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Session 2 Report: Building Codes, Green Certification and Implementation Issues, Market Challenges

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The purpose of this paper is to provide a current state of affairs regarding what building codes currently exist in relation to thermo-active foundations, if any exist at all. This paper also explores regional incentives in the form of energy and carbon requirements for new structures as a potential driver for thermo-active foundation implementation. Two Green Certification programs, LEED and BREEAM, are discussed which both offer credit for shallow geothermal energy systems. The actual implementation of thermo-active foundation technology has proved to be challenging due to the complications arising out of the concept development stage and the coordination required among the various parties involved in the design stage. A discussion of these challenges and an outline of the deliverables needed of those in academia and industry in order to progress is included.

1. Introduction

Thermo-active foundations are a highly promising emerging energy efficiency technology with benefits for both energy savings and carbon footprint reduction. However, due to their novelty and non-traditional design there are various implementation issues and market challenges. This paper summarizes the current status and future challenges of energy foundations as related to building codes, green certification, and tax incentives.

2. Building Codes, Standards, and Design Tools

2.1. Current Status of Building Codes Relating to Energy Foundations

Formal building codes and design standards for thermo-active foundations do not currently exist in any country. The creation of such is problematic due to each country's independence in creating their own standards. However, standards and/or design guidelines do exist for both foundation piles and geothermal heating/cooling systems. (Note that the scope of this paper is larger than just thermo-active piles, but due to their status as the leading thermo-active foundation technology, standards for piles are shown). Table 1 summarizes these standards and guidelines by country.

It would be expected that any thermo-active foundation, in this case thermo-active piles, would have to meet the same structural and geothermal system requirements as those given in the design recommendations and codes listed in Table 1. From a geotechnical standpoint it is possible to implement thermo-active pile design into existing design methodologies. This could work in both LRFD (Load Resistance Factor Design) where the additional thermal loads are treated as another factor, and in SLS/ULS (Serviceability Limit State/Ultimate Limit State) design when the thermal loads are known the ground response can be estimated. Obviously the thermal loads need to be quantified, which is a current area of research that is discussed in detail in the Session 5 report of this special issue. Similar design methodologies are also being developed for the thermal behavior of these systems to ensure adequate heat exchange for typical pile geometry, which is different from conventional borehole heat exchanger geometry.

2.2. Thermal Pile Heat Exchange Design Guidelines

At present, there are only two guidance documents which deal with thermo-active piles and other thermo-active geotechnical systems and no codes of practice which directly cover them. The Ground Source Heat Pump Associations (GSHPA) Thermal Pile Standard gives guidance about what considerations are required for thermal design of piles but does not provide a step by step guide. Guidance from the Swiss Society of Engineers and Architects (SIA) provides more detailed advice including methods for calculating the steady state thermal capacity of thermo-active piles based on the thermal resistance of the pile (Rb) and the ground (Rg).

Much greater guidance is available for geothermal system design more generally, and specifically for the commonly constructed borehole heat exchanger. International Ground Source Heat Pump Association (IGSHPA) and American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) both give calculation methods for borehole lengths based on Rb and Rg. These assume a simple line source heat model or a cylindrical source heat model for Rg respectively. Both methods use simplified peak thermal loads to accompany the ground models and should not be relied upon solely for geothermal system design for more complex buildings. For such cases it is more common to also use a one of a number of software programs which can handle more complex load cases. In addition to monthly and even hourly varying thermal loads, such programs tend to include more sophisticated ground and borehole models that consider both small time-step and long term thermal behavior. Typically it is these programs which are adopted or adapted for use in pile thermal design at present. However, these programs need to be updated to include the solutions to the heat equation (G-functions) that are representative of the geometry of thermo-active foundations (Loveridge and Powrie 2013).

2.3. Thermal Pile Geotechnical Design Guidelines

The Ground Source Heat Pump Association (GSHPA) has developed the first ever recommended guidelines for thermo-active piles. Though this manual admits that many areas of research are still ongoing, it is a remarkable step forward for the promotion and acceptance of thermo-active foundations. The purpose of the manual is to set standards that will ensure 'Best Practice' by protecting the environment and ensuring a high level of installation quality. The standards set minimum requirements according to most recent research available.

This manual provides guidelines outlining the design process, as this is often an area of confusion regarding thermo-active foundations, and stating the responsibilities of all involved. It then gives guidance in developing a SLS/ULS based design for geotechnical performance of thermo-active piles (see Figure 1) and also lays out the requirements for both a borehole and pile thermal response test. It gives specifications regarding materials, loop installation and connections, and quality control procedures.

2.4. What is Still Needed

The largest need is for a generally accepted design procedure that is backed by sufficient research. The Thermal Pile Standards is a great place from which to start, but similar standards need to be developed for other types of thermo-active foundations and then accepted by the geotechnical engineering community. It is important to clarify the mechanisms of thermo-active pile behavior for both short and long-term in terms of deformation and failure. Simply applying a large factor of safety may not be an appropriate route as it may lead to expensive foundations, restricting wider adoption of thermo-active piles. The standards and design recommendations also need to be expressed in software with simulation capabilities of both the pile performance as a structural element and a heat exchanger.

3. Existing Incentives to Utilize Green Energy

3.1. Environmental and Economic Incentives

Of the many trends that the 2010 United States census highlighted, perhaps one of the most significant is that of urbanization. The census reports that the nation's urban population increased 12.1% from 2000 to 2010 whereas the national growth rate was only 9.7%. Additionally, urban centers now account for 80.7% of the US population (it was 79.0% in 2000) (United States Census Bureau, 2012). While urban centers have been shown to reduce overall CO_2 emissions from buildings and transportation when compared to suburban areas (cite Criterion Planners), electricity consumption of urban buildings is very high with the large majority being consumed for space heating and cooling (Howard, 2012). Furthermore there is a heat island effect that reduces the heating demand but increases the cooling demand of urban buildings and this effect is expected to increase as global temperatures increase as a result of climate change (Kolokotroni et al., 2012).

There are several environmental and economic consequences. Environmentally, this will result in increased CO_2 pollution. As Kolokotroni et al. (2012) mention, cooling is predominately achieved by electric energy. Thus, as the cooling demand grows from the heat island effect and global climate change, the electricity consumption will also grow. If the electric energy is generated using any form of fossil fuels, an increase in electricity consumption corresponds to an increase in CO_2 emissions. For some cases, Kolokotroni et al. (2012) estimate CO_2 emissions could increase by 200 to 500% by the year 2050. Urbanization will further compound the problem as the urban centers expand.

Recently Zhang et al. (2014) conducted a GIS-based city-scale simulation to identify how many GSHPs could be installed in a city of Westminster, London, without overusing the capacity of ground's heat storage and calculated the ratio of its contribution to the heating and cooling demands of the buildings within the city. Results show that more than 50% of the buildings can install enough boreholes to support their own heating and cooling demands.

Economically, a geothermal system that uses thermo-active piles is extremely beneficial. The system saves the owner money in heating and cooling costs and is far less expensive than a traditional geothermal energy system that requires drilling numerous boreholes. This system uses the already required foundation as the method of accessing the geothermal energy and only requires the additional cost of the circulation tubes and associated labor to harvest the energy. Brandl (2006) reports that the investment period is typically 2 – 10 years depending on the ground characteristics, foundation type, and energy prices. And if balanced seasonal operation is maintained, these systems can save up to 75% in electricity compared to conventional air-conditioning systems.

3.2. Governmental Regulations

There are various incentives already in place that encourage the utilization of green energy in the form of governmental regulations that specify thresholds for embodied energy and energy consumption. Thermo-active foundation technology has the potential to play a significant role in enabling construction projects to meet these green energy standards. Below is a brief overview of the different incentives that exist by region.

European Union – The European Union issues directives on energy efficiency in buildings which must be followed by all member states (IEA, 2008). The directive on Energy Performance of Buildings (2010/31/EU) requires all member states to set standards for energy efficiency in new buildings and to revise those standards at a minimum of every 5 years. The objective is nearly zero-energy buildings by 2020. The 2009 directive 2009/28/EC promotes the use of energy from renewable sources.

France – France has strict primary energy restrictions. The Thermal Regulations 2012 limit a building's primary energy consumption to below an average of 50kWhEP/m2/year for all new buildings (residential and otherwise). The Grenelle I Act also aims to reduce energy consumption by at least 38% by 2020.

United Kingdom – In addition to enactment of the EU Directives, the Merton Rule in the United Kingdom requires new developments to generate at least 10% of the energy needs from on-site renewable equipment. The threshold is 10 homes or 1,000m^2 of non-residential development

(Merton Council, 2013). The UK also has a goal of zero-carbon homes by the year 2016. BREEAM, a green certification program that will be discussed later, also exists in the UK.

United States – The United States has currently has no federal requirements regarding carbon emissions or primary energy consumption. However, some states and local ordinances have adopted green policies. The state of California, for example, has created Building Energy Efficiency Standards that are updated every 3 years and defines minimum energy efficiency requirements. The standards allow the energy budget for the proposed design building to be reduced if on-site renewable energy generation is installed (California Energy Commission, 2013). LEED, a green certification program that will be discussed later, also exists in the United States.

4. Green Certification

4.1. Leadership in Energy and Environmental Design (LEED)

The preeminent green certification in the United States is the LEED program. LEED, or Leadership in Energy and Environmental Design is a certification process from the U.S. Green Building Council that classifies buildings as either certified, silver, gold, or platinum based on the amount of points they receive from their environmentally friendly aspects. There are five rating systems including building design and construction, interior design and construction, building operations and maintenance, neighborhood development, and homes.

Currently, shallow geothermal systems do classify for credit leading to a LEED classification. Depending on the type and configuration of the system, they could add as many as 10 combined points in the space heating and cooling, domestic hot water, refrigerant management, and indoor environmental quality categories.

A building in Olathe, Kansas was able to obtain LEED Platinum certification, the highest level of certification, in part by using a geothermal heating system (Shabbir, 2014). The Holy Wisdom Monastery in Madison, Wisconsin achieved the highest LEED rating to date and also uses a geothermal heating/cooling system (USGBC, 2010).

4.2. Building Research Establishment Environmental Assessment Methodology (BREEAM)

In the United Kingdom and other countries, BREEAM, or Building Research Establishment Environmental Assessment Methodology classifies buildings in a similar way to LEED. It was developed by the UK Building Research Establishment (BRE). The ratings used by BREEAM are pass, good, very good, excellent, and outstanding that are awarded in the new construction, international new construction, in-use, refurbishment, and communities categories. Several countries including Spain, Germany, and Austria have country-specific BREEAM guidelines (in which case the ‘international new construction’ does not apply). This certification is now performed on all new buildings in the U.K. Currently, shallow geothermal systems count for BREEAM credit.

There are several notable buildings that have received BREEAM credit for GSHP systems. The Institute of Biological, Environmental and Rural Sciences at Penglais received an ‘Excellent’ rating and the specification of a GSHP will lead to a 12.6% reduction in CO_2 emissions of the building (BREEAM 2014). The Coleg Menai Energy and Fabrication Centre in Bangor has achieved a 24% reduction in its CO_2 emissions and uses 2 GSHPs (Building 4 Change 2011).

Chegut et al. (2014) has reported that BREEAM certified buildings in London were able to generate a 19.7% premium on rent and 14.7% for sales. The study also found that non-certified buildings, when in neighborhoods containing many certified buildings saw some of the gentrification benefits that accompany certified buildings.

The Code for Sustainable Homes (CSH) in the United Kingdom was established in 2007 as the required assessment standard for all new houses in England. It is based off of BRE Global’ EcoHomes scheme. The CSH sets mandatory performance requirements in energy and CO_2 emissions, water, materials, surface water run-off, waste, and health and well-being. Each project is awarded anywhere from a 0 to a 6, with 6 being the highest. Several case studies have implemented ground-source heat pumps to meet the energy and CO_2 emissions requirements.

4.3. Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL)

The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL) was developed by the Institution of Civil Engineers (ICE), U.K., and is touted as a sustainability assessment tool for civil engineering projects. Whereas LEED and BREEAM apply mainly to buildings, CEEQUAL can be used to evaluate airports, bridges, dams, metros and metro stations, pipelines, power generation, public realm works, remediation works, tunneling, wind farms, and many more. There are six different types of CEEQUAL awards including the whole team award, client and design award, design award, design and construction award, construction award, and the interim client and design award. There are also four award levels; pass, good, very good, and excellent.

To qualify for a CEEQUAL award, an assessor who has been trained by CEEQUAL will evaluate the project on eight or nine different sections, depending on the assessment scheme chosen. Some of those sections include people and communities, land use (above and below water) and landscape, and physical resource use and management.

5. Implementation Issues and Market Challenges

There are numerous implementation issues that are hindering thermo-active foundations from becoming more mainstream. These challenges include concept development and coordination among the various parties.

5.1. Concept Development

Concept development refers to the bidding, design, and implementation process of thermo-active foundations. Within this process, there are many obstacles that often times prevent designers from even considering thermo-active foundations. In many cases, the geothermal heat exchangers in thermo-active foundations are not sufficient to accommodate the thermal load demands of the overlying building. Accordingly, thermo-active foundations are usually used as a supplement to a set of GSHP heat exchangers in vertical boreholes, or are used in combination with a conventional heating, ventilation and air conditioning (HVAC) system such as a natural gas furnace combined with an air-source heat pump. In the second case, the thermo-active foundations are used to carry the base thermal load of the building, and the conventional HVAC system is used during peak heating or cooling events. The first implementation obstacle encountered with thermo-active foundations is associated with the philosophical choice of the designer to use a GSHP system, which may have a higher up-front cost than a conventional HVAC system. The use of thermo-active foundations is not expected to lead to a significant cost increase beyond a conventional GSHP system, but further documentation from research-level or demonstration projects may help in establishing typical cost expectations. It may be necessary for GSHP systems to be promoted by industry first, focusing on their long-term benefits, and promotion of thermo-active foundations will follow as a natural accompaniment.

A second obstacle results from the non-traditional method by which the thermal load, ground-source heat pump system, and thermo-active foundation have to be designed. This is an integrated process, potentially requiring input from mechanical engineers, geotechnical engineers, and structural engineers. In particular, the lack of knowledge of geotechnical and structural engineers on the GSHP design is a significant barrier to the wider use of thermo-active foundations. Hence, a better understanding for the GSHP design needs to be primarily promoted.

Calculation of the peak thermal load required for the building is a process mechanical engineers and heating, ventilation, and air-conditioning professionals have been doing for many years. For GSHP systems and thermo-active foundations, it is also necessary to calculate the thermal loads over the year. In the United States there are programs such as Energy Plus or EQUEST that can be used. The load will be the same regardless of the system used, whether it be a thermo-active foundation system or a traditional HVAC system. However, challenges that still exist include the need for more robust and long-term monitoring of these systems. This is crucial as soil properties can be dependent on temperature and any significant temperature change of the soil surrounding the foundation could affect the foundation’s ability to carry load.

Another obstacle is in the ground-source heat pump system design. Traditionally after the thermal load was determined, a GSHP system would be designed to accommodate that load. In the case of thermo-active foundations, the design of the GSHP system is restricted by the design and type of foundation. Thus the current design tools cannot handle the irregular geometries of pile groups, the large diameters of piles, and the ground-surface building interaction. Furthermore, this may require an iterative process that involves both the geotechnical and mechanical engineers as a thermo-active foundation GSHP system is designed for both optimal structural capacity and GSHP performance.

Integrated with the GSHP system design is the actual foundation design. In the case of thermo-active piles, how many loops can be effectively placed in a pile so that they will not significantly interfere with the thermal properties of the other piles nor with its (their) structural integrity. There are also thermo-mechanical aspects that are not fully known, yet must be considered. These are discussed in Session 4 paper.

5.2. Coordination of Various Parties Involved

As mentioned above, thermo-active foundations are interdisciplinary systems and as such there are many parties involved in their design and installation. They include, geotechnical engineers, mechanical engineers, GSHP designers, contractors, the owner, architects, and others. A summary of the different considerations in the design of thermo-active piles, along with the responsible parties for each component of design is summarized in Figure 2. Because of the traditional timeline in which the HVAC design, foundation design, and construction take place, these individuals do not often work together making coordination difficult for a project that wishes to utilize a thermo-active foundation. These coordination efforts are discussed in more detail in the Session 1 report.

The GSHPA's Thermal Pile Standards build upon the methodology set out in the ICE Specification for Piling and Embedded Retaining Walls (2nd Edition) to offer some guidance on how the coordination among the various parties may take place. Although this guidance is specifically for thermo-active piles, it can easily be extended to any thermo-active foundation. The significant change between the traditional methodology and the methodology that incorporates thermal piles is the addition of the Mechanical and Electrical (M&E) Designer and the GSHP Designer. Geotechnical engineers working on the foundation have traditionally had little or no interaction with these two parties. But this interaction will be essential for use of thermo-active foundations to become more widespread.

There are two models of organizational structure, these are: Engineer Based Design and a Contractor Based Design. The details of how thermo-active foundations can be designed using these two organizational structures are summarized in the following sections.

5.2.1 Engineer-Based Design

The interaction between the parties as well as the responsibility of each party during the construction timeline for an Engineer Based Design are summarized in the schematics in Figures 3 and 4. According to ICE-SPERW 2013, the engineer should refrain from selecting a proprietary pile design, and in this case the engineering team consisting of the geotechnical engineer, the M&E designer, and the GSHP designer should create a design for the thermo-active foundation that is not based on a proprietary system. Note that in this case it is the responsibility of the geotechnical engineer to coordinate with the M&E designer and the GSHP designer to develop detailed designs, specifications, and drawings.

5.2.2 Contractor Based Design

The interaction between the parties as well as the responsibility of each party during the construction timeline for a Contractor Based Design are summarized in the schematics in Figures 5 and 6. In this case it is the responsibility of the geotechnical engineer to coordinate with the M&E Designer and the GSHP Designer to provide performance criteria for the thermo-active foundation system, but the responsibility of the contractor to develop detailed design, specifications, and drawings.

6. The Road Ahead

There are some definitive steps that must be taken by academic and industry professionals as well as geotechnical engineers in order to overcome these daunting implementation issues and market challenges.

6.1. Academic and Industry Professional's Role

The roles of academics and professionals from industry in overcoming the implementation issues and market challenges associated with thermo-active foundations are as follows:

- Develop software and analytical tools that will make it easier for architects, engineers, and any other party involved to explore various options, estimate system performance, and streamline the process.
- Begin to answer significant questions regarding long-term performance, thermo-mechanical soil-pile interactions, and design approaches. Contractors and designers that have the power to implement these systems need to be able to assure their clients that these systems will perform well and not significantly affect the ability of the foundation to support the structure.
- As questions are answered, express the results in terms that can easily be integrated into current design methodologies, whether it be LRFD or SLS/ULS.

6.2. Geotechnical Engineer and Contractor's Role

The roles of geotechnical engineers and contractors in overcoming the implementation issues and market challenges associated with thermo-active foundations are as follows:

- Educate themselves on 'Green Energy Jargon'. This is required in order to promote these systems to clients and is not something geotechnical engineers or contractors have typically had to know as foundations are not generally associated with green energy.
- Develop a basic understanding of GSHP and HVAC systems. A basic understanding will be required in order to skillfully coordinate between the various parties involved in the design process.
- Commit to monitoring the systems over the long term. This will allow a database of performance case histories to be created and then referenced to more accurately understand the technology.

7. Conclusions

Thermo-active foundation technology is at a critical stage. It is at a point where there is sufficient research to begin developing standards and guidelines for practice, such as those laid out in the Thermal Pile Standards manual. But now it faces the two challenges laid out in this paper: market acceptance and practical implementation. In order to encourage the acceptance of thermo-active foundation technology among project owners, it is crucial to take advantage of the economic drivers that already exist in the form of governmental regulations and green certifications. However, this is a technology that merges two traditionally independent realms – geotechnical engineers and ground source heat pump designers. There is considerable confusion as to the design and implementation of these systems from a practical standpoint. Again, guidance such as what is laid out in the GSHPA's Thermal Pile Standards manual is useful in bridging the gap towards application and further work is needed to improve this manual. If this technology is able to overcome these challenges, it is well on its way to becoming a leading force in green energy and integrated building systems.

8. Acknowledgement

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LIST OF TABLES AND FIGURES

Table 1. Some current design guidelines and codes for piles, shallow geothermal systems, and thermo-active piles.

Region	Topic	Document	Document Type
United States	Pile Design	Federal Highway Administration "Design and Construction of Driven Pile Foundations"	Design guidance
		U.S. Army Corps of Engineers "Design of Pile Foundations"	Design guidance
	Geothermal System Design	ASHRAE Standard 90.1	Design guidance
		International Ground Source Heat Pump Association "Design and Installation Standards"	Design guidance
	Thermal Pile Design	None	
Europe	Pile Design	Eurocode 7	Code
	Geothermal System Design	EN 15459 heating Systems – Design of heat pump heating systems	Code
	Geothermal System Design	SIA 384/6 (SN 565) (2009) “Borehole heat exchangers for heating and cooling” (Switzerland)	Design guidance
	Geothermal System Design	VDI 4640 Blatt 1-4 (2010) “Thermal use of the underground, part 1-4” (Germany)	Design guidance
	Geothermal System Design	Ground Source Heat Pump Association "Vertical Borehole Standard"	Design guidance
	Thermal Pile Design	Ground Source Heat Pump Association "Thermal Pile Design Guidelines" (see section 2.2)	Design guidance
	Thermal Pile Design	SIA D 0190 (2005). “Use of earth heat through foundation piles, etc.” (Switzerland)	Design guidance

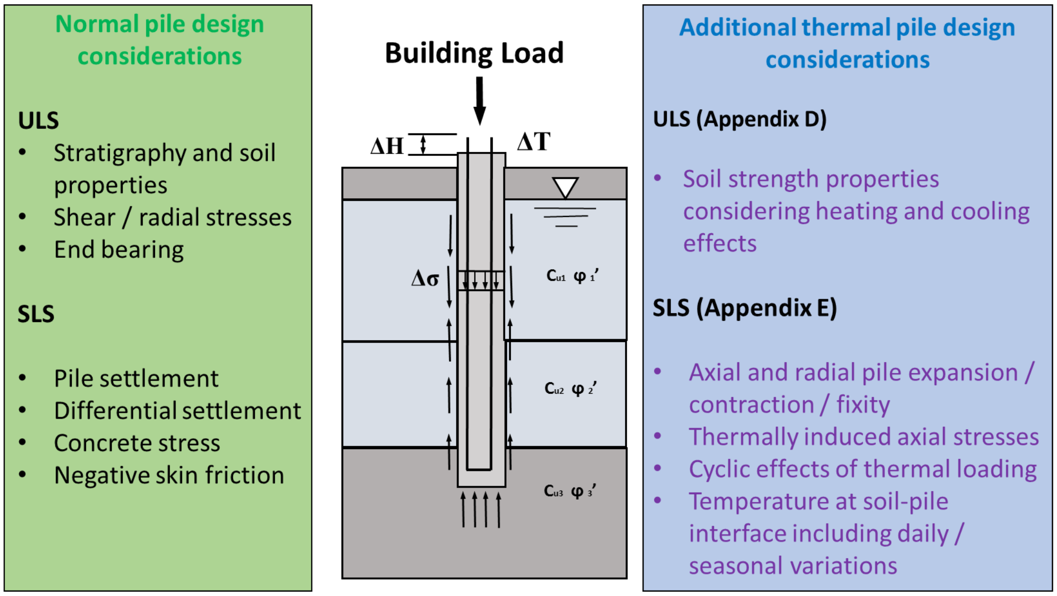

Figure 1. Differences in design approach for a conventional pile vs. a thermal pile (redrawn after GSHP Association, 2012).

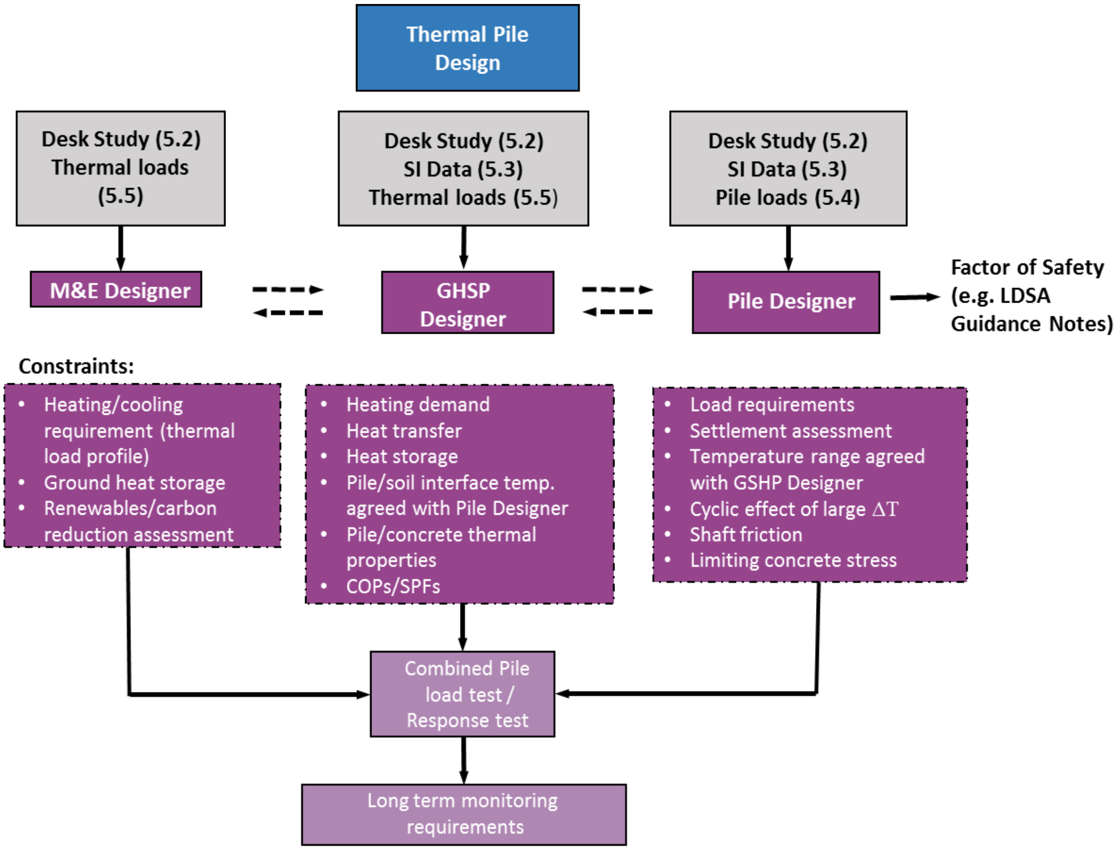

Figure 2. Thermal pile design considerations (redrawn after GSHP Association, 2012).

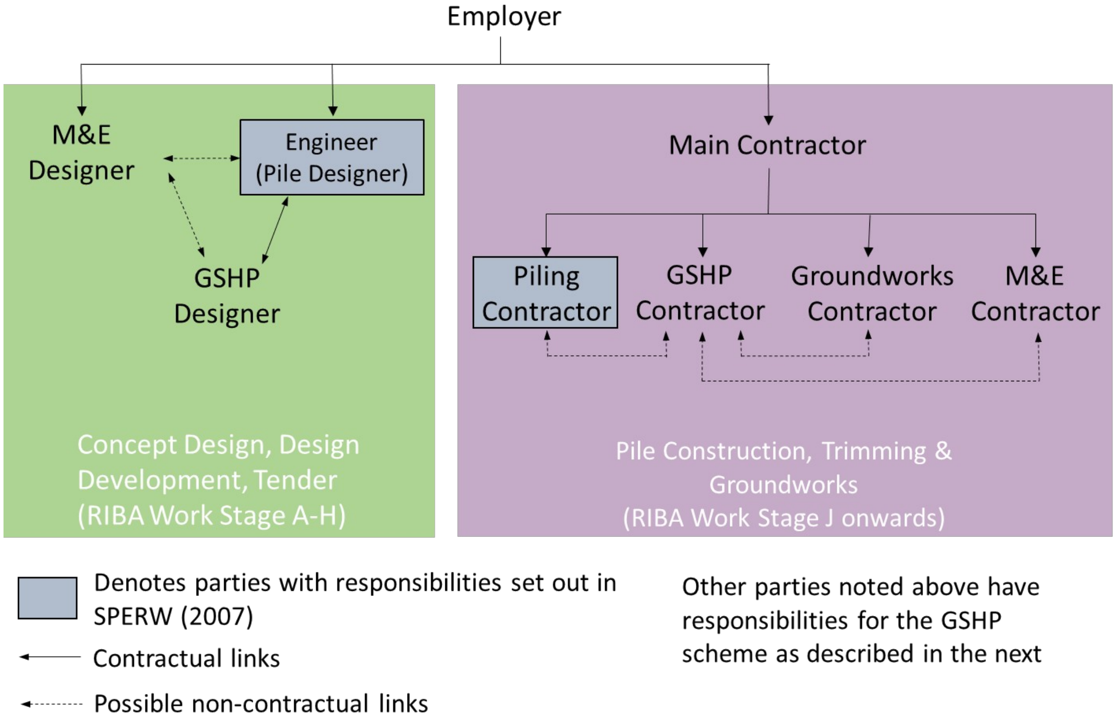

Figure 3. Interaction of various parties for an Engineer Based Design (redrawn after GSHP Association, 2012).

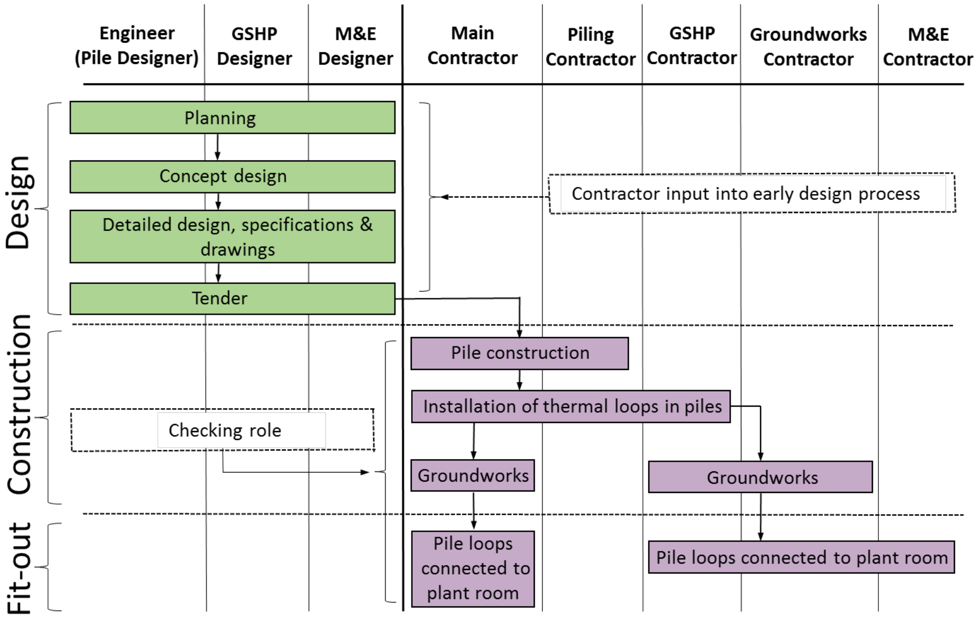

Figure 4. Responsibilities of various parties for an Engineer Based Design (redrawn after GSHP Association, 2012).

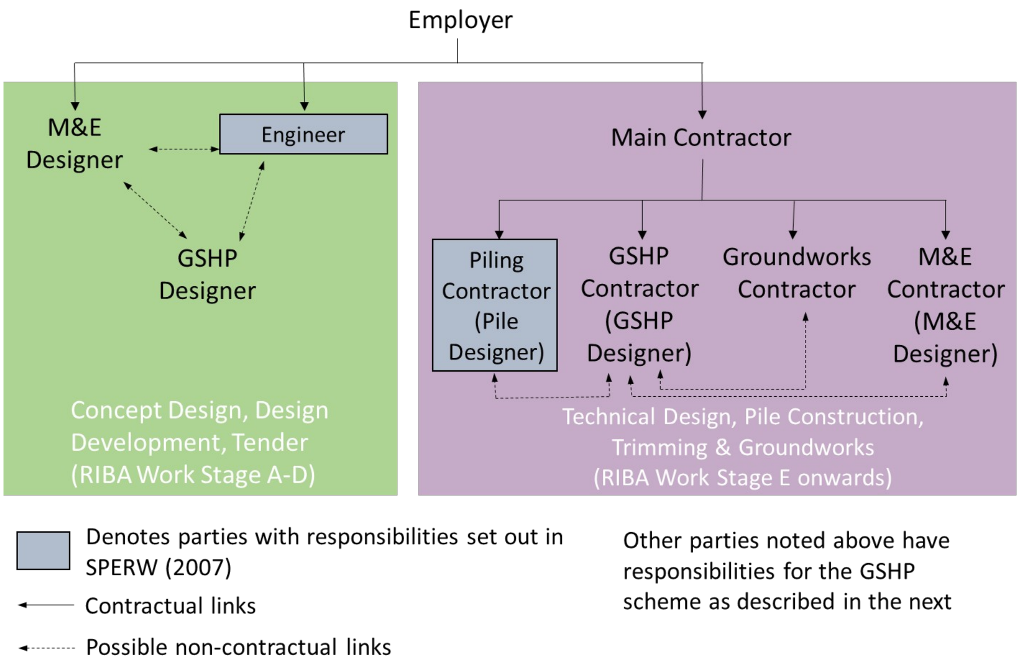

Figure 5. Interaction of various parties for a Contractor Based Design (redrawn after GSHP Association, 2012).

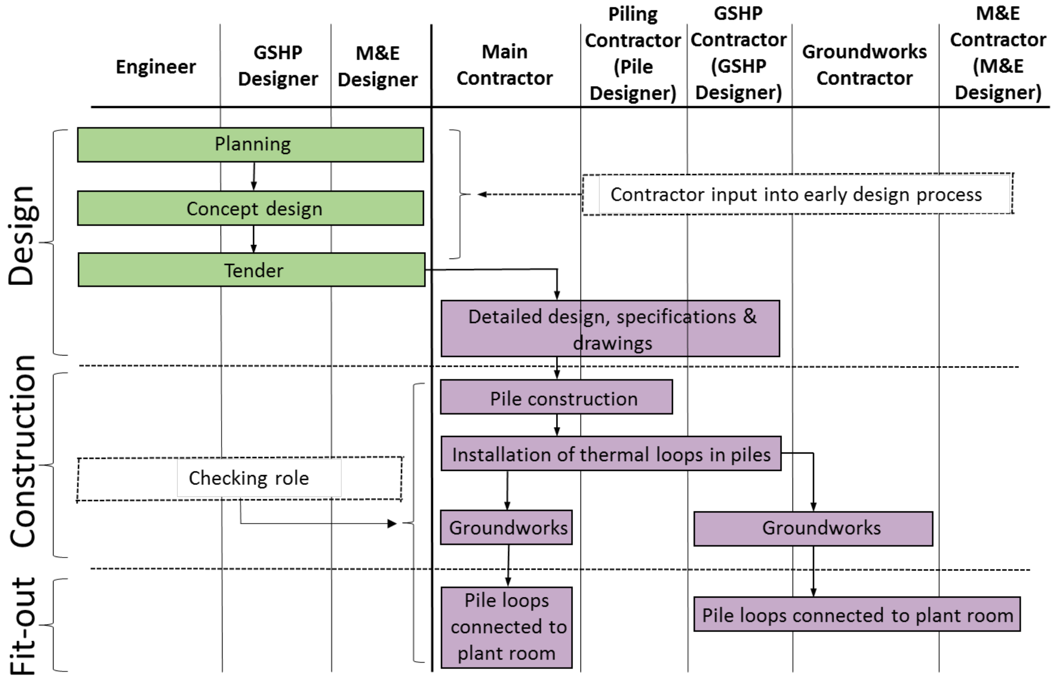

Figure 6. Responsibilities of various parties for a Contractor Based Design (redrawn after GSHP Association, 2012).