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Data Article

Experimental and numerical data of thermal response tests executed in groups of energy piles connected in series

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ABSTRACT

The use of energy piles as heat exchangers for Ground Source Heat Pump (GSHP) systems, providing heating and cooling, is a well researched application worldwide [1]. However, a broader implementation in practice still faces resistance, mainly because of the lack of accessible, easy to implement design methods and uncertainty regarding the thermo-mechanical effects. These issues need to be addressed to close the gap between research and practice. This work presents data of a full-scale thermal response test (TRT) undertaken in a group of eight energy screw piles connected in series, that are part of an operational GSHP system of a building located in Melbourne, Australia. The temperature was measured in the inlet and outlet of the pipe circuit (circulating water temperature) and at the bottom of each pile (external pipe wall temperature). Besides providing insights regarding the thermal performance of short energy pile groups, the test was used to validate a finite element numerical model (FEM). The model was then used to expand the database of thermal performance of energy pile groups by simulating several long thermal response tests,

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considering different energy pile group geometries, configurations and material properties. The experimental data presented can be used for analyses and validation of thermal modelling methodologies that consider the group effect of energy piles, given the lack of TRTs performed in groups of energy piles reported in literature. Moreover, the extensive set of simulated data can be analysed to understand the thermal behaviour of energy pile groups and evaluate how alternative simpler heat transfer models, feasibly applied in industry practice, perform in a range of scenarios that could be encountered in daily practice.

Specifications Table

Subject	Geothermal Energy, Geotechnics, Engineering
Specific subject area	Experimental (real) and Numerical (synthetic) temperatures recorded during a field thermal response test in a group of energy screw piles.
Type of data	MS Excel file Figures
How the data were acquired	Experimental data obtained through the execution of a full-scale thermal response test in eight energy screw piles connected in series, on a site located in Melbourne, Australia. The temperature was recorded by thermistors (Dixell brand, NTC type, accuracy of ±0.5 ^{0}C) located at the inlet and outlet of the circulating pipe and at the bottom of each one of the energy screw piles, inside the steel case. The surface air temperature and heater power consumption also were measured, all with the help of a multichannel datalogger (RST brand, model DT2055B). Numerical data were generated using finite element modelling built with the software COMSOL Multiphysics 5.6, validated with the experimental data, considering different pile geometry and thermal properties.
Data format	Raw Analysed
Description of data collection	The tested energy screw piles are part of the underground heat exchangers built for an educational building. The 61-hours test occurred during construction stage, after the eight piles were drilled, grouted, and connected (in series). The synthetic TRTs were simulated using FEM, considering 189 test scenarios of piles connected in series, varying the total number of piles, pile diameters, pile-to-pile spacing and both ground and grout thermal conductivity values.
Data source location	Experimental data measured at the Plumbing Industry Climate Action Centre (PICAC), in Narre Warren – VIC, Australia. Synthetic data maintained in University of Melbourne server/database (Parkville - VIC, Australia).
Data accessibility	Data supplied in article as excel file – supplementary data Repository name: University of Melbourne Figshare Archive https://doi.org/10.25504/FAIRsharing.d86aee Data identification number: 10.26188/22631077 Direct URL to data: https://melbourne.figshare.com/articles/dataset/Experimental_and_numerical_data_of_thermal_response_tests_executed_in_groups_of_energy_piles_connected_in_series/22631077
Related research article	*Bandeira Neto, L. A., Narsilio, G. A., & Makasis, N. (2023). Analytical interpretation and numerical analysis of multiple energy pile thermal response tests. Computers and Geotechnics, 157, 105314.* https://doi.org/10.1016/j.compgeo.2023.105314

Value of the Data

- The experimental Thermal response test (TRT) data consist of a unique group test of eight energy screw piles connected in series and can be of use to researchers that are interested in energy structures, specifically short energy pile groups.
- The numerical data was generated using complex and computationally expensive numerical methods, using HPC facilities from The University of Melbourne, valuable for other researchers interested in modelling energy piles.
- The dataset can be used to expand the analyses presented in the related research article, using different methods to interpret TRTs that were not covered in the original study.
- The validated data can be used in the development and validation of new methodologies to predict the thermal behaviour of energy structures, including numerical modelling.

1. Objective

The TRT reported here is executed on one of the largest number of energy piles presented in the literature; it was originally undertaken to evaluate the thermal behaviour of a group of several short heat exchangers and compare it to an equivalent long one (e. g. a borehole) more typically used with ground source heat pumps. The fluid temperatures gathered in the inlet and outlet points are used to obtain thermal parameters for the piles and the soil where they were built in, and the temperatures gathered by the thermistors located at the bottom of each pile enabled the validation of a finite element model, used to simulate the test under different conditions. The numerical data were used to evaluate how group thermal response tests, such as the original one, could be interpreted in a range of scenarios, considering different pile geometries, pile configurations, soil and concrete thermal properties. By making this dataset available, it is expected to give other researchers the opportunity to expand the TRT analysis presented in [2] and evaluate how other heat transfer calculation methodologies perform when modelling groups of heat exchangers.

2. Data Description

The data describe the temperature recorded by several sensors during the execution of a thermal response test (TRT) on a group of eight energy screw piles connected in series, constructed in Melbourne, Australia. Besides the inlet and outlet fluid temperatures, traditionally recorded during TRTs, temperatures were recorded by eight thermocouples installed outside the circulation pipe walls in the bottom of each one of the tested energy screw piles and the temperatures were recorded in it. Besides this experimental setup, represented in Fig. 1, additional sensors registered the air ambient temperature and the heater power consumption during the test. The data collected by this experiment, presented in Fig. 2, were used to validate a FEM model and produce data for several simulated TRTs in pile groups of different configurations and considering different thermal properties for the soil and concrete around them. For each combination of pile geometry, arrangement, and materials, the inlet, outlet, and average fluid temperatures were calculated over the simulated test time. Fig. 3 presents the average temperature over time of some simulated tests using the same graphical scale for comparison. Fig. 4 presents the distribution of the mean relative fluid temperature difference values (Mean $T_{f,Bore-Group}$) of each group scenario to its equivalent single borehole (i.e. same pile/borehole diameter and same material thermal properties, but different number of heat exchangers and pile-to-pile spacing) . Fig. 4 is presented in the form of boxplots: each box ranges from the first quartile to the third quartile of the distribution, while the median is indicated by a line across the box. The lines reach to each extreme (minimum and maximum) value in the distribution. The distribution is presented in two separate groups (4 and 8 piles) and sorted according to the values of each

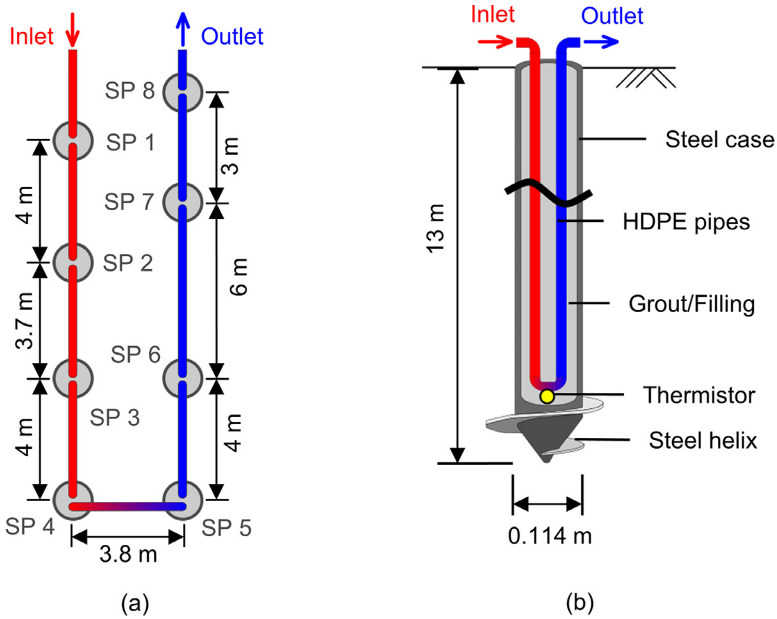

Fig. 1. Top view of the group of energy screw piles (a) and side view of the typical screw pile tested (b).

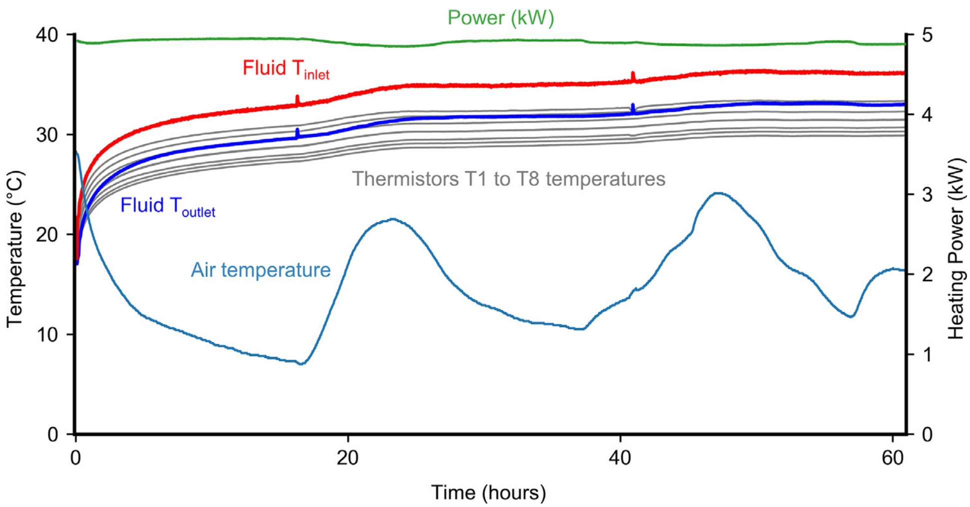

Fig. 2. Temperatures and heating power recorded during the TRT.

parameter considered in the numerical simulations. A total of 189 TRT simulations were undertaken with the numerical model. All experimental and numerical data described are provided on a supplementary file available through the repository link provided.

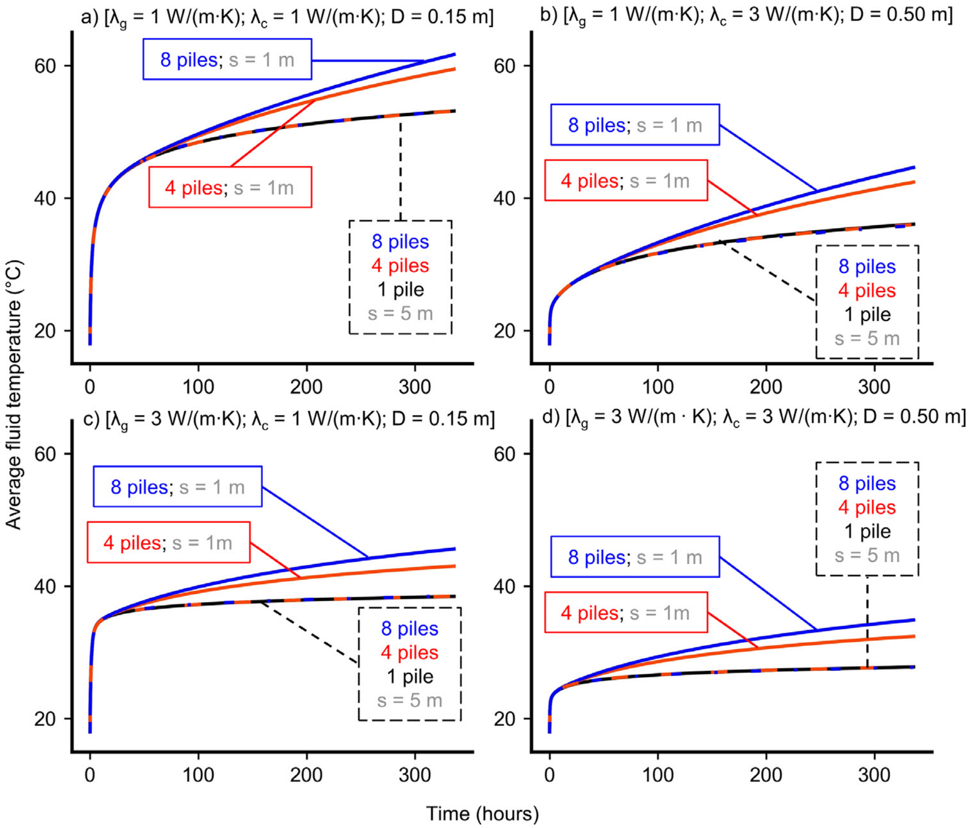

Fig. 3. Average fluid temperature recorded by the simulated TRTs, considering different number of piles, pile spacing (1 m and 5 m) and parameter combinations described.

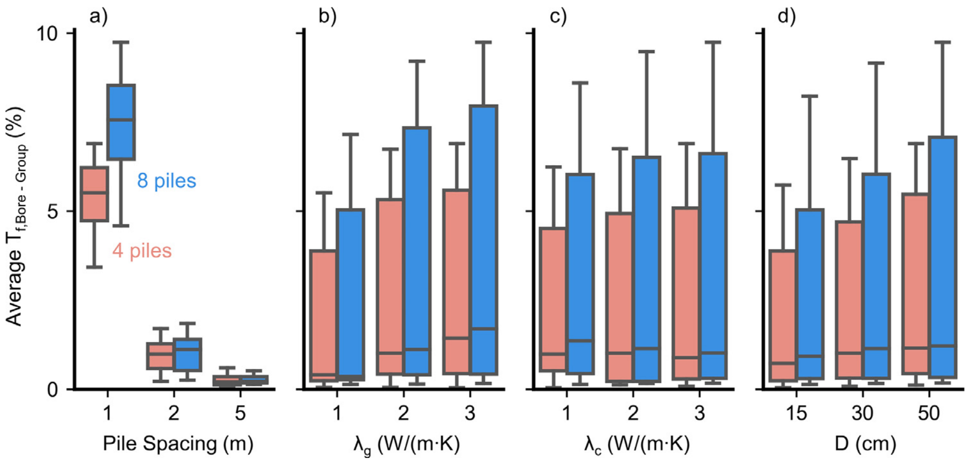

Fig. 4. Distribution (Boxplots) of the mean relative fluid temperature difference values observed in the pile group scenarios in comparison to its equivalent single borehole (i.e. same λ_g, λ_c and r_b) from all scenarios simulated.

3. Experimental Design, Materials and Methods

The Plumbing Industry Climate Action Centre building (PICAC) foundation consists of several short screw piles, and some were built as energy piles for a GSHP system that provides thermal comfort to the building (for a detailed description of the system, see [3–5]). Inside eight of these energy screw piles, thermistor sensors were attached to the circulation pipe wall on the “U-loop” curb located in the bottom of each pile, inside the pile steel case. The details of the geometry and construction of the piles are shown in Fig. 1 and more information can be found in [6]. The soil on site consists of brown-grey clay until 41 meters depth, and the water table is located 7 meters below the surface. A TRT was carried on these eight piles connected in series (with the surface pipes thermally insulated) for almost 61 hours, using a nominal thermal power of 5 kW (however, the recorded power was slightly lower). During the test, the fluid temperatures were recorded at the inlet of the first pile (SP1) and the outlet of the last pile (SP8), as well as at the thermistors at the bottom of each of the 8 piles. The ambient temperature was recorded on the surface close to the TRT equipment. The temperature values and the heating power recorded are presented in Fig. 2.

This experimental test was then used to validate a numerical methodology developed within The University of Melbourne (see [7,8] for more details on the methodology and [6] for the aforementioned validation). The model, built with COMSOL Multiphysics [9], takes the thermal load and fluid flow rate as an input and calculates the fluid temperatures over time, considering the conductive-convective heat transfer within the circulating fluid and conduction only within all other materials. Therefore, the model does not consider groundwater flow effects. The top boundary (pile head and soil surface) considers perfect thermal insulation, while the side and bottom boundaries are constant temperature. More in this specific model is presented in [2]. The numerical model was then used to simulate several TRTs on groups of energy piles with different configurations, as well as on a single borehole heat exchanger configuration, to compare the thermal performance of each scenario. Different thermal properties were also considered for the soil and pile material. The data presented in this work consists of 189 simulations, each simulation considers a test duration of 14 days, considering different heat exchanger diameter (D), different number of heat exchangers and different spacing between then, as well as different thermal conductivities of the pile material (λ_c) and the surrounding soil (λ_g). Fig. 3a) to d) show the average fluid temperature obtained in some of the simulations, indicating the impact that each parameter considered on the simulations has on the fluid temperature and therefore on heat transfer.

To evaluate the level of thermal interferences that happens between piles in each geometry arrangement (number of piles and spacing between them), the fluid temperature of each group of piles during the test is compared to its equivalent scenario with a single borehole (i.e. same λ_g, λ_c and r_b- Fig. 4).

Ethics Statements

Ethics approvals not required for this work.

CRediT Author Statement

Luis Bandeira Neto: Conceptualisation; Investigation; Methodology; Software; Writing – original draft. **Guillermo Narsilio**: Supervision; Data curation; Funding acquisition; Writing – review and editing. **Nikolas Makasis**: Conceptualisation; Supervision; Data curation; Writing – review and editing. **Ruchi Choudhary**: Data curation; Funding acquisition. **Yale Carden**: Data curation; Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Experimental and numerical data of thermal response tests executed in groups of energy piles connected in series (Original data) (University of Melbourne Figshare Archive).

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