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A full-scale investigation of the short-term continuous and intermittent operation of an energy piled wall section

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The growing demand for highly efficient renewable energy technologies has positioned shallow geothermal energy as an attractive alternative. The initial high capital cost of traditional ground heat exchangers (GHEs), mainly associated with drilling, has extensively hindered their implementation. Conventional geostructures overcome this drawback, and their use as GHEs is getting more attention. Piles [4, 8, 10], pavements [7], and walls [1, 5] are some of the structures that are being used. Energy piles have been the most popular among them, and their implementation has increased steadily since the 1980's [5]. After more than two decades of intensive research, a large dataset of full-scale energy pile foundation observations is available [6], and a thermo-mechanical conceptual framework [2, 3] has been formulated.

Piles are not limited to foundations; they are used in retaining walls. In contrast to foundations, retaining walls mainly work under lateral stress conditions instead of axial loads. In principle, energy piled retaining wall's initial state, circuits configuration and boundary conditions control their response. Nevertheless, in the context of (energy) piles, observations appear limited to a few full-scale thermo-mechanical studies to date [1, 5]. More attention to this energy geostructure from the scientific and engineering practice communities is required, and the documentation of additional case studies is needed to promote the energy piled walls implementation more broadly.

In this work, a series of full-scale thermo-mechanical field testing has been performed in an energy piled wall section. The retaining wall system section consists of three piles equipped with pipes to work as heat exchangers. Each houses 4 U-loops in series made of high-density polyethylene (HDPE) pipe with an outer diameter of 25 mm and HDR of 11. The pipe circuits are connected in parallel through a common header manifold operated on the surface. Two of these piles have been instrumented with 10 pairs of vibrating wire rebar strainmeters with temperature sensors located on diametrically opposing sides of the pile. One is close to the excavation, whereas the other is to the ground side - see more details in [10].

The thermal activation of the wall section occurred at 34.7 m depth and was achieved through an in-situ Thermal Response Test (TRT) unit. The unit heats a carrier fluid through constantly powered electrical heating components and pumps the fluid in the pipe loops within the GHEs. To emulate a conventional thermal load (e.g., energy piles 30-70 W/m, [9]), the entire wall section is supplied with a heating power of 5.5 kW over 5 days active period, and the thermal load is provided under either continuous or intermittent conditions (i.e., 5 thermal cycles, 12 hours on/off). Five recovery days allowed the ground to return partially to its initial thermal equilibrium. The testing period lasted 26 days of constant monitoring.

The obtained measurements in one pile are presented in Figure 1. It compares the measured strains at different construction stages (i.e., excavation to 32.5, 36.4, and 34.7 m depths) against those observed at the end of both operation modes (i.e., 5 days, 5th cycle). It is noticed that the temperature-induced strains recorded by the available sensors (i.e., 11/20 in this case) are, in most cases, within the axial strain's envelope derived from previous excavation and construction stages. Only one sensor at 33 m indicates tensile axial strains larger than those observed at different excavation depths; nevertheless, it

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represents a minor deviation compared with the increment recorded at the same depth during the last excavation and anchors removal. Based on these observations and assuming a thermoelastic response, thermally induced axial stresses remain within the design ranges delimited by design envelopes.

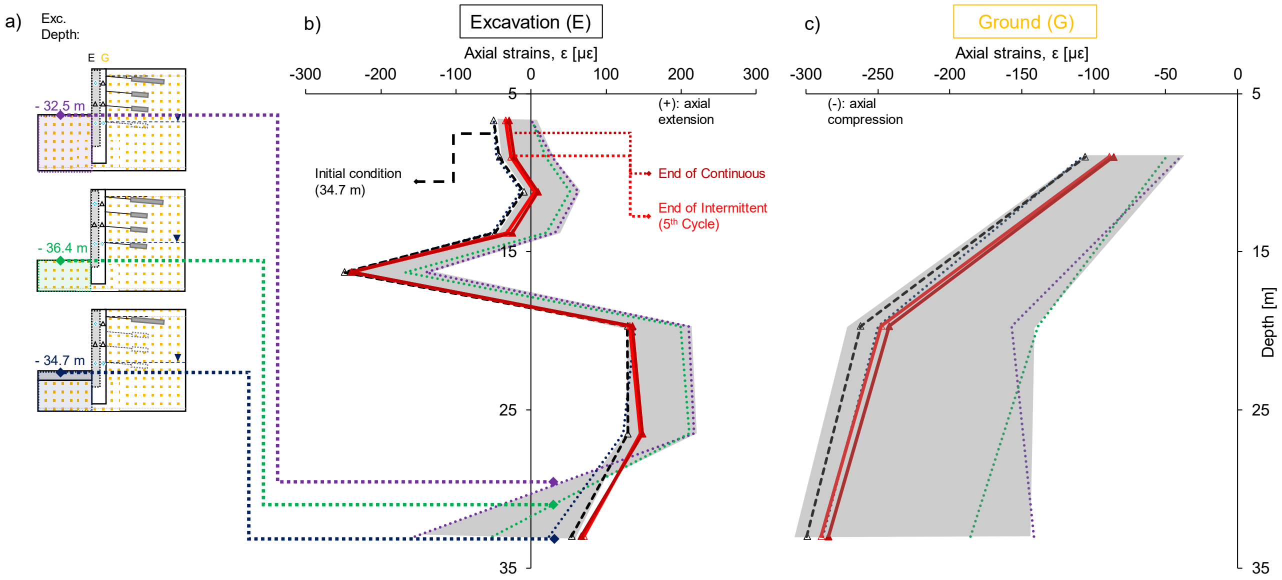

Figure 1. Axial strains comparison: (a) construction stages, (b) excavation side, (c) ground side

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 Villegas Negrette: Conceptualisation; Data Acquisiton; Methodology; Formal Analysis; Writing – original draft. **Raul Fuentes**: Conceptualisation; Writing – review and editing. **Guillermo A. Narsilio**: Supervision; Fund Acquisition; Writing – review and editing.

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References

[1] Adinolfi, M., Rotta Loria, A. F., Laloui, L., & Aversa, S. (2021). Experimental and numerical investigation of the thermo-mechanical behaviour of an energy sheet pile wall. Geomechanics for Energy and the Environment, 25. doi:10.1016/j.gete.2020.100208
[2] Amatya, B. L., Soga, K., Bourne-Webb, P. J., Amis, T., & Laloui, L. (2012). Thermo-mechanical behaviour of energy piles. Géotechnique, 62(6), 503-519. doi:10.1680/geot.10.P.116
[3] Bourne-Webb, P. J., Amatya, B., & Soga, K. (2013). A framework for understanding energy pile behaviour. Proceedings of the Institution of Civil Engineers - Geotechnical Engineering, 166(2), 170-177. doi:10.1680/geng.10.00098
[4] Bourne-Webb, P. J., Amatya, B., Soga, K., Amis, T., Davidson, C., & Payne, P. (2009). Energy pile test at Lambeth College, London: geotechnical and thermodynamic aspects of pile response to heat cycles. Géotechnique, 59(3), 237-248. doi:10.1680/geot.2009.59.3.237
[5] Brandl, H. (2006). Energy foundations and other thermo-active ground structures. Géotechnique, 56(2), 81-122.
[6] Cunha, R., & Bourne-Webb, P. (2022). A critical review on the current knowledge of geothermal energy piles to sustainably climatize buildings. Renewable and Sustainable Energy Reviews, 158, 112072.
[7] Gu, X., Makasis, N., Motamedi, Y., Narsilio, G. A., Arulrajah, A., & Horpibulsuk, S. (2021). Geothermal pavements: field observations, numerical modelling and long-term performance. Géotechnique, 1-15.
[8] Laloui, L., Moreni, M., & Vulliet, L. (2003). Comportement d'un pieu bi-fonction, fondation et échangeur de chaleur. Canadian Geotechnical Journal, 40(2), 388-402. doi:10.1139/t02-117
[9] Laloui, L., & Rotta Loria, A. F. (2019). Analysis and design of energy geostructures: theoretical essentials and practical application: Academic Press.
[10] Zhong, Y., Narsilio, G. A., Makasis, N., & Scott, C. (2022). Experimental and numerical studies on an energy piled wall: The effect of thermally activated pile spacing. Geomechanics for Energy and the Environment, 29, 100276.