Fig. 1: Hollow stem auger drilling in groundwater-bearing sands & gravels.

Geothermal boreholes constructed using hollow stem augers

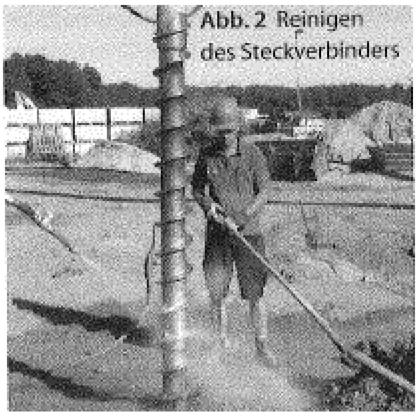
Drilling technology ■ Drilling with hollow augers is a recognised method used in well construction. Today, it is primarily used for wells with low flow requirements, such as garden wells or water level monitoring. It has the advantage of enabling wells to be constructed easily, quickly and cleanly. Due to the simultaneous installation of a protective pipe, there is no danger of borehole collapse when using the hollow stem auger system, even when drilling through ground-water bearing sands and gravels. With the type of geological conditions found in the Rhine plains, this method is also suitable for the installation of geothermal probes.

Many federal states along the Rhine have limited the depths of geothermal probes to suite the local geology, so that the permitted borehole depths are generally between 20 and 60 meters. Due to this limitation, the hollow stem auger (HSA) is a cost-effective and simple drilling method. Krämer Bewässerung/Geobohrung GmbH (irrigation and geo-boring) has performed tests on HSA systems from various manufacturers since 2008 with a variety of diameters and lining methods being used. After two cold winters, results are now available that confirm the performance of the probes.

Technology

An HSA made by STDS-Jantz was used for drilling. The auger sections are joined using octagonal plug and socket connections which are sealed using O-rings. This enables the sections to be connected and disconnected quickly, with low wear. The octagonal plug and socket joints transmit the torque whilst the axial forces are resisted by two splint pins which hold the sections together. These pins must be driven out in order to disconnect the sections. High torques can be transmitted in both directions, without running the risk of sections twisting out or the connections seizing up. Especially with deep boreholes, it is sometimes necessary to be able to reverse at full torque. There is a lost bung in the form of a point at the foot of the HSA .

Fig. 2: Cleaning the plug and socket connections



Prior to the start of drilling this lost bung is located at the base of the auger. An O-ring is again used which seals the bung to prevent the ingress of water. After reaching the final depth, the tip is detached and remains in the bore. For this reason, it is referred to as a lost tip.

Principle
Krämer Bewässerung/Geobohrung GmbH has 50 meters of hollow auger sections, with an overall diameter of 195 mm and an internal bore diameter of 106 mm. A hydraulic rotary head rated at 1,800 daNm is used to turn the HSA. This head is attached to the boom of a 16-tonne excavator in place of the excavator bucket. The torque and speed have proven to be sufficient for boreholes up to 50 meters in depth.

Because there is a constant upward material flow when the HSA is turning, care must be taken to match the penetration rate to the rotary speed. If it is advanced too quickly, the HSA will not be able to flight the material and clog the auger. In extreme cases it must then be rotated in reverse to clear the blockage but this is not a problem for the octagonal connections.

If the penetration rate is too slow for the rotational speed, too much excavated material is flighted resulting in additional sands and gravels being drawn in from the bore walls. For boreholes in sands and gravels, this is one of the most important considerations when using HSA. Underwashing, which can occur with water or air flush drilling methods, can be avoided using HSA by ensuring the correct drill rate and can be easily monitored with the spoil arisings. Work can therefore progress reliably and constantly with HSA drilling while preventing the undesired and uncontrolled formation of cavities.

Additionally no drilling fluids or other additives are required and there is subsequently no residue in the aquifer or flush medium to dispose of.

Geothermal loop
When the borehole has reached the required depth the geothermal loop is then installed using a decoiler suspended from the excavator arm. The probe is then inserted down the smooth, defined wall of the auger stem to the final depth. There are no breakouts or underwashed areas to complicate or prevent the loop installation. A 25 kg weight holds the loop securely to the floor of the borehole and assists in the insertion within the drill stem.

Geothermal energy

Fig. 3: Installing the probe using a decoiler

Fig. 4: Disconnecting the lost tip using water pressure

Fig. 5: Moving the HSA into place when drilling and withdrawing the auger

Recovery

Before the HSA is removed, the lost bung must be released from the drilling head and this is normally done using water pressure. A special adapter is installed between the HSA and the hydraulic motor for this purpose (Fig. 4).

The bung, the weight, and the geothermal loop are pressed out of the HSA simultaneously under a water pressure of up to six bar. A manometer can be used to monitor when the tip has been released from the HSA. After the pressure rises to about six bar, the tip is released and the pressure drops off. A constant flow pressure is established. The constant water flow prevents the drilled material from penetrating into the HSA stem and the probe from jamming in the HSA. The HSA is drawn out by rotating it in the opposite direction. As mentioned previously, it can be reversed at the full driving torque if needed. Part of the drilled material is reintroduced around the flights and the space around the probe is thus securely filled in. Filter gravel can be used if necessary. The borehole is filled with bentonite above and below the aquifer providing the probe with a secure seal.

Immediately after the HSA has been retracted, it can be driven into the adjacent hole (Abb. 5). To do this, the wheeled excavator is positioned so that it can rotate to the next borehole by simply swinging the boom around. This saves a great deal of time and effort during the drilling process.

Grouting of the loop

Grouting of the loop is deliberately avoided because the groundwater along the Rhine has a very high flow rate and the performance of the probe would be reduced by grouting. The grouting of the loops in the first

Ground water table is explicitly described in VDI4640 5.2.3. The experienced drill operator knows that grouting is not possible in sand and gravel within high water flow aquifers. The grout would dissipate into the sands and gravels and reduce the groundwater flow. Flowing groundwater increases both the performance and the regeneration speed of the geothermal loop.

Arrangement
When aligning the individual geothermal bores, it is vital that the groundwater flow direction is considered. It has been found to be advantageous if the loops can be sunk in a line transverse to the groundwater flow direction. This prevents them from interfering with each other through the cold plumes.

For final depths of 50 meters, the bores can be spaced 3 meters apart. Using a HSA, a straight, vertical borehole can be drilled. Because geothermal boreholes are often used for refurbishment projects, where only the front garden is available for boreholes a wheeled excavator is often used and operated whilst parked on the street.

Misapprehensions
Two erroneous ideas persist both in specifiers and in some regulatory offices.
1. Grouting in solid rock boreholes is, without a doubt, an important element of the overall construction of a geothermal loop. Both the connection of the loop to the rock and the sealing of aquifers are ensured by grouting where appropriate. In water-bearing sands and gravels, however, grouting is both impossible and unnecessary.

2. Grouting provides no protection against runout of the brine in case of a leak. A cement suspension can form neither a chemical nor a physical seal with a polyethylene pipe. In order to protect the borehole from surface water, bentonite is used, which has been proven over years in well construction. It is installed above the counterflow filter, just as in well construction. Of course, if grouting is not used, the techniques used must be agreed with the regulatory agencies and the customer.

Results
In recent winters, when temperatures were under ten degrees below zero for many nights, temperature probes were mounted on two heat pumps. The inlet and outlet temperatures were measured over a period of several days. The lowest inlet temperatures were 4 °C, and the lowest return temperatures were 0.5 °C. The most interesting thing about the measurements was that, after power had been cut off by the energy provider for 1.5 hours, the inlet temperatures were 10 °C again. The probes had regenerated themselves due to the groundwater flow.

Boundaries
This shows that the depth limits imposed by regulators do not have to have a negative effect on the performance of the probes. In fact, probes in the upper aquifer have both improved extraction capacity and more rapid regeneration due to the groundwater flow. Regulators and geothermal drillers should address this situation together in order to find optimal solutions. Limitations due to groundwater protection could thus also be recognized and accepted as advantages in using geothermal energy.

Summary
The hollow stem auger will surely remain a method with only limited application for geothermal boreholes. However, for boreholes in groundwater-bearing loose rock in particular it is a reliable and efficient drilling method. Under other geological conditions, such as in clays and silts, the method is also conceivable and has already been performed. This article is intended to promote the exchange of experience and to stimulate discussion.

Illustrations: Krämer Bewässerung/Geobohrung GmbH

Author:
Edelbert Krämer
Krämer Bewässerung/Geobohrung GmbH Gewerbering 6 76706 Dettenheim
Tel.: 07255 7193-10
Fax: 07255 7193-11
Email: e.kraemer@kraemer-bg.de
Internet : www.kraemer-bg.de