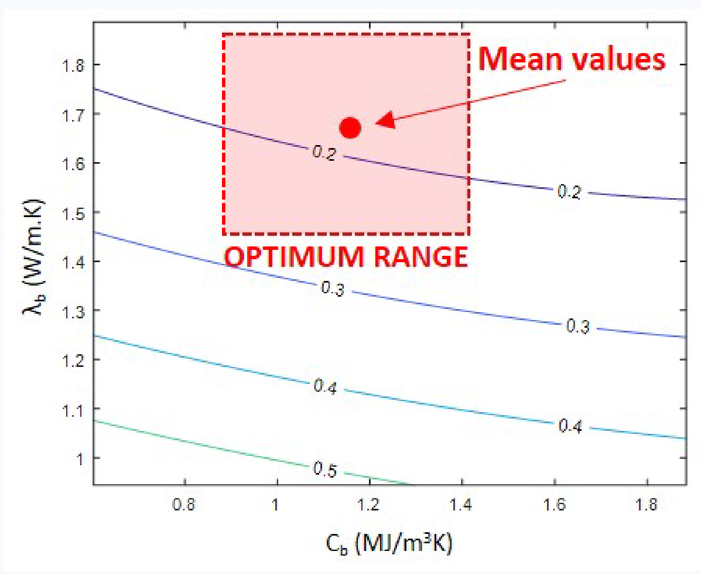
The numerical model has been run for 9 combinations of values for the input factors λ_b and C_b into the *DoE*. Once the *RMSE* for these synthetic experiments are determined, it has been approached the surface function for this indicator.



Results can provide local minimums, or for this case, an extensive area where minimum cannot be sensed.

For a tighter approach, higher number of experiments are necessary. But it is quite important to select the most suitable zone to keep looking for the optimal solution, which must also present physical consistency. For this purpose, the help of additional experimental data is essential.

Experiments over the samples assure a certain range of the parameters values where physical consistency can be guaranteed. There is an uncertainty associated to these experiments as the borehole is remarkably deep, therefore important changes in its thermal characteristics can appear along it.



PARAMETER	Average	Range
λ_b(W/m.K)	1.65	1.46 – 1.83
C_b (MJ/m^3.K)	1.18	0.88 – 1.41

4. Conclusions

It has been demonstrated the usefulness of making experimental procedures applied to samples of the borehole filling material in a vertical GHE:

i. Including this sample characterization, it can be ensured that the values of all the parameters used by models are experimentally based, while conventionally, at least two of them must be supplied without this experimental basis.

ii. When this characterization is applied to a model tuning, it brings the initial values of the considered parameters closer to the final solution, identifying a reliable range where to search the effective set of values. Thus, the number of model executions can be significantly reduced.

Acknowledgement

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