STADT MARKTREDWITZ

Bayerisches Staatsministerium für
Umwelt und Verbraucherschutz

Bayerisches Landesamt für
Umwelt

9. Marktredwitzer Bodenschutztage

Bodenschutz beim Planen und Bauen

Informations- und Diskussionsforum für Wissenschaftler und Anwender
mit Tätigkeiten im Bodenschutz

12. bis 14. Oktober 2016
Marktredwitz, Bayern

Schirmherrschaft:
Ulrike Scharf MdL
Bayerische Staatsministerin für Umwelt und Verbraucherschutz

ITER Project: How physical-thermal properties of soils affect the heat transfer in very shallow geothermal application

DI SIPIO, Elosia, BERTERMANN, David
Lehrstuhl für Geologie, FAU Erlangen-Nürnberg,
Schloßgarten 5, 91054 Erlangen
E-Mail: eloisa.di.sipio@fau.de

Abstract: *In the near future the shallow geothermal energy resource is becoming increasingly important as renewable energy resource for heating/cooling residential and tertiary buildings.*

Therefore, it is worthy of interest to get a better comprehension of how the different soil typologies (i.e. sand, loamy sand...) affect and are affected by the heat transfer exchange with heat collectors, especially when horizontal ones (very shallow geothermal installations) are adopted.

Keywords: very shallow geothermal systems, thermal conductivity, horizontal collectors, soil properties

Schlagworte: flache geothermische Anlagen, Wärmeleitfähigkeit, Erdwärmekollektor, Bodenkennwerte

1 Relationship between thermal and physical properties of soils

The thermal behavior of soils depends on several factors, as the grain size, the water content, the mineralogical content, the ground temperature, the organic matter presence, the texture (FAROUKI 1981; SAXTON ET AL 2006; HIRAIWA ET AL 2000; GONZALEZ ET AL 2012; NIKOLAEV ET AL 2013).

Therefore, the performance of very shallow geothermal systems, as horizontal collector systems or special forms, refering to the first 2 m of depth from ground level, is related to the kind of soil locally available, and mostly by their soil moisture content and grain size. In fact, as shown by the recently ended ThermoMap EU Project (http://www.thermomap-project.eu/), an improvement of heat conductivity transfer is expected when the soil water content is increased (BERTERMANN ET AL 2014 + 2015). In addition, a small addition of a natural additive (i.e. clay) to a coarse soil (i.e. sand) leads to an increase of its thermal conductivity (Farouki 1981; Smits et al 2010; Nikolaev et al 2013).

Taking into consideration these premises, one of the main aim of ITER Project (Improving Thermal Efficiency of horizontal ground heat exchangers, http://iter-geo.eu/), funded by European Union, is to understand how to enhance the heat transfer of the sediments surrounding the pipes, considering the interactions between the soil, the horizontal heat exchangers and the surrounding environment, avoiding needles excavated soil.

The preliminary results of the project, based on laboratory and field test data, are here presented.

The laboratory activity foresees to analyze the physical-thermal properties of two natural sands, characterized by different grain size, alone and mixed with two clay additives, under different water content percentages and different consolidation degree. In addition, also a natural sandy clay sediment is tested. The same parameters are monitored in a test site, located in Eltersdorf, near Erlangen (Germany), where 5 Helix heat baskets are installed in an horizontal way (3m length) instead of the traditional vertical option were located at a depth of 0.6 m below ground level and the trenches were filled with 5 different materials, ranging from natural material to commercial products, analyzed also in laboratory.

2 Material and method

Main parameters determined in laboratory and on test field are:

- *thermal conductivity* by thermal properties analyzer (KD2Pro apparatus, Decagon Devices, Inc.), operating according to the transient line source method (ASTM D5334-08);
- *moisture content and bulk electrical conductivity* (measured simultaneously) by time domain reflectometry (TDR) device (TRIME IMKO GmBH).
- *electrical resistivity* by using a high precision instrument for determination of soil resistivity (4point light hp earth resistivity meter, Lippmann Geophysikalische Messgeräte)
- *bulk density* is determined on duly collected sample according to the DIN 52102;
- *water content* is determined on duly collected sample according to the DIN 18121;

Grain size and mineralogical content analyzed for each mixture are now under processing and are being completed in the near future.

3 Results and discussion

According to the laboratory working plan, more than 100 samples have been prepared, gradually varying the reference material (pure or with additive), the kind of additive (2 different clay), the water content (fresh water added gradually to the dry unconsolidated sediment in incremental steps) and the pressure applied. The relationship between thermal conductivity (λ) and volumetric water content (θ) shows for all mixtures and at each load an improvement of heat transfer with the increase of the water content, until oversaturated condition are reached.

In contrast to the test site in Eltersdorf, measurements of thermal conductivity, moisture content and electrical resistivity have been collected monthly since November 2015. At the time of paper writing, seven data acquisition campaigns (16.11.2015; 25.01.2016; 22.02.2016; 05.04.2016; 26.04.2016; 31.05.2016; 01.07.2016) were completed and the preliminary results for thermal conductivity and moisture content were collected.

The mixtures specially created for the project reveal a better performance than the pure material only, both in surface (10 cm depth from the ground level) and at depth (20 and 40 cm from the ground level). However a decreasing of thermal conductivity values is noticed from top to bottom in each sector where the new compounds were adopted, due probably to differences in disposing the material in the trench. Therefore, guiding criteria for the emplacement of the material must be defined in order to avoid differences in bulk density able to affect the thermal performance of the material itself.

4 Acknowledgements

This project has received funding from the European Union’s Framework Programme for Research and Innovation Horizon 2020 (2014-2020) under the Marie Skłodowska-Curie Grant Agreement No.[661396-ITER].

5 References

BERTERMANN, D., KLUG, H., MORPER-BUSCH, L., BIALAS, C. (2014): Modelling vSGPs (very shallow geothermal potentials) in selected CSAs (case study areas). Energy. 71: pp. 226-244.

BERTERMANN, D., KLUG, H., MORPER-BUSCH, L. (2015),: A pan-European planning basis for estimating the very shallow geothermal energy potentials. Renewable Energy. 75: pp. 335-347.

FAROUKI, O.T. (1981): Thermal properties of soils - Cold regions research and engineering lab, Hanover NH, No.CRREL-MONO-81-1

HIRAIWA, Y.; KASUBUCHI, T. (2000): Temperature dependence of thermal conductivity of soil over a wide range of temperature (5–75 °C). European Journal of Soil Science, 51.2: pp. 211-218.

GONZALEZ, R. G., VERHOEF, A., VIDALE, P. L., MAIN, B., GAN, G., WU, Y. (2012): Interactions between the physical soil environment and a horizontal ground coupled heat pump, for a domestic site in the UK. Renewable energy. 44: pp. 141-153

NIKOLAEV, I. V., LEONG, W. H., ROSEN, M. A. (2013): Experimental investigation of soil thermal conductivity over a wide temperature range, International Journal of Thermophysics. 34(6): pp. 1110-1129.

SAXTON, K. E., RAWLS, W. J. (2006): Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil science society of America Journal. 70(5): pp. 1569-1578.

SMITS, K. M., SAKAKI, T., LIMSUWAT, A., ILLANGASEKARE, T. H. (2010): Thermal conductivity of sands under varying moisture and porosity in drainage–wetting cycles. Vadose Zone Journal. 9(1): pp. 172-180