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Ground-Source Heat Pump Systems

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Heat contracting for ground-source heat pumps in Austria

A new ARI / ISO standard for water- and brine-source heat pumps

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centre

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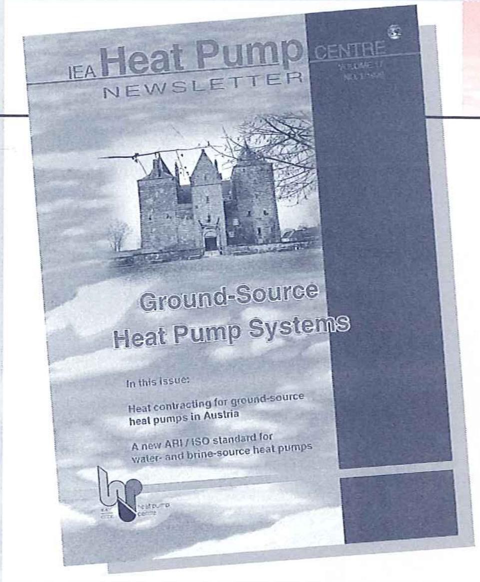

Ground-source heat pump systems

Ground-source heat pump systems for heating-only or heating and cooling are gaining a larger market share in several countries around the world. This issue focuses on residential as well as commercial/institutional applications without underground thermal storage. Since high investment costs are still one of the main drawbacks to a further increase in the use of ground-source heat pump systems, this issue includes improved design systems and other strategies to lower costs.

Front cover:
The photo on the front cover shows the Dutch castle Slot Loevenstein that was recently retrofitted with a heat pump (see page 12).

COLOPHON

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HEAT PUMP NEWS

FEATURES

Heat exchanger pile system for heating and cooling at Zürich airport

Daniel Pahud, Antoine Fromentin and Markus Hubbuch, Switzerland

The Dock Midfield, a new terminal building planned at Zürich airport, will be constructed on foundation piles that will also serve as heat exchangers with the ground. The piles will be equipped with a pipe system coupled to a heat pump for heating purposes. During the summer, part of the cooling load will be met by using the piles for direct cooling.

The Dock Midfield is a new terminal for 26 planes. The building (500 m long and 30 m wide) will be built on 350 foundation piles as the upper ground layer, consisting of lake deposits, is too soft to support the building. The piles will stand on moraine, which lies at a depth of about 30 m. With a diameter of 1-1.5 metres, the concrete piles will be cast on-site.

Renewable energies are used extensively throughout this building. Renewables are expected to meet 65% and 75% of the heating and cooling requirements respectively. The foundation piles contribute by being used as heat exchanger piles. The amount of energy purchased for heating is very small. The associated heating energy index (auxiliary energy and electricity for the heat pump), defined by the ratio of the annual energy demand and the total heated floor area, is about 30 MJ/m^{2}y. The total electric energy index, estimated at 400 MJ/m^{2}year, is also low for a fully air-conditioned building which will be used 18 hours a day. Construction of the Dock Midfield will start in 1999 and will continue for around four years.

Heat exchanger piles

These are foundation piles equipped with a pipe system, through which a heat carrier fluid is circulated. The two main functions of these piles are therefore to support the building and to serve as a heat exchanger with the ground. The piles are connected hydraulically and coupled to an electric heat pump. During the winter, the heat pump extracts thermal energy from the ground and supplies heat to the building, meeting part of the heating demand. No significant regional ground water movement is expected at this site, so thermal regeneration does not take place automatically. This means that the temperature of the ground around the piles drops. This is actually an advantage during the summer when the heat exchanger piles are used for direct cooling, i.e. the flow circuit is connected directly to the cold distribution system in the building. Direct cooling enables thermal regeneration of the ground and is beneficial for heating the following winter. **Figure 1** shows a schematic view of the heat exchanger pile system.

The principal constraint on the system is that the thermal function of the piles must not cause any deterioration of their mechanical properties, In particular, the piles must not be allowed to freeze.

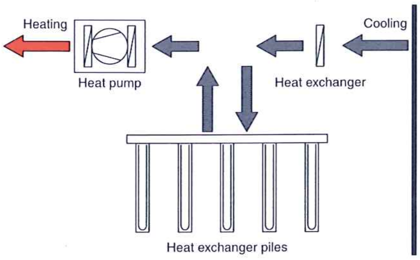
This temperature constraint influences the size of the heat pump which, in turn, affects the heating potential provided by the heat exchanger piles. When direct cooling is supplied, the cooling potential also depends on the temperature level of the fluid in the cooling system (maximum 20°C for this application). The annual extracted and injected thermal energy through the piles determines how the ground temperature changes over time. This can affect the thermal performance of the system. An accurate assessment of the heating and cooling potential requires a dynamic simulation of the system, including both short-term and long-term thermal performance. The system's thermal characteristics, local ground conditions and the use of an accurate simulation tool are essential elements.

Simulation tool

Simulation tools for heat exchanger pile systems have been developed by the Laboratory of Energy Systems (LASEN), at the Swiss Federal Institute of Technology in Lausanne (EPFL). They were developed using TRNSYS, a transient simulation programme. Measurements of existing systems, were used for comparison and validation. A non-standard simulation model, devised for heat storage in the ground with borehole heat exchangers, has been adapted for heat exchanger piles. Within the framework of the Dock Midfield project, the experience gained in simulating heat exchanger pile systems was used to create PILESIM, which allows the system's thermal performance, the thermal potential of heat exchanger piles and a variety of system designs to be assessed.

The net space heating and cooling

Figure 1: Schematic view of the heat exchanger pile system.



requirements of the building were simulated in hourly values for one year , and used as input data for PILESIM. These heating and cooling requirements take into account passive solar gains, internal gains, heat recovery units on exhaust air, free cooling with outside air and cooling for heating purposes. At this stage of the project, a constant performance coefficient of 3.5 is assumed for the heat pump.

The piles will be equipped with four U-pipes fixed on the inner side of the reinforcing steel: four plastic pipes drive the heat carrier fluid (a glycol-water mixture) down to the bottom of the pile and four others bring it back up. Even with thick piles of 1-1.5 metres in diameter, more U-pipes do not significantly improve the steady state heat transfer from the fluid to the ground in the immediate vicinity of the pile. A laminar flow regime in the piles is recommended when four U-pipes or more are used. Simulations have shown that the supplementary pumping energy needed to make the flow non-laminar is not compensated by improved thermal performance. Around 300 piles will be heat exchanger piles, each with a heat transfer length of about 25 m.

Sizing

Detailed simulations have shown that an undersized heat pump, in relation to the total length of the heat exchanger piles, does not greatly improve the performance coefficient of the heat pump. As the heat exchanger piles contribute significantly to the investment cost, an undersized heat pump results in increased cost per heat unit. On the other hand, an oversized heat pump may lead to a critical situation, as the risk of freezing exists. Freezing can be avoided by reducing the heat pump power. For the Dock Midfield, the heat pump is sized so that a power reduction of up to 10% is acceptable.

Figure 2 shows the simulated classified hourly heat and cold energy demands, together with the corresponding energy rate provided by the heat exchanger pile system. An 800 kW heat pump at the condenser will meet 90% of the 4,600 GJ (1,280 MWh) net annual heat demand. The remainder, 470 GJ (128 MWh), will be met by district heating, with a maximum peak load of 1,500 kW. Nearly all the net annual cold demand, estimated at 2,230 GJ (620 MWh), can be met through direct cooling by the pile system. However, an auxiliary cooling unit with a cooling peak capacity of 110 kW should be available to reach the expected temperature level of the cold distribution.

A higher ground temperature means less cooling energy provided by the piles, so an increase in ground temperature over a period of time should be avoided. In order to prevent this increase, the annual extracted heat (2,950 GJ or 820 MWh) must be greater than the heat injected through cooling (2,200 GJ or 610 MWh), due to the heat dissipation from the building to the ground. Expressed per metre of pile, the annual energies and maximum thermal powers extracted and injected by the piles are relatively high, mainly due to the large pile diameter. Values are given in **Table 1**.

The economy of the heat exchanger pile system is similar to conventional heating and cooling, but has the advantage that less fossil fuels are required for heating. Direct cooling through the piles requires less electricity than a cooling machine. The electricity saved on cooling during the summer compensates for the electricity used by the heat pump during the winter.

Conclusions

Foundation piles offer an interesting alternative for providing heating and cooling energy to a building, especially when they can combine the two. Just heating or cooling requires a thermal regeneration of the ground from year to year, which can be performed naturally if the regional ground water flow is large enough. Heat exchanger piles are best integrated into a bivalent system; the peak power loads are met by auxiliary energy. The Dock Midfield presents good conditions for optimal use of heat exchanger piles. Reduced fossil fuel consumption will be realised, without increasing the overall electric energy demand.

Further information
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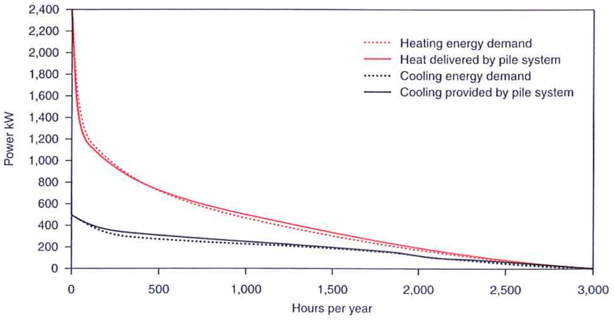
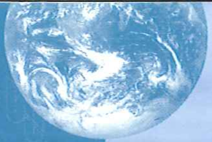
▼ *Table 1: Maximum capacity and annual energy extracted.*

	Maximum capacity	**Energy extracted**
Heat extraction (heating)	75 W/m	110 kWh/m per year
Heat injection (direct cooling)	60 W/m	80 kWh/m per year

▼ *Figure 2: Simulated classified hourly values of the net energy demands for heating and cooling the Dock Midfield. The corresponding energy rates met by the heat exchanger pile system are also shown.*





International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on the IEA Heat Pump Programme, contact your National Team or the address below.

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