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Novel Ground Heat Exchanger for GSHPs

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ABSTRACT

A novel form of ground heat exchanger (GHE) for use in GSHP applications is described. Known as a Thermo Screw Pile™ (TSP), it is an extension to the use of mechanical screw piles that are already being deployed as a rapid, clean, concrete-free, low-carbon method of building foundation installation. By adapting the steel screw pile to become a GHE as well, a closed-loop ground collector installation can be achieved by interconnecting a number of TSPs. The solution is quicker to install and significantly less costly than an equivalent borehole installation. The paper presents the concept and explores the evolution of the TSPs and comments on the potential range of applications to which TSPs may be applied.

1. INTRODUCTION

For a variety of different reasons, there is growing interest in the concept of constructing modular, lightweight buildings in the controlled factory environment. (eg "Build Off-Site"). These finished modules are then shipped to site and rapidly "installed". Prior to arrival at site, one of the time limiting constraints can often be foundation construction. To overcome this delay, Mechanical Screw Piles (MSPs) offer the possibility of rapid, clean and accurate foundation emplacement. Given the additional interest in delivering buildings with low to zero carbon performance, the possibility arises of using these screw piles as thermal "probes" to extract or reject, to and from, the ground under and around the building footprint. This poster presents the concept of suitably modified Mechanical Screw Piles that can be interconnected and used as Thermo Screw Piles (TSPs) to act as the ground collector/emitter for a closed loop ground source heat pump system (GSHP).

2. SCREW PILES

The screw pile was invented by Alexander Mitchell in 1833. The first use of screw piles was for the Maplin Sands lighthouse in the Thames estuary in 1838. Most of the pleasure piers built in the Victorian era used screw piles for foundations. Today, screw piles are an ideal foundation for modern methods of construction, as they provide laser level accuracy, are concrete-free and very quick to install using only lightweight plant, (up to 40 piles per day per machine). The piles do not create any spoil or vibration during installation and the machines used have a low bearing pressure.

The screw piles developed by geoLOGIC are installed by applying a turning moment to the head of the shaft using a torque motor attached to a mast on a small excavator, which rotates the pile into the ground. At the end of life, the piles can be "unscrewed" and removed from the ground. (Figure 1)

The geoLOGIC screw piles as currently developed are approximately 6m in length in order to fit into a standard ISO container for local and international shipping. Whilst they obviously cannot be used in hard rock, they can be used in a wide variety of other ground conditions. The carrying capacity of the piles is determined primarily by the density and distribution of the helical "blades" attached to the central shaft, not by the overall length of the central shaft. In practice, the piles can be shortened to as little as 2m, and in severe conditions lengthened up to ~10m.

Given the interest in modular lightweight rapid construct buildings, the screw piles can be used as foundations for low rise, two to three story lightweight modern buildings. An additional benefit for some types of construction, is the ability to rapidly emplace the ground floor slab, on top of the installed screw piles. If required, this floor can contain embedded tubing to act as the emitter for underfloor ("hydronic") heating.

Figure 1 illustrates the type of low weight equipment required to install a screw pile and Figure 2 illustrates a completed installation.

Figure 1: Screw pile installation

Figure 2: Typical application of mechanical screw piles as foundations for multi-family housing.

3. THERMAL SCREW PILES

Given the construction of the geoLOGIC mechanical screw piles, it is a relatively straightforward conceptual step to Thermo Screw Piles (TSPs). Enviga Geothermal has been formed to transform the MSPs into TSPs. By inserting a suitably dimensioned plastic tube down the centre of the MSPs and developing a suitable pile-head hydraulic connection, the MSPs are transformed into short, co-axial, closed loop thermal "probes". Once installed, the TSPs can be interconnected hydraulically with pipework routed via suitable "geothermal" manifolds to deliver circulating ground loop fluid to a ground source heat pump. This can then deliver both space heating (and /or cooling) and domestic hot water to the building.

The thermal benefits of TSPs as ground loop collectors are:

a) given that the TSPs are steel, the thermal contact with the ground is excellent (there is no grout involved).

b) Co-axial probes have low thermal resistance characteristics compared to U-tubes.

The combination of these two factors leads to very low borehole thermal resistance values.

From an installation point of view, there are the benefits of being able to provide both the mechanical foundation and an integrated thermal ground collector using low cost, lightweight, installation methods, without any on-site waste arisings.

3.1 Thermal design considerations.

The TSPs described here are not going to provide a ground loop collector solution for all buildings. They obviously only apply to new construction. In addition, because there is a depth limit (ie ~6m to 10m max) they are only going to service a limited ratio of thermal energy required to available ground area. In practice this will amount to lightweight, low rise, well insulated, low heat demand buildings. This however is a sector of the construction market that is rapidly growing, worldwide. There will be some variation arising from the ground thermal conditions.

If the ground is viewed as a thermal battery, significantly improved performance and overall energy delivery can arise if an annual energy balance to / from the ground is achieved. Techniques such as mechanical ventilation heat recovery, solar thermal injection and passive or active cooling rejection to the ground are all useful possibilities.

3.2 Hydraulic considerations.

Closed loop ground array designers need to take into account the requirement to achieve turbulence in the active thermal elements of the ground array, whilst minimizing the overall pressure drop and hence parasitic pumping energy required to operate the

Figure 3: Thermo Screw Pile

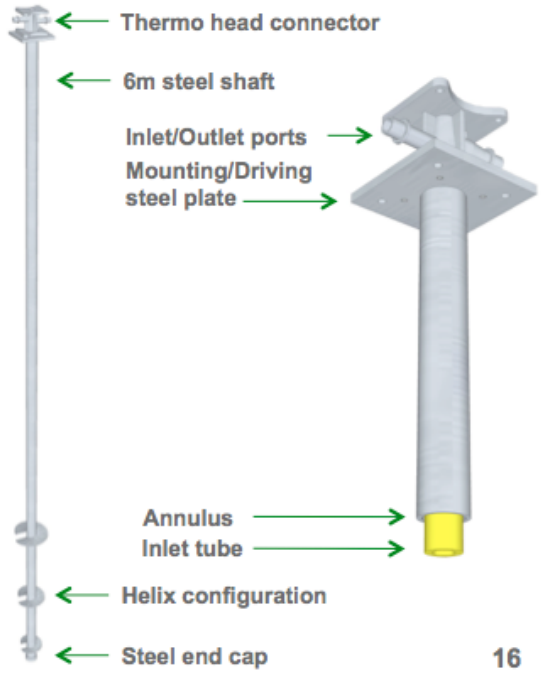
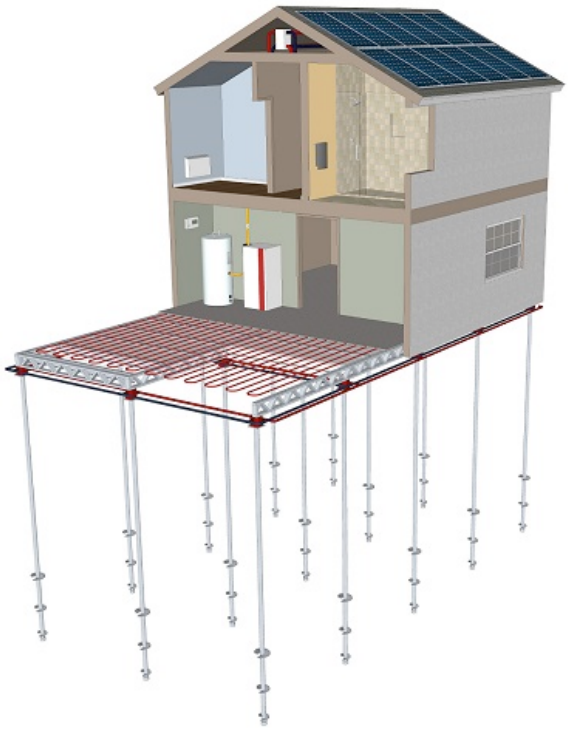


Figure 4: TSPs serving as foundation and GSHP ground collector for a two story, low energy family house.



ground loop. To this end there is a consideration of how many piles are run is series and how many groups of piles are run in parallel. The overall total flow rate through the ground elements is governed by the requirements of the heat pump.

In order to minimize parasitic pumping it is also useful to employ a suitable, low viscosity thermal transfer fluid (TTF) with appropriate inhibitors and biocides. The corrosion inhibitor aspect becomes more significant in the case of TSPs because of their steel construction, compared to conventional plastic U-tube collectors.

4. CONCLUSIONS

Mechanical screw piles have been in existence for a long time and are an accepted method of providing foundations for buildings. The MSPs provided by geoLOGIC have been developed using modern materials and manufacturing techniques to service a particular sector of the construction market. With the advent of new construction materials and methods it is possible to design and construct new lightweight buildings with very low heating and/or cooling demands. It therefore becomes possible to match the thermal output of the TSPs to these low energy demands. It is acknowledged that the adoption of ground source heat pumps, driven by low carbon electricity, is a major method of achieving near zero or very low carbon buildings. Thus the potential of utilising the Thermo Screw Pile as both an attractive foundation mechanism, while also acting as a component of a ground collector array, is perceived as having significant economic and performance benefits.

The geoLOGIC mechanical screw piles are already being used both in the UK and New Zealand. The final components required for the Thermo Screw Piles have been designed and manufactured and will very shortly undergo testing and installation in demonstration houses. Given our experience, and tools for designing closed loop ground source heat pump arrays, it is fully anticipated that it will be possible to deliver long term, high efficiency, thermal performance using these integrated systems.

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