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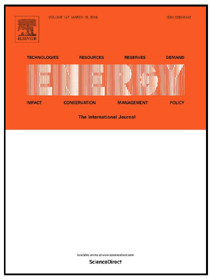

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Recycling construction and industrial landfill waste material for backfill in horizontal ground heat exchanger systems

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Abstract

This research experimentally and numerically investigates the possibility of recycling some low cost construction and industrial waste landfills materials as potential backfills in horizontal ground heat exchangers (HGHE). The aim of this study was to compare the temperature distribution development in different backfill materials with respect to time. The tested materials include sand, crushed basalt, broken brick, crushed concrete, and metallic by-products including copper slag, aluminium slag, mill-scale and iron ores (fine and pellets). Initial thermal testing on these materials in an environmental climatic chamber indicated concrete and crushed brick had similar performance to sand, whereas metallic materials had better performance by up to 77% improvement compared to sand. Various percentages of the backfill material (20, 40, 60, 80 and 100%) blended with the remaining percentage of sand showed that the higher the percentage addition of the waste material, the better the heat storage of the enhanced sand. Particle size distribution was also a significant parameter in backfill selection, where medium sized particle sizes (1.18-2 mm) performed 92% better compared to course and fine gradations of the same material. An experimental set-up of a HGHE system was then constructed and filled with the best performing backfill materials to determine the heat storage and release processes on the thermal performance of the system. The paper also reports results from a transient three-dimensional finite volume model developed in ANSYS Fluent 17.2 computational fluid dynamic (CFD) software of a thin section of a HGHE. The experimental and numerical model were used to predict and analyse the temperature distribution developing within the surrounding backfill material with respect to charging (heating) and discharging (extracting heat) modes of the HGHE. Results obtained from both experimental and numerical studies show the temperature range and duration of hot water produced from the system were in line with low temperature space heating guidelines and that mill-scale, copper slag and aluminium slag were the best backfill materials, where the thermal capacity of the HGHE system can be doubled using these materials, compared to the use of sand alone. Congruence between the numerical simulations and experimental data was found.

Keywords: (Energy, Horizontal ground heat exchanger, Waste materials, Temperature distribution, Space heating)

1. Introduction

1.1 Background

Growing environmental concerns including climate change, air pollution and depletion of natural fossil resources require urgent long term sustainable development actions (Dincer and Rosen, 2004; Ozyurt and Ekinci, 2011; Diaz, Sierra and Herrera, 2013). Energy supply, and associated energy prices, are gradually becoming more sustainable by introducing renewable energy resources, particularly solar, wind, hydropower and geothermal energy (Bourrelle, Andresen and Gustavsen, 2013; Esen and Yuksel, 2013; Lund *et al.*, 2016). Recent developments into incorporating these resources to provide heating and cooling demands of buildings is becoming more popular in the developing world. Solar photovoltaic and thermal collector technologies have been proven to provide sustainable electricity and heat to homes, however, the mismatch between the time the energy is available (sunlight hours) and the time it is required (demand period) has led to further developments in thermal energy (heat) storage systems (Ozgener and Hepbasli, 2005; Henning, 2007; Axaopoulos and Fylladitakis, 2013; Esen and Yuksel, 2013; Gao *et al.*, 2013; Emmi *et al.*, 2015; Awani *et al.*, 2017).