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Research Article

Modeling of foundation heat exchangers—Comparison of numerical and analytical approaches

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Abstract

Foundation heat exchangers (FHXs) are an alternative to more costly ground heat exchangers utilized in ground-source heat pump (GSHP) systems serving detached or semi-detached houses. Simulation models of FHX are needed for design and energy calculations. This paper looks at two approaches used for development of simulation models for FHX systems: a simplified analytical model and a detailed numerical model. The analytical model is based on superposition of line sources and sinks. The numerical model is a two-dimensional finite volume model implemented in the HVACSIM+ environment. Both the analytical and numerical models have been validated again experimental results from a test house located in Oak Ridge, Tennessee. Six geographically diverse locations are chosen for a parametric study; results of the two models are compared, and differences between the results are investigated.

Keywords

foundation heat exchanger,
ground-source heat pump,
simulation,
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Building Systems and Components

1 Introduction

Ground source heat pump (GSHP) systems are widely used in residential, commercial and institutional buildings due to their high energy efficiency. Ground heat exchangers used with GSHP systems are typically either placed in trenches (horizontal) or in drilled boreholes (vertical). However, the high costs of trench excavation required for horizontal ground heat exchanger (HGHX) installation and the high costs of drilling boreholes for vertical ground heat exchangers are often a barrier to implementation of GSHP systems. In the case of net zero energy homes, or homes approaching net zero energy, the greatly reduced heating and cooling loads, as compared to a more conventional construction, make it possible to use a ground heat exchanger which is significantly reduced in size.

Recently, a new type of ground heat exchanger that utilizes the excavation often made for basements or foundations has been proposed as an alternative to conventional ground heat exchangers (Christian 2007; Shonder and Spitler 2009). These ground heat exchangers, referred to here as foundation heat exchangers (FHXs), are placed within the excavation made for the basement and foundation along with other excavations used for utility trenching as shown in Fig. 1. By locating the tubes in the excavation made for the basement, FHXs can significantly reduce installation cost compared with the conventional ground heat exchangers.

To date, foundation heat exchangers have been successfully installed in several homes in eastern Tennessee (Christian 2007; Shonder and Spitler 2009). The overall goal of this work is to develop models that can be used to examine the potential of utilizing foundation heat exchangers in future homes, with data for validation drawn from experimental measurements at the existing houses. Recently, several works have shown the potential for numerical modeling of FHX systems. Spitler et al. (2010) developed a two-dimensional finite difference model which was used to study the sorts of climates and building types for which an FHX is a feasible alternative in European countries. Cullin et al. (2012) extended this analysis with an improved numerical model to generate a map of feasible locations for foundation heat exchangers in the United States. This work also showed that the behavior of the FHX is tightly coupled to the heat transfer through the basement, meaning that any numerical

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