Peer-reviewed Conference Contribution

Thermo-mechanical behavior of energy micropiles

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Since the first application of piles as energy geostructure in Austria in the 1980s [1], the use of geostructures has steadily increased worldwide. Energy geostructures are complex systems that combine structural, geotechnical, and thermal performance. They are based on the exploitation of the soil thermal energy at shallow depths to provide heating and cooling to buildings [1], allowing to reduce both the consumption of non-renewable energy and the harmful carbon emissions. Pile foundations are currently among the most used geostructures. They are particularly suitable for exploiting the ground thermal energy, as they reach depths where soil temperature is quite constant and independent from daily or seasonal variations [2–4] .

Micropiles are small, drilled, and grouted-in-place piles having a diameter between 90-300 mm and a length up to 20 m [5–7]. Generally, they are constructed by drilling a borehole, placing reinforcement, and grouting the hole [6]. Micropiles can be loaded directly to transfer structural loads, both axial (compression and tension) and lateral, to a deeper stable stratum like in new foundations or they can reinforce the soil to theoretically make a reinforced soil composite (reticulated piles) that resists applied loads like in underpinning of existing foundations [6]. Due to the relatively small cross-sectional area of micropiles, load carrying capacity resulting from end bearing is generally considered to be negligible in soil or weak rock, thus micropiles mainly rely on shaft resistance for load bearing [6,7]. Innovative and vigorous drilling and grouting permit high grout-bond values to be generated along the micropile's periphery. High-capacity steel elements, occupying upto 50% of the hole, can be used as the principal load bearing element with the surrounding grout serving only to transfer by friction the applied load between the soil and the steel [6]. The axial capacities of micropiles are in the range of 50–500 kN and up to 1000 kN when installed using pressure-grouting techniques [7]. In the Titan system, the hollow bar simultaneously acts as the drilling rod, injection tube and reinforcement for the micropile [8]. This system is fast, simple and flexible, can be used in restricted sites when access is difficult, can be installed with low vibration and noise in any type of soils including unstable soils. In the context of building rehabilitation, retrofitting, and underpinning of existing structures, the energy micropiles stand frequently as the best solution over energy piles [6]. The Titan 73/53 Energy micropile is a dual used micropile: as a geothermal energy pile with an equal extraction capacity as double U-pipe and as a foundation pile with characteristic load capacity of $R_{M,K}$ = 900KN [9]. Although energy micropile (EMP) systems are very similar to energy pile (EP) systems, their behavior cannot be assumed to be similar both from the mechanical point of view (axial load supported mainly by lateral resistance with almost null end bearing capacity) and the thermal point of view (potentially lower energetic efficiency, due to shorter primary circuit and smaller contact surface with the soil) [10]. For example, pile diameter and pipe diameter have been found to play respectively an important role and an insignificant role in energy piles [11] while the contrary was observed for energy micropiles [12]. Nevertheless, the thermal performance of micropiles in terms of specific heat flux (about 50W/m in fine grained soils) has been found encouraging to predict their use in heating, ventilation and air-conditioning systems[10]. Thermal response tests conducted on TITAN 73/53 energy micropiles show that their specific extraction capacity can be 111W/m in wet sediments, and between 60-80W/m depending on the soil's properties[9]. To date, several studies are dealing with the thermo-mechanical behaviour of energy piles [13] and also the thermal performance of energy micropiles has been looked at to an extent by various

DOI: https://doi.org/10.59490/seg23.2023.548

researchers [10,12,14]. However, the coupled thermo-mechanical behaviour of energy micropiles is not well understood. In fact, the short and long terms effects of combined thermal and mechanical cyclic loading, the "group effects" of energy micropiles, among others, still need to be investigated. This study investigates the thermo-mechanical behavior of a TITAN 73/53 energy micropile, with the aim of identifying suitable evaluation criteria and design parameter for optimizing the structural, geotechnical, and thermal performance of energy micropiles. To achieve this objective, thermal response tests on instrumented TITAN 73/53 energy micropiles, and 3D Finite element analysis will be carried out. The results of the in-situ tests will be used to calibrate the numerical model of our simulation. Then the short and long terms performances of the system in various thermal, geotechnical, and structural conditions will be evaluated.

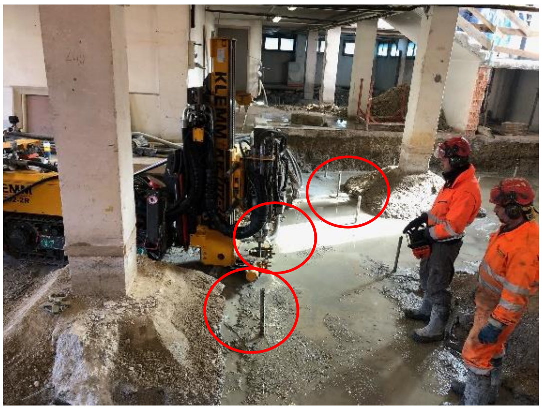

Figure 1: Installation of Ischebeck Titan micropiles for seismic retrofitting (The red circles enclose the micropiles)

Contributor statement

Melissa Fabiola Yozy Kepdib: Conceptualisation, writing - original draft.
Johann Antonio Facciorusso: Conceptualisation, resources and visualization, writing - review and editing.
Rao Martand Singh: Conceptualisation, project administration, resources and visualization, writing - review and editing.
Claudia Madiai: Conceptualisation, resources and visualization, writing - review and editing.

Acknowledgements

This paper is based upon work from COST Action FOLIAGE, CA21156, supported by COST (European Cooperation in Science and Technology). The authors would like to express their gratitude to FRIEDR. ISCHEBECK GMBH for providing information and data on Titan micropiles and for organizing site visits. The authors also appreciate the support of AXER Srl in Italy.

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