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The use of a residential building's foundation as Energy Geo-Structures: A case study in the Mediterranean environment

Lazaros Aresti[1,2,*], Georgios Florides[2], Toula Onoufriou[1,2], Christos Makarounas[2] and Paul Christodoulides[2]

[1] EMERGE CoE, Lemesos, Cyprus
[2] Faculty of Engineering, Cyprus Univeristy of Technology, Lemesos, Cyprus
* Corresponding author: lg.aresti@edu.cut.ac.cy

Geothermal energy, a type of renewable energy obtained from the Earth, can be used by Ground Source Heat Pumps (GSHPs) for space heating and cooling. GSHP systems extract/reject heat from/into the earth via a network of pipes or tubes known as Ground Heat Exchangers (GHEs),. GHEs can be horizontal or vertical and come in a variety of forms, including slinky loops and vertical spiral loops for horizontal configurations, and single U-tube, double U-tube in series or parallel, coaxial pipe, and spiral/helical pipe for vertical configurations. Although GSHPs exhibit a higher performance than conventional Air Source Heat Pumps (ASHPs), the systems are less appealing as investments due to their longer payback times and greater upfront costs. A competent design of the GSHP system with the appropriate GHE sizing, including the case of employing the GHEs in the structures foundations, can minimize the initial cost. Such structures are referred to as Thermo-Active Structure systems or Energy Geo-Structures (EGS), which have already found applications as energy piles, barrette piles, diaphragm walls, shallow foundations, retaining walls, embankments, and tunnel linings [1, 2, 3].

Residential buildings in Cyprus have a higher cooling than heating demand, with an extended payback period for the investment, especially if the system is solely utilized for heating [4]. EGS coupled with a GSHP could offer a substitute to reduce the system's initial expenses and make it more attractive as an investment. EGS have not yet seen applications in Cyprus, therefore an initial computational analysis utilizing the COMSOL software and relevant data is taken into consideration. To determine the heating and cooling loads, a three-bedroom, two-storey house with a total floor space of 190 m^2, with nearly Zero Energy Building (nZEB) characteristics, is used as the typical case for a single detached residential building in Cyprus. The TRNSYS software was used to calculate the heating and cooling loads. In order to analyze the rejected/absorbed energy from the earth, typical foundations were constructed as full sized models in COMSOL (Figure 1). With the exception of pipes, where a 1D solution is employed, the convection diffusion equation for heat transfer is utilized with 3D conservation of heat transfer for an incompressible fluid. A detailed methodology can be found in Aresti et al. [5].

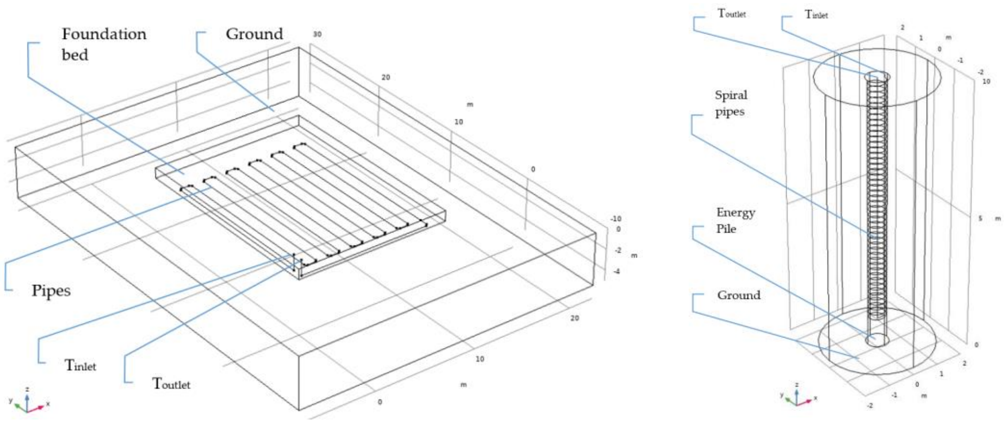

Figure 1: COMSOL model geometry of buiding's foundation bed (left) and piles (right).

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For the COMSOL compuations, the site ground temperature characteristics and the local ambient temperature were taken into account. Based on the provided loads, the inlet and outlet temperatures were hourly calculated for the highest demand months: February for winter – heating, and July for summer – cooling.

To assess the potential of using the foundation bed as an alternative to energy piles, a comparison on the performance of the two cases is presented in Figure 2 for both summer and winter conditions. The foundation bed is seen to work in a steady manner, which is highly desired in a system. However, it performs less well, with a lower COP than the energy piles system, which exhibits greater COP values than the foundation bed system both in winter and summer. It remains that both systems exhibit high enough COPs and nearly steady conditions. The COPs vary between 4.4 and 4.8. A yearly simulation (not shown here) yielded a lowest COP value of 4.5.

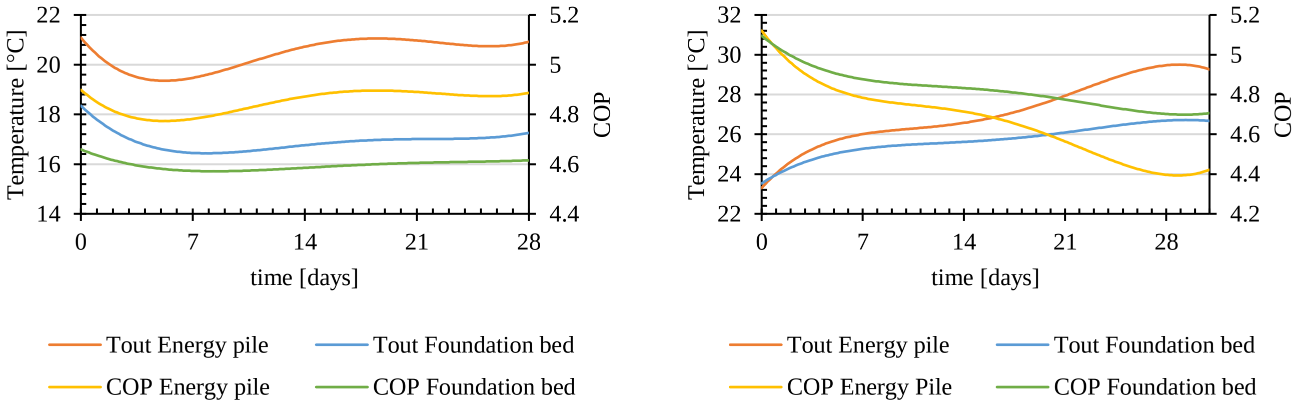

Figure 2: Performance comparison between the two foundation EGS types for the months of February (left) and July (right).

The systems were also assessed economically by being compared to a convectional ASHP system. The economic study demonstrated that the suggested foundation systems had relatively short payback times, making them a plausible alternative. More detailed discussion on the results can be found in Aresti et al. [5]. As a future objective, an environmental and Life Cycle Analysis investigation, similar to the one performed by Aresti et al. [6], could provide a deeper insight of the plausibility of using the building foundation as EGS.

Contributor statement

L.A.: Conceptualization, methodology, software, validation, formal analysis, writing; P.C.: Conceptualization, methodology, validation, formal analysis, review and writing; C.M.: Software; G.A. & T.O.: Review.

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