| Document Title: | | Part # and Rev. | |
|---|---|---|---|
| Description, AN, THERM, Understanding How RHO Changes with Changing Density, Temperature, Composition, and Water Content of Backfill | | 13946-02<br>Release Date: | |
| Rev. | Description | Revision By | Date |
| 02 | Updated format to Thermal App Note | Rhea Booth | 5-25-12 |
| | | | |

**Production Filename:** 13946 (In Product Library)

**Path to Working Files:** DecaDoc\Application Notes\Master\Thermal Properties\13946-02 AN Understanding How RHO Changes

**Dimensions:** 8.5 inch wide, 11 inch tall

**Material:** Paper, 92 Bright White or better, 75g/m² or heavier

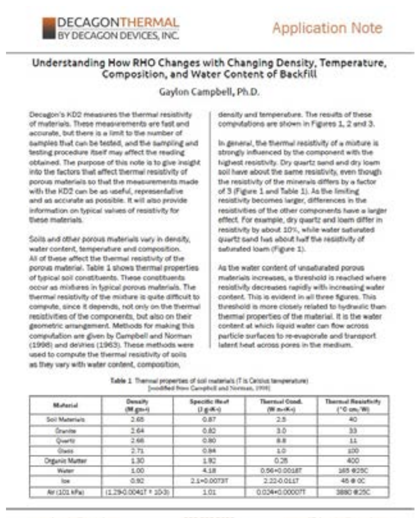
**Colors:** Color Print on White

**Printer:** HP Color LaserJet 8550-PS

**Finish:** None

**Adhesive:** None

**Special Notes:** Illustrations are Ref Only ** Not to Scale ** (Shown page 1 of 2)


DECAGONTHERMAL BY DECAGON DEVICES, INC. Application Note

Understanding How RHO Changes with Changing Density, Temperature, Composition, and Water Content of Backfill

Gaylon Campbell, Ph.D.

Decagon's KD2 measures the thermal resistivity of materials. These measurements are fast and accurate, but there is a limit to the number of samples that can be tested, and the sampling and testing procedure itself may affect the reading obtained. The purpose of this note is to give insight into the factors that affect thermal resistivity of porous materials so that the measurements made with the KD2 can be as useful, representative and as accurate as possible. It will also provide information on typical values of resistivity for these materials.

Soils and other porous materials vary in density, water content, temperature and composition. All of these affect the thermal resistivity of the porous material. Table 1 shows thermal properties of typical soil constituents. These constituents occur as mixtures in typical porous materials. The thermal resistivity of the mixture is quite difficult to compute, since it depends, not only on the thermal resistivities of the components, but also on their geometric arrangement. Methods for making this computation are given by Campbell and Norman (1998) and deVries (1963). These methods were used to compute the thermal resistivity of soils as they vary with water content, composition, density and temperature. The results of these computations are shown in Figures 1, 2 and 3.

In general, the thermal resistivity of a mixture is strongly influenced by the component with the highest resistivity. Dry quartz sand and dry loam soil have about the same resistivity, even though the resistivity of the minerals differs by a factor of 3 (Figure 1 and Table 1). As the limiting resistivity becomes larger, differences in the resistivities of the other components have a larger effect. For example, dry quartz and loam differ in resistivity by about 10%, while water saturated quartz sand has about half the resistivity of saturated loam (Figure 1).

As the water content of unsaturated porous materials increases, a threshold is reached where resistivity decreases rapidly with increasing water content. This is evident in all three figures. This threshold is more closely related to hydraulic than thermal properties of the material. It is the water content at which liquid water can flow across particle surfaces to re-evaporate and transport latent heat across pores in the medium.

Table 1 Thermal properties of soil materials (T is Celsius temperature) (modified from Campbell and Norman, 1998)

| Material | Density (Mg m-3) | Specific Heat (J g-1 K-1) | Thermal Cond. (W m-1 K-1) | Thermal Resistivity (°C cm/W) |
|---|---|---|---|---|
| Soil Materials | 2.65 | 0.87 | 2.5 | 40 |
| Granite | 2.64 | 0.82 | 3.0 | 33 |
| Quartz | 2.66 | 0.80 | 8.8 | 11 |
| Glass | 2.71 | 0.84 | 1.0 | 100 |
| Organic Matter | 1.30 | 1.92 | 0.25 | 400 |
| Water | 1.00 | 4.18 | 0.56+0.0018T | 165 @25C |
| Ice | 0.92 | 2.1+0.0073T | 2.22-0.011T | 45 @ 0C |
| Air (101 kPa) | (1.29-0.0041T * 10-3) | 1.01 | 0.024+0.00007T | 3880 @25C |

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