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Insights on the thermo-mechanical behavior of energy geostructures from laboratory-scale samples to urban-scale installations - Experimental, numerical, and analytical frameworks

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Summary

The world energy demand is constantly growing and currently primarily based on the use of fossil fuels, the main responsible of the critical air pollution condition. Therefore, there is an urgent need to develop technologies for the exploitation of renewable resources, which can reduce the dependence on traditional sources at the national level. The heat contained in the most superficial layers of the Earth's crust, i.e., the Low Enthalpy Geothermal Energy (LEGE) represents one of the most common forms of renewable energy and it can be effectively exploited in various practical applications.

The first examples of exploitation of this resource are based on heat pump systems (GSHP), used for Heating, Ventilation, and Air Conditioning (HVAC) systems for buildings, allowing a significant reduction in CO2 emissions compared to the traditional systems. More recent applications, the so-called Energy Geostructures (EGs), encompass a variety of examples of geotechnical structures, including deep foundations (Energy Piles - EP, and Energy Micropiles - EMP), combining the dual role of supporting structural loads and generating a thermal exchange with the surrounding soil. Other promising applications are Energy Tunnels (ET), which could play a fundamental role in the current challenge of addressing the increasing need for clean and renewable sources of energy, having the capability to cover long distances and thus provide for needs on a larger scale.

The understanding of the Thermo-Mechanical (TM) behavior of EGs has been the subject of numerous studies in the literature, which offer a broad view of the analysis methods and experimentation for evaluating the effects induced using the geothermal resource. Although the research has both intensified and broadened in recent years, the objective of this PhD research is to provide a comprehensive overview of different analysis approaches and insights on the Thermo-Mechanical behavior of EGs, with particular reference to Energy Piles (EPs), Micropiles (EMPs) and Tunnels (ET), throughout different scales of investigation: Laboratory-Scale (Experimental campaign), Building-scale (Numerical Modelling), and Urban-Scale (Analytical Modelling).

Keywords

Shallow geothermal energy, energy geostructures, soil-structure interface, thermo-mechanic effects.