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USE OF GEOTHERMAL PILES COMBINED WITH PILE FOUNDATIONS

Introduction

Based on US energy statistics 40% of the annual energy consumption is spent on residential and commercial buildings. More than half of these costs falls on heating, ventilation and air conditioning [1]. A similar situation is observed in central Europe.

Given the increase in energy prices and the fight against harmful emissions of CO_2, heat pumps equipment are developing rapidly. Ukraine has implemented many projects using ground heat exchanger and geothermal probes, but these scheme are possible only in the presence of a large free area near the house. Usually the most active part in the implementation of energy efficient technologies performs commercial developers in central areas of major cities. One of the main obstacles to the realization of the project is to provide buildings with heating and cooling. Often heating providing of object is impossible without reconstruction of city heat network and has substantial capital costs.

Geothermal pile can help to solve this question. The idea of using geothermal piles is not new and was first implemented in Austria at the end of 1980, which allowed to get 25÷50 W/m low-grade heat energy, depending on the soil [2].

1. Analysis of published data and staging problems

Calculations and construction schemes for geozonds and geocollectors are well described in the literature [3, 4] and are widely used in everyday life among the assembly and design organizations.

Geothermal pile - is loaded bearing piles with closed loop pipe attached to the frame of the pile and used as a soil heat exchanger for heat pump systems or

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as a passive cooling source. The technology driving of using geothermal piles requires a complex calculation, clear universal methods of calculation not exist to date. Despite the fact that the some objects using geothermal piles today and will be design to the future, many leading universities are working on research using thermal piles [5-7], the guarantees structural strength and increase its durability.

2. The purpose and objectives of research

The aim of the study is to conduct a pilot experiment on the use of geothermal piles to evaluate the effectiveness of their work in central European climate.

To achieve these goals were set and solved the following problems:
– Determination of the thermal capacity of the soil by drilling test well and the establishment of the geological section;
– Creation of experimental stand for realization experiment and recording received data;
– Determine the average heat flux from a geothermal piles to assess the feasibility of its use;
– Determine the lower critical temperature concrete in piles under thermal load.

3. Materials and methods of research geothermal piles

Based on the assumptions [8] and in accordance with the recommendations of the normative literature [9], group of experts LLC «UNIVENTHERM» respectively project «BIP PM» «Construction of residential complex with offices, technical premises and underground parking on the street. Mechnikov 11-A in Pechersk district at Kyiv» was conducted an experiment in which drilling-hammer pile height of 20 meters was used. This pile was passing the test of strength and will not be used as a load-bearing structure of the building in the future. Soil geological section shown in Figure 1.

3.1. Technology installation of geothermal piles

• Contours of pipes PE80 (SDR 11) DIA 32 mm were fixed to hard welded reinforcing cage
• Since the depth of 6 m. was installed thermoresistance pair temperature sensors every 5 m to establish deflection temperature gradient in piles throughout its length. Total installed 5 pairs of sensors
• Frame of piles lowered into the well

The contours of the pipeline brought out piles and filled heat carrier (ethanol solution of 25% by volume).
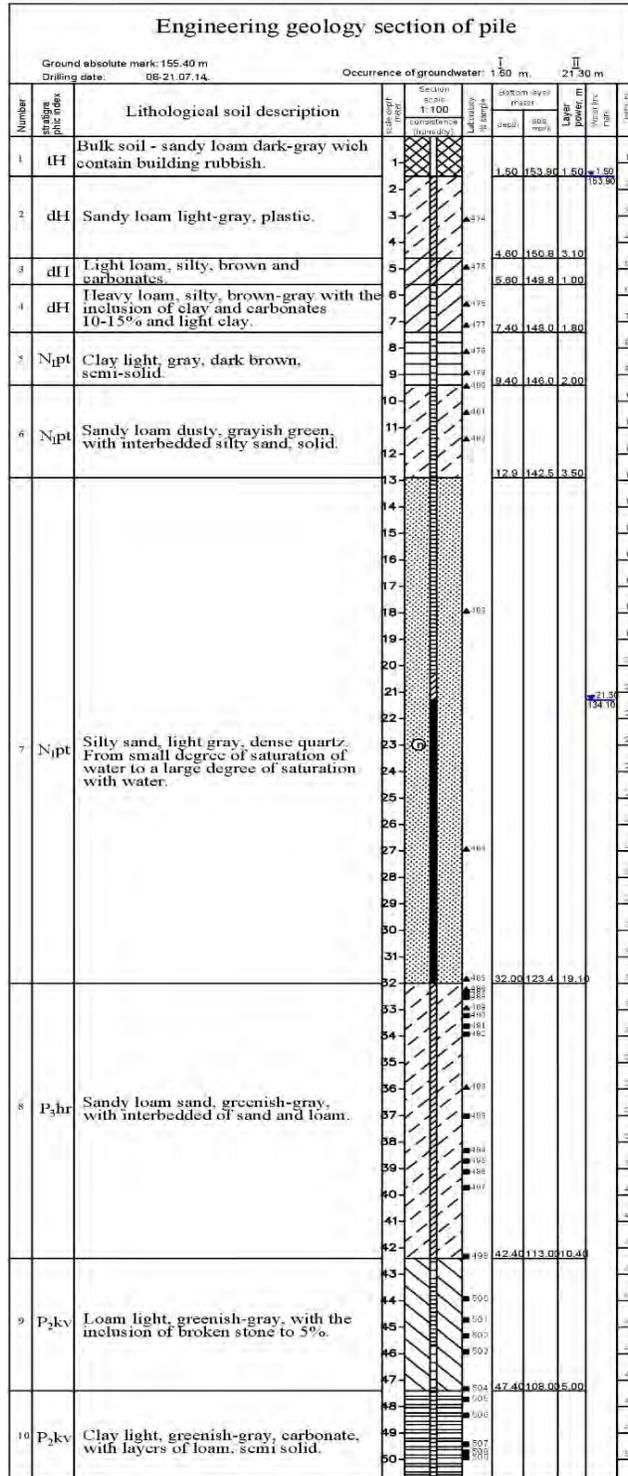
Fig. 1. Geological section of soil

- An installation of control equipment with gauge at the end of the pipeline
- Before concreting made test system integrity, pushing of pressure of 6 bar
- Tops pipelines stretched beyond the pile to prevent damage when casting concrete piles. Pouring concrete made to complete filling of the pile
- Connection - directly from the pile to the heater

3.2. Description of establishing stand

To perform the test was installed test stand, which include next monitoring equipment:

- Air-heating aggregate Volcano mini, which utilizes the heat received from the contours of pipes laid to the pile
- Circulation pump Grundfos UPS 20-40 130, which provides a constant circulation of heat carrier
- Water meter VLF-R ½ "
- Radial ½" bimetal thermometers are installed on a return and supply pipelines
- Balancing valve Oventrop Cocon QTZ, for control heat carrier and regulate the amount of heat received from the contour of pipes, wich are laid in the pile
- Shield Automatics with the panel temperature data, received from the temperature sensors in the pile

Equipment stand directly connected to the contours of pipes laid in the pile and operates as a single system. Schematic diagram of the experimental stand shown in Figure 2.

1 - Ball valve DIA 25 mm
2 - Ball valve DIA 15 mm
3 - Balancing valve Oventrop Cocon QTZ DIA 25 mm
4 - Bimetallic thermometer 1/2"x5 cm
5 - Radial manometer 0...6 bar DIA 1/2"
6 - Water meter VLF-R 1/2"
7 - Circulator pump Grundfos UPS 20-40 130
8 - Strainer DIA 25mm
9 - Water heater - Volcano mini
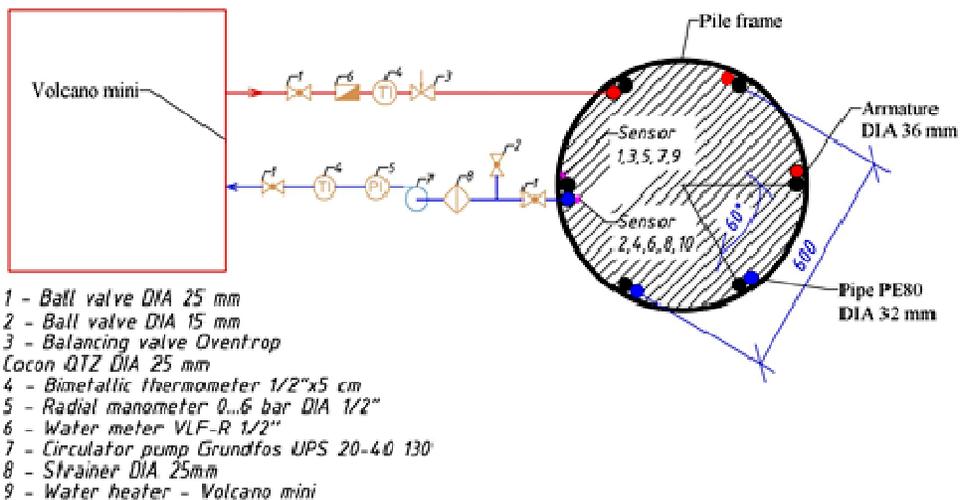
Fig. 2. Scheme experimental stand for research efficiency geothermal piles

4. Results of the experiment and data processing

Work on measurements performed from 02.09.2015 to 02.17.2015 using automation systems and temperature sensors. To study the conditions were close to reality using all necessary parameters. Measurements are taken once a day. The length of the pile, used as a heat exchanger - 20 m. Table 1 data are indicators of experimental measurements of the stand.

TABLE 1

Monitoring of thermal pile temperature

Date	Heat carrier amount [m³/hour]	Average outdoor temperature T [°C]	Temperature of supply heat carrier T1 [°C]	Temperature of recirculation heat carrier T2 [°C]	Sensor data № 1 [°C]	Sensor data № 2 [°C]	Sensor data № 3 [°C]	Sensor data № 4 [°C]
02.09.2015	0.36	−5.4	12.5	9.5	11.6	11.7	14.1	11.3
02.10.2015	0.36	−9.1	10.4	7.3	11.8	11.9	14.2	12.2
02.11.2015	0.36	−9.0	9.1	6.1	9.8	9.1	11	9.2
02.12.2015	0.36	−2.0	8.2	5.0	8.7	8.8	10.5	8.9
02.13.2015	0.36	−1.0	7.8	4.8	8.7	8.7	10.3	8.7
02.14.2015	0.36	−3.0	7.0	4.0	8.3	8.1	9.9	8.1
02.15.2015	0.36	−3.0	7.0	3.5	8.1	7.8	9.4	7.8
02.16.2015	0.36	−6.27	6.0	2.0	7.5	7.1	8.8	7.0
02.17.2015	0.36	−7.1	6.0	2.0	7.2	6.7	8.2	6.6

TABLE 2

Monitoring of thermal pile temperature (continuation)

Sensor data № 5 [°C]	Sensor data № 6 [°C]	Sensor data № 7 [°C]	Sensor data № 8 [°C]	Sensor data № 9 [°C]	Sensor data № 10 [°C]	Q [kW]
14.5	9.8	13.3	12.2	10.5	9.4	1.05
14.7	9.5	13.9	12.2	11.9	10.2	1.09
10.7	6.8	10.5	8.9	8.7	7.1	1.05
10.3	6.3	10.1	8.6	8.5	7.0	1.12
10.1	6.2	9.9	8.4	8.3	6.9	1.05
9.6	5.5	9.4	7.7	7.6	5.9	1.05
9.1	5.1	9.0	7.3	7.4	5.7	1.23
8.4	4.7	8.4	6.5	6.6	4.7	1.40

The amount of heat is obtained from a pile of pipes paths calculated by the formula №1.

$$\frac{dQ}{d\tau} = \frac{c \cdot m \cdot (dT1 - dT2)}{d\tau} = \frac{c \cdot \rho \cdot V \cdot (dT1 - dT2)}{d\tau} \qquad (1)$$

where:

Q - heat [J],

c - heat capacity of ethanol solution [J/(kg·°C)],

T1, T2 - heat carrier temperature supply and return [°C],

ρ - ethanol solution density [kg/m^3],
V - ethanol solution volume [m^3].

$$Q_{middle} = (3.75 \cdot 0.36 \cdot 945 \cdot (8.2 - 4.9)/3.6)/1000 = 1.17 \text{ kW} \qquad (2)$$

The average heat flux from 1 meter of piles:

$$q_{middle} = Q_{middle}/L = 1.17/20 \cdot 1000 = 58.5 \text{ W/m} \qquad (3)$$

where L - length of pile [m].

Compliance with the standard [9], the minimum temperature of the return heat carrier can be 2°C to avoid freezing of the soil, so the research focused on this mark. Thus, the minimum external temperature piles, for the entire period of the experiment, was 3.6°C. Therefore, we can conclude that the minimum heat carrier temperature will not affect the strength characteristics of the pile, as it is within acceptable norms.

Note that when we will use the heat pump, the temperature of supply and returne heat carrier will remain stable during the heating season and will make an average of 11/8°C. As the heat carrier will not cooling by the outside air and specified by settings of the heat pump, heat flow will be stable.

5. Discussion research results effectiveness of using thermal piles

After the study of thermal efficiency piles in Ukraine can be said that this technology is appropriate for use and fits well with cold climate. The amount of heat obtained from contour of pipes per hour ranged from 1.05 to 1.4 kW. According calculated specific amount of thermal energy per meter was about 58.5 W/m, which is a confirmation of the theoretical calculations. It should also be noted that geothermal pile can be used as a passive or active cooling source not in the heating season, which considerably increases the potential for their use.

Conclusions

Apparently require a detailed study of the processes of heat exchange between piles and surrounding soil and to determine the optimal parameters of soil heat exchanger. In addition, you should note that the temperature inside the pile unchanged throughout the experiment, indicating not stationary mode pile and may adversely affect the load-bearing characteristics of pile.

The use of thermal facilities in piles in cold climate can be considered reasonable and considered as a partial version of the needs of cold / heat building.

From the data we learn that the average amount of heat that can be obtained from single pile - 1.17 kW·h.

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Abstract

The possibility of using geothermal piles as an evaporator for the heat pump system. Analyzed experience of implementation of these technologies in leading countries, based on existing calculation methods, performed an experiment by introducing thermal piles with corrections to the conditions of construction in the cold climate.

Keywords: heat pumps, energy pile, geothermal energy, energy efficiency

Zastosowanie pali geotermalnych w połączeniu z konstrukcją fundamentu

Streszczenie

Rozpatruje się możliwość wykorzystania pali geotermalnych jako parownika dla systemu pompy ciepła. Na podstawie przeanalizowanych metod i badań przeprowadzono eksperyment polegający na wprowadzeniu gruntowego wymiennika ciepła w pale fundamentowe z uwzględnieniem warunków klimatycznych panujących na obszarze chłodnego klimatu.

Badania potwierdziły obliczenia teoretyczne, a otrzymany wynik pokazał, że średni strumień ciepła uzyskiwanego z 1 mb pala wynosi 58,5 W/mb niskotemperaturowej energii cieplnej. Parametry te są zadowalające, a stosowanie danej technologii - aktualne, ponieważ niesie znaczne oszczędności w kosztach inwestycyjnych związanych z instalowaniem źródła energii cieplnej dla pompy ciepła.

W trakcie przeprowadzenia eksperymentu zaobserwowano niestacjonarny stan termiczny pala, dlatego należy bardziej szczegółowo zbadać wpływ zmiany temperatury nośnika ciepła na wytrzymałość (nośność) pala. Należy również opracować optymalny tryb działania pali geotermalnych i prowadzić dalsze badania.

Słowa kluczowe: pompy ciepła, energia pali, energia geotermalna, efektywność energetyczna