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Research Project:

Drilling techniques for the installation of ground source heat exchangers and development of tools for technology and economic planning

Summary

Chair of Project: 
Univ. Prof. Dr.- Ing. R. Rauh
Universität Siegen - LuFG Baubetrieb
Paul-Bonatz-Str. 9-11, 57068 Siegen

Project Team: Dipl.-Ing. T. Becker, LuFG Baubetrieb, Universität. Siegen
Dipl.-Ing. T. Scherer, Institut für Konstruktion, Universität Siegen
Dipl.-Ing. A. Scholl, Institut für Geotechnik, Universität Siegen
Dipl.-Ing. M. Brockmann, IEK, Abt. Gebäudetechnik, Universität Hannover

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1 Research objective

Rapidly increasing energy prices and numerous support and financing programmes have created a strong demand for geothermal heating installations. Geothermal heat is mostly extracted by means of borehole heat exchangers. Exclusively experienced drilling companies should be in charge of drilling ground coupled systems, e.g. well drillers. However, over the last few years it could be observed that an increasing number of inexperienced players have entered this prospering market for geothermal installations. Frequently these newly established companies were founded by people coming from the plumbing industry. They mostly restrict their drilling activities onto the installation of heating systems up to 30 kW and a maximum depth range of 100 m below surface. In general, entering the drilling market is simple for companies who have none or very little knowledge about issues of geology or drilling technology. This is because the ruling regulation, i.e. the VDI 4640 promotes a basic standard for the installation of small geothermal systems. The user's lack of experience significantly increases the risk for geological and/or technological failure of the system. The risk level becomes further increased if there is not an independent planner involved in the project organisation. The attached research study gives evidence that this is frequently the case. In the past, large-scale accidents have occurred when ground source heat exchangers were installed. This does not only show how important it is to follow standards for the drilling process, but also demonstrates the impact of deficits in construction quality as well as in the area of managing planning activities and site supervision.

In order to find a holistic approach toward promoting ground source heat exchanger technologies, the presented research project takes aspects of process technology, economics and quality into account. The goal is to provide a contribution for achieving a higher level of quality within the field of installing ground source heat exchangers.

To satisfy the criteria of application-orientation, the following sub-goals were developed within the framework of this overriding objective. These sub-goals are technical and economic planning aids designed for practical use:

- Determination of criteria for the application of drilling techniques and formulation of a catalogue which lists capability characteristics for planning the drill rig employment.
- Identification of areas of potential fault in the construction process.
- Systemisation of tasks for the installation of ground source heat exchangers.

- Design of technically detailed specifications that are in line with the VOB regulation (= contract procedure for building works).
- Development of tools for the calculation of costs.

2 Execution of the research project

The following chapter describes the content of four separate work packages (part A - D) which were determined to address previously stated sub-objectives.

In **part A „device and process engineering“** drilling techniques for the installation of ground source heat exchangers were analysed and recommendations given. The advantages and disadvantages of different drilling techniques were identified and their application limits defined.

Technical data of drill rigs for vertical and slanted drilling (all of them available in the market) were provided by the manufacturers following their corresponding methods of explanation. This makes it impossible for drilling companies and start-ups to directly compare the performance data. In order to remedy this situation, special data sheets for geothermal drilling rigs were designed. Then the performance data of drill rigs were analysed which were produced by German manufacturers. By means of the data sheets, it could be proven that the scope of the technical specifications published by the manufacturers were insufficient in many cases. For example: the force available at the drill head correlates to the engine's number of revolutions. Hence it is not the individual parameters by themselves which are of relevance – as mostly published by manufacturers - but the relationship between these two parameters which allows for a sound estimate of the torque available at the drill head.

It could be shown that problems concerning the consistent definition of technical specifications impact the proper ordering of drilling machines as given in the official "list of construction equipment" (German: "Baugeräteliste (BGL)"). Also the correlation between specifications and costs as stated in the BGL was critically reviewed. The maximum torque available at the drill head is not a meaningful indicator by itself. Thus it is recommended to use the investment costs as a BGL classification parameter for construction equipment.

Actual projects were documented in **part B „project documentation“**. A standardised documentation form was designed to consistently document technical and economical data. By taking into account expenditures of time and utilised resource capacities, the work processes and the efficient utilisation of equipment and crew was evaluated. The data

recorded during the project documentation were used to verify the results of the post calculation of production costs in part D of this research project.

The data from these projects clearly showed that carefully taking into account the local conditions is a prerequisite for drilling in an existing property. Confined space poses a particular challenge for installing ground source heat exchangers. To work under such conditions, drill rigs must be compact in design, manoeuvrable and suitable for cross-country transport. The jobsite set-up was not centrally managed. It was common that peripheral equipment and auxiliary devices, needed for operating the drilling rig, were positioned, whenever possible, on access roads or driveways. The connection to the drilling rig was done with utility lines.

Mostly flush drilling techniques were applied at the jobsites. Rotational flush drilling was done at most jobsites when the underground was of a soft to medium consistency. The standard for rock conditions is DTH drilling (down-the-hole) because the penetration rate is high and the necessary power requirements relatively low.

The project time needed for installing ground source heat exchangers was comparatively short. To provide a single-family house with geothermal energy in an average two to four bores are drilled down to 100m below surface. Normally one week is needed to drill the boreholes and complete the heat exchanger installation. Yet relatively small-scaled disturbances in the workflow can cause significant delays due to the short project times. This impacts subsequent projects since the scheduling from drilling companies is usually very tight. More than half of the documented projects were affected by significant delays. The problems were mostly caused by mechanical breakdowns and problems in completing the boreholes.

The analysis of contract data revealed that drilling companies have frequently reserved the right to change existing plans; for example by splitting up the overall drilling length into shorter bores in cases where it was impossible to reach the initially planned bore depth. In some cases the bore was even discontinued whereby a borehole heat exchanger of reduced length was installed, although there was no revised heat extraction calculation. The findings at the observed jobsites established that the measures of project control and quality assurance are still insufficient and that there is urgent need for improvement.

Among other things, quality assuring measures are taking samples of drill cuttings continuously, testing the grout density and to pressure-test the heat exchangers in accordance to the VDI 4640 regulation. These measures serve the need for documentation of work carried out as required by the owner and legal authorities which will assure functional safety as well as the environmental compatibility of the geothermal system. It was found that many quality assuring measures (test and sampling activities) was not been carried out on

type and scope according to the standards. Even the work of certified drilling companies was flawed.
The results of the quality analysis regarding the execution of construction work can also be explained by the fact that in many of the documented projects, no specialist planner was involved. Instead the owner simply asked the drilling company for an offer. By doing so, key elements of the pre-planning phase (partly the entire planning) were transferred to the drill company as the executing entity. In this way of project management a conflict of interest in the area of project management is pre-programmed, which most likely leads to disadvantageous consequences for the quality of work committed. This is because the tasks of planning, execution and control are in the same hands.
The evidence found about the way geothermal projects were often handled on the jobsite leads to the recommendation to clearly define the technical scope of supply in order to improve the quality of construction work. This represents an instrument for quality control if formulated as a work description.

Thus, a significant part of the research project comprised the design of technically detailed work descriptions. This was done in **part C: "work descriptions".**
The VOB/C provides only a few specific statements about tendering for the installation of ground source heat exchangers, as the analysis revealed. On the other hand it was found that many of the example texts offered on the market for the description of work, did not conform in many aspects to the set of rules as specified by the VOB. A typical example within this context is the summary of different services under one position (e.g. drilling, borehole completion and installation of connection pipes), which is not allowed in accordance to VOB/A § 7 chapter 12.
Within the framework provided by part c „work descriptions" a special, practice-oriented system was designed to ensure that contractual work descriptions regarding the installation of borehole heat exchangers can be technically detailed while being in line with the VOB.
The results of this work can be used as standard form for actual tender calls. For drilling companies, this simplified calculation thereby allows the customer to more easily compare and evaluate the offers.

In part D: „calculation of costs", the construction costs were calculated for the ground source heat exchanger installation work. These calculations can be used as a model calculation for the contractor's quotation thereby factoring cost for a given project based on predetermined surcharges. In order to support the application of these tools in SME's, the necessary calculations were performed in Excel. The cost calculations are based on previously prepared modular standard texts for writing work specifications.

The advantage for the drilling company is obvious: consistently generated cost calculations greatly facilitate the internal cost comparison of different projects. Past experiences will influence recent offers. Thus the compilation of installation expenses at cost for installing borehole heat exchangers is directly supported by the calculation tool developed in this research project.

The identification of cost intensive parts of the project is of significant importance for economic project planning and execution. The analysis of the differently impacting planning and process approaches with regard to the cost situation was based on case studies. It could be shown that expenses related to drilling and borehole completion represent the biggest share of the total hole forming and installation costs. These results emphasise the importance of the sound selection of drill rig and drilling technology. Drilling techniques which require a lot of peripheral machinery, e.g. down-the-hole drilling techniques where an extra compressor is necessary, balance the disadvantage of increased machinery costs with a faster drilling progress.

Summary of results

The research project revealed that the currently existing organisational and technical measures of quality control are not sufficient in the area of geothermal collector drilling. Yet many of the companies taking part in the project documentation either possessed a seal of approval or achieved certificates in accordance with DVGW-W- 120 standard numerous whereby significant shortcomings became obvious. Hence it is necessary to introduce a system of quality assurance for planning and drilling boreholes to support the further prosperous development of geothermal technologies in the long-term. Within this context, it could be useful to involve privately accredited experts in water management as already practised by Bavarian authorities should geothermal water/water systems require governmental approval. These measures are necessary in order to protect groundwater and underground.

Within the framework of in this research project, the following application-oriented results were identified regarding the task distribution between contractor and owner:

1. Design of a data sheet in order to compare the performance specifications of drilling rigs.
2. The formulation of technically detailed work specification texts according to VOB standards
3. Development of calculation modules in order to determine costs.