

ECOROOF SOIL THERMAL PROPERTY TESTS

PRELIMINARY RESULTS

by

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One key constituent of ecoroof constructions is the growing media (or soil) within which the plants grow. While traditional building energy models have the capacity to implement an insulating soil layer as an outer layer of a roof construction, the ecoroof module being developed at Portland State University allows for the interaction of this soil layer with a vegetation canopy. The key challenge with respect to the growing media is to determine the thermal and radiative characteristics of the soil layer. Since ecoroof soils are typically much less dense than traditional soils with significantly lower thermal conductivity it is important to have accurate thermal property data. The alternative, which has been used in the past, is to simply use the properties of common soils. This has the potential to significantly underestimate the insulating potential of ecoroof soils. Furthermore, as ecoroofs are subject to variations in moisture (due to normal precipitation and evaporation cycles as well as irrigation) it is important to know how the soil thermal properties vary with moisture content.

Unfortunately, there currently exist virtually no data in the literature related to the thermal properties of ecoroof soils. To address this need we designed an experiment to determine these properties. The experiment relies on a dual-needle probe device that is capable of measuring both thermal conductivity and thermal diffusivity. The operating principle is based on the analytic solution to the heat equation for heat conduction in a semi-infinite medium subject to a line source of heat. In the traditional implementation (IEEE Standard 442-1981 and ASTM Standard D 5334-00) a thin needle probe is inserted into a large container of material (soil). A heat pulse of known magnitude and duration is emitted from the probe. Through subsequent measurement of temperature at the probe location it is possible to infer the thermal conductivity of the

material. In the case of thermal diffusivity this design must be modified to include a second needle at a fixed and known distance from the first probe. Transient measurement of temperature at a second radial location allows one to solve the energy equation for both conductivity and diffusivity. The probe we use is capable of applying this technique to resolve both conductivity and diffusivity to within 5 %. Due to inhomogeneity of samples our experiments resulted in slightly higher variability (typically less than 8%).

The experiments that we have conducted were designed to provide data for use in our ecoroof energy model, but also to provide reasonable boundaries on the physical property data for a range of soils and moisture levels. The resulting experiment design included 8 test samples using pumice or shale as a base aggregate, sand, and organic matter in varying quantities. In addition we have tested a few samples using AXIS (a porous silica based aggregate from AMS Inc.) as the sole aggregate (see Table 1):

Table 1. Composition of ecoroof soil samples (% by volume).

Sample #	AXIS	Pumice	Expanded Shale	Compost	Sand
DH01	0%	50%	0%	10%	40%
DH02	0%	50%	0%	0%	50%
DH03	0%	75%	0%	0%	25%
DH04	0%	75%	0%	10%	15%
DH05	0%	0%	50%	10%	40%
DH06	0%	0%	50%	0%	50%
DH07	0%	0%	75%	0%	25%
DH08	0%	0%	75%	10%	15%
DH09	50%	0%	0%	10%	40%
DH12	75%	0%	0%	0%	50%

We tested each sample at moisture states corresponding to dry and wet. First, each sample was dried so that it was essentially devoid of water. It is estimated that this “very dry” state had less than 5 g of moisture per liter of soil. The “dry” and “wet” states were then achieved by adding water: 42 g/liter for the “dry” sample and 225 g/liter for the “wet” sample. All samples were thoroughly mixed and lightly compacted as the water was added to simulate compaction levels corresponding to in situ soils.

The experiment protocol called for 2 repetitions of experiments with 3 replicates each for a total of 6 readings of thermal properties for each sample at each moisture state. As a general

rule the results were reproducible with average variability of less than 8% from the mean value. The results are summarized in Table 2. Corresponding albedo and emissivity measurements are under development and will be incorporated in future reports along with data from intermediate moisture states and alternative soil formulations.

Table 2. Thermal properties of “dry” and “wet” samples

Sample #	K (W/mK)	Cp (J/kgK)
"Dry" Samples (42+/-5 g/liter)		
DH01	0.25	1089.8
DH02	0.30	1105.9
DH03	0.20	999.0
DH04	0.20	1122.6
DH05	0.34	951.6
DH06	0.33	830.3
DH07	0.31	961.2
DH08	0.26	1035.5
DH09 (A1)	0.20	1065.2
DH12 (A4)	0.16	1243.2
"Wet" Samples (225+/-5 g/liter)		
DH01	0.45	1355.8
DH02	0.46	1321.7
DH03	0.34	1387.9
DH04	0.31	1602.3
DH05	0.57	1259.3
DH06	0.62	1124.7
DH07	0.46	1085.3
DH08	0.41	1150.9
DH09 (A1)	0.35	1428.2
DH12 (A4)	0.24	1541.3

Detailed analysis and further QA/QC are ongoing. The initial results, however, are in line with expected outcomes as follows:

1. Conductivity increases with moisture content – nearly doubling for the range of conditions tested.
2. Conductivity is lowest for soils with larger percentage of aggregate
3. Specific heat capacity increases with moisture content.
4. With respect to aggregate choice, samples using AXIS had the lowest conductivities as compared to the corresponding mixes using either pumice or shale (compare DH01 with DH05 and DH09 OR DH04 with DH08 and DH12). AXIS generally had slightly higher specific heat capacities than corresponding pumice and shale mixes.