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Numerical model of energy foundation behavior: the prototype of a geothermal micro-pile

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Abstract

This paper presents the results of a numerical study performed in the design stage of an innovative geothermal technology – the geothermal micro-piles – recently developed and currently under testing at the University of Perugia for the exploitation of low enthalpy geothermal energy in existing buildings. In this investigation, micro-piles are equipped with a primary circuit of a traditional GSHP system, where the circulation of a heat carrier fluid (i.e. glycolic water) permits a thermal interaction with the surrounding soil. The numerical study has been performed to simulate the thermal behavior of such prototype and to obtain useful information concerning its functioning under real operating conditions. The first results of the study showed that this new technology can provide a thermal flux comparable with the one provided by traditional geothermal piles.

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Keywords: Geothermal energy; FE analysis; energy foundations; micro-piles; thermal efficiency

1. Introduction

Low enthalpy geothermal resources contained in the first layers of the Earth are inexhaustible and available in all areas of the world; for this reason, they represent one of the promising renewable energy sources that can be exploited for sustainable space heating and cooling, ensuring a significant reduction of the CO_2 production caused by traditional HVAC (Heating Ventilating and Air Conditioning) systems [1,2]. The traditional technologies capable of

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exploiting geothermal energy are based on the use of GSHPs (Ground-Source Heat Pumps), combined with structural (i.e., piles, sheet walls, tunnels, etc…) or non-structural (i.e., boreholes, horizontal trenches, etc…) systems. Recently, particular attention has been paid to the possibility of using deep foundations, such as driven or bored RC piles, to contain the pipes that circulate the heat exchanger fluid [2,3].

A different possible perspective in the exploitation of low enthalpy geothermal energy is represented by energy micro-piles, which are very appealing for their relatively low-cost and simple installation procedures. The term "micro-pile" is used to denote replacement piles having a diameter in general of less than 300 mm. They have become increasingly popular throughout the world since their inception in Italy in 1952, when innovative and reliable methods of underpinning historic buildings and monuments were being sought in that war-damaged country [4]. Nowadays, since they offer an additional bearing capacity to the existing shallow foundations they keep covering a well-defined civil engineering area of application: the one related to the consolidation works and/or the integration of multifunctional structures for the storage and the production of renewable energy [5].

To study the feasibility of such kind of energy foundation, two prototypes have been recently developed and are currently under testing at the University of Perugia. In this paper a FE model of this innovative geothermal technology, for the exploitation of low enthalpy geothermal energy in existing buildings, is presented.

2. Geothermal micro-pile prototypes for experimental tests

In order to understand the behavior of energy micro-piles, both from an energetic point of view (in terms of the specific heat flux evolution with time) and from a mechanical point of view (in terms of pile and soil thermal-induced stresses), two different prototypes have been designed and tested at the Engineering Campus of the University of Perugia. The area where the experimental field has been installed is constituted prevalently by silt in the first 15 m and the groundwater table is at about 6 m of depth from the ground surface (Fig. 1a).

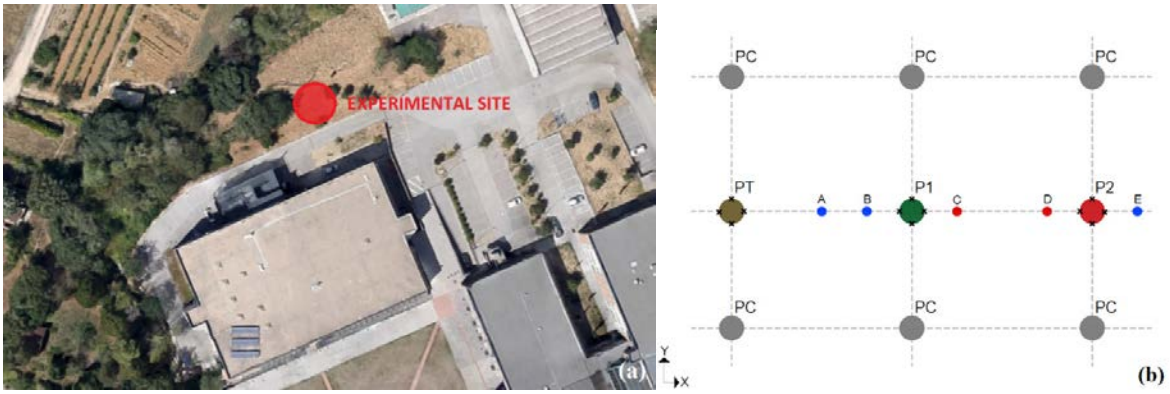

Fig. 1. (a) Experimental site; (b) pile layouts.

The two prototypes have the same geometrical characteristics (*i.e.*, external diameter d = 0.18 m and length L = 10.73 m) except for the tip that in one case (prototype P1) is characterized by a copper coil which is wound in a spiral around the bottom portion of about 2 m of the micro-pile; in the other case (prototype P2) the pile tip is formed by a tank having a maximum capacity of about 6 liters and containing part of the thermal fluid circulating in the pipes of the primary circuit.

A grid of 9 micro-piles – cast in place along three horizontal and vertical alignments – has been realized in the experimental field, as shown in Figure 1b. The central alignment is constituted by the three instrumented micro-piles, namely the 2 prototypes (P1 and P2) and 1 traditional micro-pile (PT). The two external alignments are constituted by non-instrumented micro-piles (PC) and used only as contrast in the loading frame.