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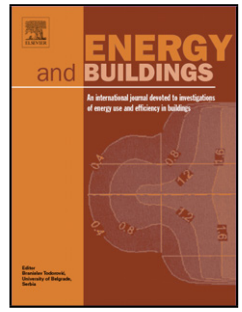

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Simplified Heat Transfer Analysis Method for Large-Scale Boreholes Ground Heat Exchangers

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Highlights

・A method to simplify analysis of heat transfer of large scale boreholes heat exchangers is proposed.
・Representative boreholes matrix can be used to replace the original large-scale boreholes for heat transfer analysis.
・The representative boreholes matrix can be determined by thermal analysis of a single borehole.

Abstract: A simplified heat transfer method to analyze the thermal performance of large-scale boreholes ground heat exchangers (GHE) has been proposed considering the geometric symmetry of borehole layout. Taking the ground heat exchanger with matrix layout of vertical boreholes as the example, the ground temperature distribution is analyzed under the conditions of no groundwater advection by the proposed simplified method. Based on the simulation results, a representative boreholes matrix can be proposed to replace the original large-scale ground heat exchanger for heat transfer analysis. Meanwhile, the results show that the representative boreholes matrix can be determined by the thermal influence radius of a single borehole by assuming all the boreholes have the same thermal loads and also in the same geological conditions, geometry parameters and operating conditions. It is indicated that the thermal influence radius of a single borehole can be obtained according to the allowed error range of the ground temperature responses, which can correspondingly determine the number of the representative boreholes matrix.

Keywords: large-scale boreholes; ground heat exchangers; heat transfer analysis; simplified method

0 Introduction

The ground-coupled source heat pump (GCHP) systems using the shallow underground geothermal energy to provide space heating and cooling have been widely applied in commercial and residential buildings in China, among which the most widely applications are the GCHP systems with vertical boreholes. The heat transfer process of the ground heat exchanger (GHE) with vertical boreholes is relatively complex especially for the system with a great number of boreholes and long-term operation because of the inevitable thermal interference phenomenon among adjacent boreholes [1]. The most currently utilized methods of the GHE are based on the heat transfer model of a single borehole in surrounding ground under the assumption of the constant thermal properties of the ground. Then the superposition principle is employed to analyze the ground temperature responses caused by all the boreholes constituting the GHE. The common heat transfer models for a single borehole include analytical models such as the line heat source model [3,4], cylindrical heat source model[5] and numerical models[6-8]. It is noticed that some large-scale GHE systems usually include hundreds or even thousands of boreholes, and the thermal analyses of such systems may be computationally inefficient due to the large number of boreholes involved. Therefore, the conventional models based on the single borehole model and the superposition principle are inconvenient for the design of the large-scale GHE systems in engineering applications.

In order to reduce the tedious computation workload, some simplified calculation methods have been proposed in previous studies. Xu [9] and Li [10] made a simplified assumption by taking the heat released by boreholes as the inner heat source of the buried pipe area. This method may reduce the complexity of calculation and save substantial computation time, yet it might result in less accurate temperature responses around the boreholes because the heat released intensively from the buried pipes was assumed to be a kind of uniform inner heat source in the whole buried pipe area. Zhang [11] conducted a study on the underground temperature variations of two different borehole configurations (i.e. 3×3 and 4×4 matrix layouts) with the operation time of dozens of days. The author drew a conclusion that a representative boreholes matrix of 3×3 can be employed to substitute the large-scale borehole GHEs according to