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Experimental validation of a serpentine horizontal ground heat exchanger model

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This study presents the results of an experimental validation of a serpentine horizontal ground heat exchanger (HGHE) model. The proposed model of the serpentine HGHE is a semi-analytical transient model which calculates heat exchanges with the surrounding soil. With a given set of input parameters (soil, fluid and pipe thermal properties, geometry) along with the volume flow rate and the input fluid temperature, the model provides the output fluid temperature and the soil temperature along the pipe.

The model is validated using a recently built experimental facility for shallow ground heat exchangers installed by the BRGM in Orléans, France. Prior to the validation test, the unknown parameters are identified and obtained by measurement or calculation. These parameters are the soil thermal properties (conductivity and diffusivity), the undisturbed ground temperature and the fluid-pipe thermal resistance.

To determine the soil properties, soil samples are extracted from the ground and thermal property measurements are performed at different humidity levels. Two correlations are then established giving the soil thermal conductivity and diffusivity as a function of the humidity ratio. During an actual test these correlations are used along with a moisture content measurement to evaluate the soil thermal properties. The undisturbed ground temperature is obtained by means of a circulation test before the experiment. This temperature corresponds to the fluid temperature at the outlet of the HGHE. The fluid-pipe thermal resistance is calculated after characterization of the flow (turbulent flow for this test) by determining the Nusselt number using the Colburn correlation.

The HGHE used for the validation consists of 8 branches joined to form a serpentine with a total length of 100 meters. The validation test consists of injecting a constant temperature fluid (40°C) at a constant volume flow rate of 0.77 m^3/h during 80 hours. The output fluid temperature and the soil temperature along the pipe are recorded and compared to the prediction of the serpentine HGHE model. The soil temperature measurement is performed using an innovative technique with optical fiber cables used as distributed temperature sensors. This technique can give accurate temperature measurements. However, in the present case, the location of the cable with respect to the pipe is not known precisely. This imprecise position near a strong temperature gradient near the pipe gives rise to inaccurate temperature measurements. Thus, this recorded soil temperature can only confirm the trend given by the model prediction. In contrast, the output fluid temperature measured by a Pt100 thermometer matches well the prediction and validates quantitatively the proposed model.