WIERTNICTWO NAFTA GAZ • TOM 25 • ZESZYT 2 • 2008

Martin Klempa*, Josef Mazáč*

REALIZATION OF BOREHOLES FOR HEAT PUMPS IN THE AREA OF THE UNIVERSITY HALL AND THE CENTRE OF INNOVATIONAL TECHNOLOGIES (CIT) VŠB-TECHNICAL UNIVERSITY OF OSTRAVA

1. INTRODUCTION

Rotary – percussion drilling is a modern way of rocks' disintegration, which has found wide use in drilling practice. Within a few recent years we have been noticing a rapid progress in heating of buildings by heat pumps in the Czech Republic. Boreholes for heat pumps belong to the so-called ground collectors, which are characterized by pumping low-potential heat from the ground. Owing to the complex geological conditions in the Czech Republic and taking into account that boreholes for heat pumps are unrecoverable products, the construction of boreholes entails considerable hazards. On the basis of the project's submitter's requirements, drilling using downhole drill hammers with utilization of selected special technologies appears to be the most suitable solution.

2. HEATING OF BUILDINGS BY HEAT PUMPS

Conventional building heating systems have been making use of burning non-renewable energy sources – fossil fuels (coal, oil, gas) in a large extent so far. During this process, exhausts (namely CO_2 – carbon dioxide) are released into the atmosphere, which has a negative impact on air quality and at the same time contributes to global warming.

In an effort to moderate this unfavourable development, industrial countries started to make use of the system of heat translation for heating. The heat is translated from one place to another, without being burnt. This system of heating is also used by e.g. heat pumps [1].

From the viewpoint of the type of the heating system, it is necessary to use a warm-water system for heating by heat pumps, namely using either radiators or floor heating.

* VŠB-Technical University of Ostrava, Czech Republic

The heat pump is a serviceable, user friendly automatic machine, which does not release any products of combustion. It only transforms the low-potential energy of rocks into thermic energy utilizable for practical purposes [5].

3. DEPTH DRILLING FOR HEAT PUMPS

The thermal energy is brought from the rocks into the heat pump by means of deep vertical boreholes. The condition of functionality of the system of the heat pump with deep vertical boreholes is that the polyethylene (PE) collector has to be hermetical in relation to the rock environment, i.e. the antifreezer does not come into any contact with this environment. This system of gaining natural thermal energy is called ‘ground-water’, i.e. rocks are sources of thermal energy, which is being taken from the rocks by means of the circulating antifreezer in the hermetical PE collector.

To be able to project optimal number, depths, and position of boreholes, it is essential to know the geological and hydrological parameters of the rock massif. From the viewpoint of methodology, when elaborating project documentation, it is necessary to read through archive geological and hydrological records about the territory of interest, and carry out terrain exploration at the same time.

In standard practice (mostly villas), the following procedure is used for borehole depth determination in the Czech Republic. On the basis of a long-term experience with functioning of heat pumps, their world-wide producers publish tabular rates of the so-called heat gain (W/m) from one metre of the borehole. These rates range between 40 and 70 W/m for various geological conditions. Further it is essential to know the cooling output of the compressor of the suggested heat pump for the particular building.

Depending on geological conditions and on drilling technique and technology requirements described above, the application of a drilling rig capable of the rotary-percussion way of rocks’ disintegration with pneumatic wash-out with water spraying appears to be the best option.

Boreholes are very slim: the diameter of the initial part of the borehole ranges between 150 and 160 mm, whereas the borehole’s final diameter mostly amounts to 120 mm. The borehole’s small diameter makes better heat translation from the rocks to the collector possible. The boreholes’ depth range mostly amounts to maximum 130 m, exceptionally up to 150 m. According to the geological conditions and to the building’s heat losses, even more boreholes can be realized in one locality. The recommended minimum distance between the boreholes is 10 m.

The initial drilling phase is realized through the use of the double rotary head. The boring gravel is controlledly drained off by water (eventually by foam) into the container, without water being splashed around the borehole. The major advantage of this technology is the possibility of casing through the instable section of the borehole, using casing pipes of a single diameter. In some regions (alternating of clays with aquifer-saturated gravel sands, shifting sands), it is necessary to case through the whole borehole down to the final depth (in these conditions maximum 70 m) because of the borehole’s barring-down process. The double rotary head is dismantled after drilling through the instable levels. A sealing cover is installed on the casing pipes’ head and the drilling continues, using only the drilling string with an ordinary downhole drill hammer. The boring gravel is controlledly drained off from the sealing cover into the container again.

After the drilling string is taken out, the PE collectors with a cap and with a steel grouting pipe are inserted into the borehole. Upward grouting of the borehole's stem from the bottom to the mouth of the borehole is then carried out through the use of the grouting pipe. The grouting mixture is prepared from bentonite, cement and water in a light steel tank in the workplace. The grouting mixture is then pumped through the grouting pipe into the borehole by means of a snail pump, which is a part of the drilling rig. The grouting pipe and finally the casing pipe are both taken out, so that there is nothing left in the borehole apart from the collector. The pipes of the collector are put c. 1 m above the terrain, and are proofed against mud penetration. The firm installing the heat pump carries out a gravity trench in the depth range between 100 and 130 cm, inserts the pipes from the borehole into it, and connects them with the heat pump in the building's boiler-room. Both the earthwork and the borehole are finally covered by soil, so that there is no sign of the borehole left upon the terrain's surface.

4. THE PARTICULAR CASE OF USING THE DOWNHOLE DRILL HAMMER WHEN DRILLING BOREHOLES FOR HEAT PUMPS IN THE AREA OF THE UNIVERSITY HALL AND THE CENTRE OF INNOVATIONAL TECHNOLOGIES (CIT) VŠB-TECHNICAL UNIVERSITY OF OSTRAVA

VŠB-Technical University of Ostrava started to build the University hall and CIT on its premises in Ostrava-Poruba in 2006. The original project presupposed the building's connection to the central heat source with a classical junction exchange station. Air-conditioning was planned to be supplied through cooling compressors. However, this project was revalued in the course of the construction, which brought a new solution based on the substitution of the original heat source and cold sources through heat pumps. According to the project, the heat pumps should be able to cover between 82 and 85 per cent of an average year's building's heat supply. Air-conditioning is planned to be operated during summer months, either by using direct expansion evaporation (by heat removal into the boreholes), or by using indirect expansion evaporation, when the heat pumps work as a cooling system. The heat of condensation is again supplied into the boreholes when necessary. Through the implementation of this project, the University hall and CIT becomes the largest building in the Czech Republic utilizing this alternative energy source.

Boreholes for heat pumps in the given area

The boreholes were realized by drilling rigs NORDMEYER DSB 2/10 on an automobile undercart Mercedes Actros, NORDMEYER DSB on an undercart Mercedes Atego/Axor.

The project stated that 110 vertical boreholes with the final depth of each borehole 140 m need to be drilled for heating the University hall and CIT. The total amount of work thus makes 15 620 m. The boreholes are dislocated in regular networks under two parking places of the University hall and New library buildings.

The construction of boreholes

The boreholes' initial diameter is 152 mm down to a c. 30 m depth (depending on geological conditions). The borehole's final diameter, 120 mm, was drilled in the depth range between c. 30 and 142 m.

The manipulation casing pipe (MCP) (in the cutting design with tungsten carbide buttons) was used for temporary stabilization of the borehole's stem in its upper part, where unconsolidated Quaternary sediments and the geest cover of the pre – Quaternary bedrock occur. The MCP was not cemented. After finishing drilling and fitting out the borehole, the MCP was taken out of it. Further casing was not realized to the borehole's final depth.

The workflow when drilling boreholes

The interval of boreholes for the MCP was drilled through using the technology of rotary-percussion drilling with pneumatic wash-out, namely with continuous casing through the borehole. The double rotary head was used, making the best of the above-mentioned advantage of the contemporary drilling and borehole's casing by means of a drilling string of thick-walled pipes ø 95 mm with the downhole drill hammer COP 44 (Atlas Copco, Sweden), with the chisel Mitsubishi ø 152 mm, and through the use of thick-walled casing pipes ø 146 mm with a casing foot with tungsten carbide buttons. The principle of the implemented technology consists in preboring the well using the downhole drill hammer with the chisel, which operates 8–15 cm in front of the casing pipe. At the same time, the MCP is drilled into this pilot hole. The MCP's rotation eliminates the possibility of its clamping in unconsolidated rocks [3].

The anticipated casing depth was 30 m, however the actual depth was dependent on the geological conditions of each borehole, and it was adjusted operatively by the drilling crew and by the engineering supervision.

After drilling the MCP ø 146 mm into relatively compact rocks, the double rotary head was dismantled and the drilling shaft was taken out.

The interval of boreholes into the final depth was drilled through using two technologies according to the type of rock:

1) rotary-percussion drilling with pneumatic wash-out, without casing; the drilling string ø 95 mm with the downhole drill hammer COP 44 and the drilling bit Atlas Copco ø 120 mm (rocky formations) was used;
2) rotary drilling with pneumatic wash-out, without casing; the drilling string ø 95 mm with a three – way drilling bit ø 120 mm (very soft rocks, clays) was used [3].

To ensure the controlled drain-off of the boring gravel, a mechanical sealing head was installed on the mouth of the MCP. The head is equipped with disks made of a special sealing rubber. The boring gravel was drained off the head through the medium of an abrasion resistance rubber hose DN 100 into the prepared container.

After reaching the final depth and after a proper clearence of the borehole by pneumatic wash-out, the drilling string was taken out of the borehole, whereas the mcp ø 146 mm was provisionally left there.

The borehole's completion

Two couples of PE collectors ø 40 mm connected with a PE cap, each 140 m long, were put on the manual drum in the course of the drilling. The drum with the PE collectors was fixed over the drill pipe ø 95 mm into the clips of the clamping head, by means of which the drum was approximated to the mouth of the cased borehole in such a way that the PE collectors could be inserted smoothly into the borehole. Subsequently, the PE collector was inserted manually into the borehole by means of unwinding off the drum, whereas grouting pipes ø 31.8 mm with the manipulating length 3 m were added at the same time.

After inserting the grouting pipe, the PE collectors were filled with water from the water-service pipe, in order to prevent their drifting out in the course of the borehole's grouting through the use of a cement-bentonite mixture (Cement PC 425, Bentonite SWELL GEL). After the borehole's grouting, the MCP was taken out of it [3].

In the end, the drilling crew carried out a water – pressure-tightness test of the PE collectors in the presence of the client, in order to verify that they are hermetical. The test was carried out by force of the pressure 0,3 MPa. After the stabilization of the pressure in the PE collector (the presence of bubbles, the liquid's compressibility), the test's duration was c. 30 minutes.

The flow of drilling works in the area

The actual drilling of boreholes for heat pumps was carried out between June 23, 2006 and August 20, 2006. The drilling of 116 boreholes (110 boreholes for heat pumps, 5 observation wells, and 1 hydrogeological well) lasted 54 days in total. During this period the drilling facility worked with almost no problem. Only ordinary operational failures occurred, e.g. untight piston rod, defective manometer (pressure gauge), failure of the compressor's starting gear, etc. Moreover, one work injury was recorded.

The working time of an ordinary drilling day lasted 16 hours. During this period the crew of one drilling rig was able to finish drilling and grouting of one borehole, and prepare another one in such a way that the drilling works could continue another day. In the course of one day, pressure tests of the inserted PE collectors were carried out in the presence of the construction supervision.

From the drilling records it is also possible to derive the average drilling time of individual types of hammers used in this area. One drilling rig needs c. 2.5 hours for the first drilling stage down to a c. 30 m depth, when the double rotary head is used. The thickness of sections in which a three – way bit was employed was variable. It ranged between c. 60 and 90 m. The drilling time was up to 4 hours. The final borehole depth was reached by the hammer COP 44 within the time period of 3–4 hours.

5. CONCLUSION

At the present time, quite a number of types of downhole drill hammers employing the rotary-percussion drilling technology are used for drilling boreholes for heat pumps, and not only for them. The currently prevailing trend is drilling under constantly higher and higher pressures. Drilling companies invest considerable financial means into efficient compressors and high-pressure hammers, in order to be able to complete a borehole as quickly as possible, at the price of higher costs. The companies that will adapt their products to this trend will belong to the most successful ones.

Downhole drill hammers have also found use in combination with special drilling technologies. Systems capable of drilling and casing at the same time approve themselves as the most outstanding ones. Drilling with simultaneous casing is dominated by systems enabling the rotation of the whole system, including casing pipes, especially when it is necessary to take the casing pipes out of the borehole later on. A realistic incoming innovation is the application of downhole drill hammers powered by water. The benefit of this technology consists in reaching even double drilling speed in comparison with the drilling using downhole drill hammers powered by air.

In the end, it can be stated that the system of heating villas, flats, halls, and other buildings through the medium of heat pumps stands a good chance, as far as its realization in the future is concerned.

Czech – English translation: Bc. et Bc. Jiří Mazáč.

REFERENCES

[1] Bujok P., Weiper M., Selzer L., Kalus D.: *Appreciation of the geological conditions in the wider surroundings of the University hall (Aula) and the Centre of Innovational Technologies (CIT) VŠB – Technical University of Ostrava*. Ostrava, 2005

[2] Koníček J.: *Utilization of the technology of rotary – percussion drilling in mining conditions and by drilling the boreholes for the heat pumps*. Ostrava, 2004

[3] Kučírek L.: *Project of the boreholes for heat pumps*. Public notice ČBÚ 239/1998 Sb. Paskov, 2006

[4] Mazáč J.: *Special drilling technologies using down – the – hole hammers.* [w:] Zemní plyn a nafta, 40, 1, Hodonín, 1995, 75–81

[5] Sidorová M., Wittenberger G.: *Low – potential Earth Thermal Energy Utilization in Heat Pump Systems.* [w:] Acta Montanistica Slovaca, Košice 1/2006, vol. 11, ISSN 1335–1788, 166–171