Urban heat storage using structure and infrastructure foundations

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Background

Heat provision in the UK accounts for around one third of all greenhouse gas emissions (POST, 2016) and 40% of energy consumption (Department for Communities & Local Government, 2015), with similar figures across mainland Europe. While recent progress has been made to decarbonise electricity generation (the carbon density of grid electricity has almost halved in the UK in the last five years, Staffall, 2017), the majority of heating provision comes from the direct burning of fossil fuels. It is therefore clear that ground heat storage is an essential option for decarbonsiation of heat.

Urban ground heat storage systems require a ground heat exchanger (GHE) connected to a heat pump and a low temperature building heating delivery system. GHE can take two main forms. Where there is plenty of space long lengths of heat transfer pipe are installed in the ground horizontally at relatively shallow depth. However, in urban areas, where space is typically at a premium, GHEs are typically special purpose boreholes, where the pipes are installed vertically. Yet, drilling is expensive and high capital cost has become a key barrier to uptake (EGEC, 2014). However, dual use of buried foundations and other structures removes the need for special purpose drilling. Piled foundations used as GHE were first developed in the 1980's (Brandl, 2006), but are now becoming more routine (Amis & Loveridge, 2014) and initial standardisation has occurred (GSHPA, 2012). But, there remains major opportunities to use other buried infrastructure for transfer and storage. Retaining walls, tunnels and water/waste water pipes can all potentially be used as so called energy geostructures (Adam & Markiewicz, 2009).

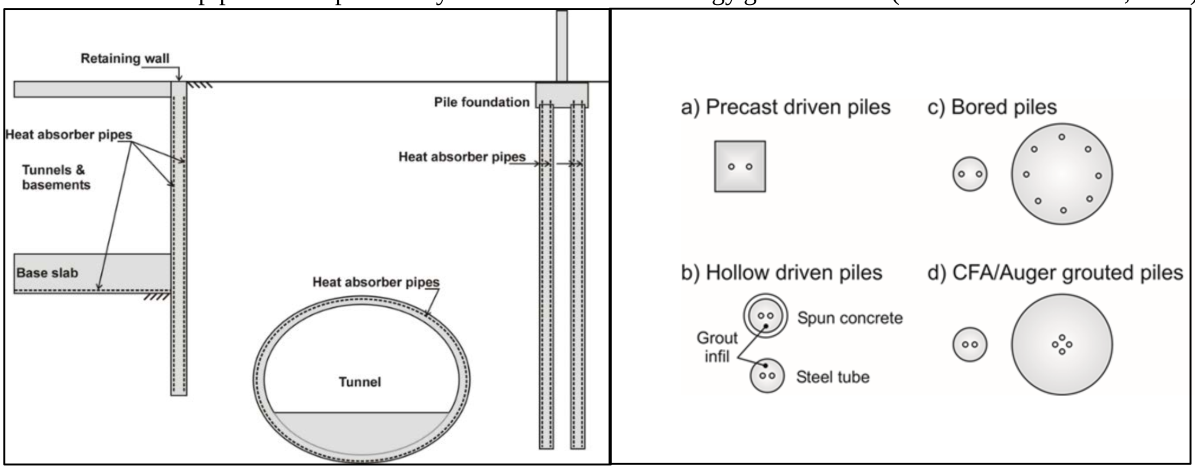

Fig. 1: Types of energy geostructures (left) and pile GHE (right). (After Bourne-Webb et al, 2016)

Energy Geostructures

Research and practical application of piles GHE has proceeded at pace since initial development. While rotary bored and continuous flight auger piles remain the most common types of construction, the practice has also been trialled or adopted with driven steel and concrete piles (e.g. Alberdi-Pagola, 2018), hollow spun piles (e.g Park et al, 2013), and screw piles (e.g. Wincott, 2011). Piles have the advantage of (i) having been shown to reduce project capital costs compared to traditional borehole GHEs (CIBSE, 2013) and (ii) superficial resemblance to boreholes making them suitable for applications of energy assessment methods borrowed from other GHE technology (e.g., Pahud 2007). Furthermore, recent years have seen the development of pile specific design approaches (Loveridge &Powrie, 2013a, Rotta-Loria, 2018, Alberdi-Pagola, 2018) that can be applied without the limitations of previous approaches (Loveridge & Powrie 2013b).

Demonstration projects of energy geostructures using slabs, walls and tunnels as GHE have followed (e.g Schneider & Moorman, 2010, Xia et al, 2012, Katzenbach et al, 2014). However, these types of energy geostructures are rarer. There are no standard analysis approaches available and every project must proceed using bespoke methods, usually based around numerical analysis (e.g. Nicholson et al, 2014). The development of infrastructure schemes for urban thermal energy storage also comes with further specific challenges regarding users for the stored thermal energy and the additional infrastructure required to reach them. Piled foundations are usually constructed to support an overlying building and therefore the building occupants are typically the energy user. For civic projects, however, the user of the thermal energy will, in many cases, be a third party. This brings further barriers to implementation: the potential need for licensing (for example the use of an Energy Service Company), and the requirement for adjacent consumers to be connected to energy supply. It is therefore likely that a heat/cool distribution network may be required to reach the third party consumers.

Despite the presence of these barriers, it is important that the energy geotechnics research community develop this technology as part of the solution to the energy challenge. This is highlighted by the quantities of energy obtainable. For pile GHE published rules of thumb indicate energy output between 20 W/m and 75 W/m (Brandl, 2006, CIBSE, 2013), which compares favourably to traditional borehole GHE (20 – 55 W/m, CIBSE, 2013). Such estimates are not typically available for other energy geostructures due to their bespoke nature. However, the actual performance of piles, walls and tunnels are compared in Table 1, illustrating the potential.

Table 1: Measured Energy Availability from Energy Geostructures (from Di Donna et al, 2017)

Piles		Walls		Tunnels	
Range	Typical	Range	Typical	Range	Typical
40 – 100 W/m2	40 – 60 W/m2	10 – 50 W/m2	<25 W/m2		<25 W/m2

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