Quantifying Irish Soil Thermal Properties – a reference for improved ground source collector design

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ABSTRACT

The Irish Soil Thermal Properties (ISTP) project set out to quantify the thermal properties of Irish soils and subsoils, building on the information of the Irish Soil Information System and further develop a national reference dataset that will facilitate the sizing of ground source collectors. The new data includes thermal conductivity and thermal resistivity, density, porosity and grain size of soils across Ireland. Horizontal closed loop collector suitability maps developed by Geological Survey of Ireland have shown the need for better characterisation of thermal conductivity and moisture content of soils and subsoils. These new data, combined with the EPA/Teagasc and GSI datasets, can provide guidelines for ground source system installation in soil and improve mapping of shallow geothermal energy resources in Ireland. One of the most common problems in the installation of a ground source collector is the reference values of heat delivered per meter of collector installed. Incorrectly sized ground source collectors can have adverse impacts on the environment and can result in increased running costs and CO_2 emissions.

1. GEOTHERMAL IN IRELAND

An increased focus on the development of renewable energy sources for the purpose of space heating and cooling in Ireland, as well as for commercial and industrial applications, has seen an increase in the development of shallow geothermal and ground source technologies since 2007. Despite a steady increase of installed ground source systems between 2007 and 2009, a modest increase from 2010 to present has been recorded as result of the economic downturn during this period. The growth rate of the shallow geothermal sector after 2010 remains poor. A lack of information on potential resources and a lack of detailed data to facilitate design remain, despite some recent project initiatives focusing on addressing these issues.

Data on subsurface thermal properties in Ireland has been the focus of recent research carried out at UCD (Hemmingway, 2012, McGuiness, 2013, Hemmingway and Long, 2012 and 2013 and Mc Guinness et al, 2014), through the SFI funded IRETHERM project and more recently through the SEAI funded Irish Ground Thermal Properties project (Pasquali, 2014). These projects are mainly focused on bedrock thermal properties for vertical closed loop collectors.

The Geological Survey of Ireland (GSI, *In Press*) has developed draft horizontal closed loop (HCL) collector suitability maps as a first effort in evaluating the widespread potential of Irish soils and subsoils for the use of HCL collectors in ground source systems. The HCL maps were developed using soil thickness and moisture content data to determine suitability for the installation of a HCL collector.

The aims of the ISTP project are to build on this work by improving the data used to compile the HCL suitability map. The measurement of density, porosity and thermal conductivity of specific soils and soubsoils will provide base data to improve collector design and performance. These properties determine the amount of linear meters of collector required to ensure the sustainable operation of the ground source heating system and to meet the energy demand of the end user. Incorporating this data with the soil thickness and moisture content datasets will give a comprehensive view of the potential for HCL heating systems across Ireland.

The 2015 phase of the Irish Ground Thermal Properties project produced vertical closed loop sizing tables modelling heat extraction from the ground. Different heat pump installed capacities; full load equivalent running hours of the system, ground temperatures and the thermal conductivity of the bedrock were modelled to produce the collector sizing tables. Given the correct parameter values the approximate W/mK in a particular location can be determined.

The ISTP soil thermal properties database will facilitate the production of sizing tables for HCL collectors to give designers an indication of the correct thermal properties reference values.

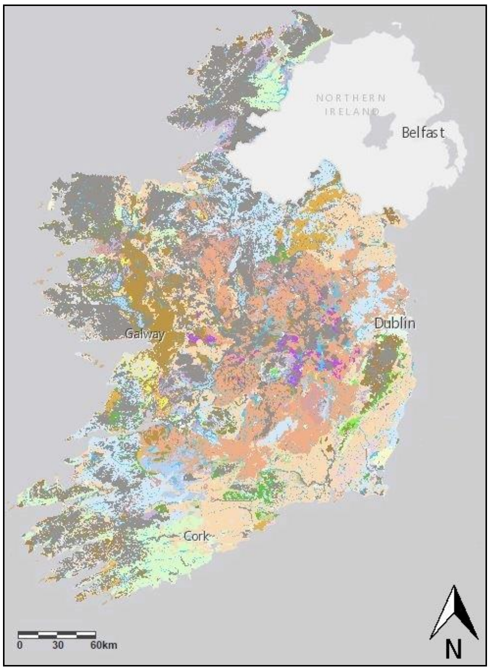

Figure 1: The Irish Soil Information System Map (Teagasc, 2014)

2. MATERIALS AND METHODS

2.1 Mapping

The study is investigating and measuring a representative number of Irish soils in an effort to quantify all varieties of soil compositions across the country. A comprehensive review of mapped Irish soil data has been carried out in order to identify a representative set of soil samples for collection and testing. This review focused on the Irish Soil information System developed by the EPA and Teagasc (Figure 1) as well as the more detailed historical counties soil mapping data produced by Teagasc (Figure 2).

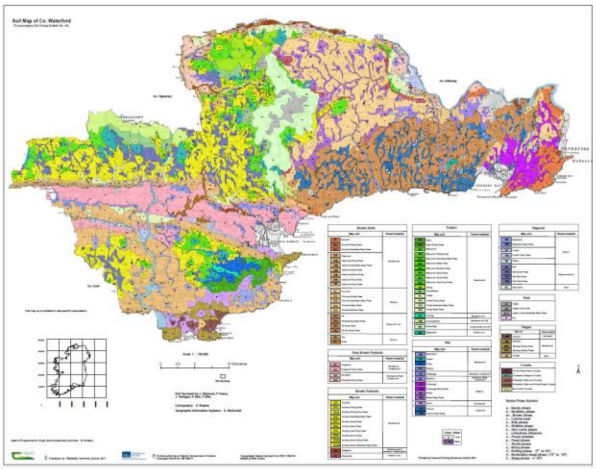

Figure 2: Soil Map of County Waterford (Teagasc, 2011)

These two data sets were used in conjunction with one another to accurately target specific soil formations across the country.

2.2 Sampling and Testing

A field work programme is being implemented based on the selection of representative sites identified through the mapped data review. The ultimate selection of the sites was based on identifying areas where undisturbed soil samples could be collected.

The undisturbed soil sampling is being carried out to ensure the in-situ structure of the soil is intact at the time of testing and to allow for more accurate test results to be obtained, as the density of soils can alter the thermal properties (Figure 3).

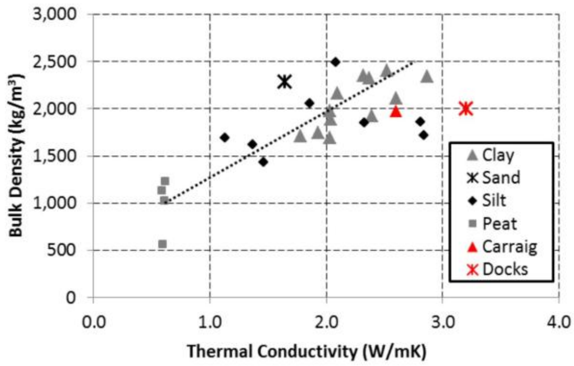

Figure 3: Dry Density vs. Thermal Conductivity (Hemmingway 2012)

A specialised auguring system is used to collect the samples (Figure 4) whereby undisturbed cylinders of soil 30cm in length and 4cm in diameter are collected encased in a plastic lining ready for testing (Figure 5).

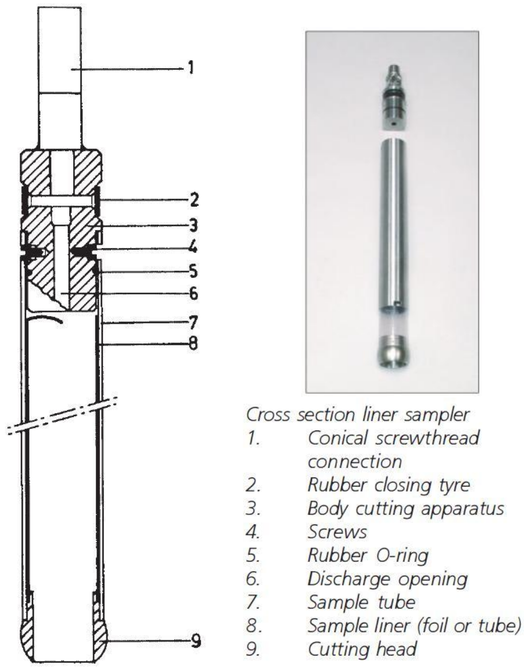

Figure 4: Auger apparatus used to collect 30x4cm undisturbed soil samples (Eijelkamp 2005)

Figure 5: 30x4cm Soil sample encased in plastic lining.

The thermal properties tests are performed to the 'ASTM D5334 – 14 Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure'. Once collected the samples are stored and transported to the School of Civil, Structural and Environmental Engineering at UCD for laboratory testing.

The laboratory sample testing includes determination of porosity, moisture content, density and thermal properties tests.

Thermal conductivity measurements are measured in the undisturbed samples, fully saturated conditions and at 0% moisture content. A total of three measurements are taken in each case and results averaged for each sample. This testing procedure is adopted to increase the accuracy of the data set whilst also accounting for the seasonal variations in moisture content of each soil and how the thermal properties act in response to changing moisture contents.

3. DISCUSSION

Quantifying the ground thermal properties for the design of ground source heating systems has been the focus of several research projects to date by Hemmingway 2012, McGuinness 2013, and Pasquali 2014.

Uptake of ground source heating systems in Ireland has been slowly growing with HCL systems being preferred, where possible due to lower capital investment costs compared to vertical closed loop collectors.

The data currently available on ground thermal properties in Ireland are heavily weighted towards bedrock geology. Only a limited reference dataset developed (Hemmingway, 2012) with few data available representing specific soil formations has been published (Table 1). The lack of soil thermal properties data makes the design of horizontal collectors difficult often resulting in inefficient systems.

Accurate soil thermal properties linked to specific soils types will be available for reference from the ISTP dataset following the completion of the field work programme.

Primary Soil Type	Secondary Constituent	Water Content (%)	Dry Density (Kg/m3)	Bulk density (Kg/m3)	TC (W/mK)
Silt		51	1225	1852	2.33
	Sand	28	1344	1720	2.84
		28	1946	2493	2.08
		60	1015	1619	1.37
	Clay	49	1254	1865	2.81
		49	1134	1694	1.13
		42	1547	2201	1.46
	Clay	30	1583	2055	1.86
Peat		666	73	559	0.6
		555	172	1128	0.59
		462	181	1020	0.61
	Silt	233	367	1224	0.62
Clay		18	1680	1974	20.3
		16	1627	1886	20.4
		18	1838	2166	2.1
		20	1415	1691	2.03
		14	1681	1920	2.39
		16	1473	1710	1.78
		15	2082	2320	2.37
		14	2067	2354	2.32
		16	2072	2407	2.52
		18	1988	2342	2.87
	Sand	12	1886	2113	2.6
		18	1464	1743	1.93
Sand		15	1987	2286	1.64

Table 1: Soil Thermal Conductivity Data. (Hemmingway 2012)

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