Thermal Cycling of Florida Rock

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Abstract

This project's goal is to measure thermal properties of Florida limestone and soil as part of a yearlong effort to measure ground temperatures throughout seasons and diurnally. We are measuring thermal conductivity/resistivity values of samples. The findings for this study are not yet finalized as the research is still in the preliminary stages, we are still in the process of reviewing and collecting data. Once ground temperature data has been collected on an annual cycle, we will be able to use the laboratory measured data to estimate the rock and soil straining due to thermal stress. This research will be useful to better understand the influence of thermal stress on civil infrastructure, specifically seasonal and diurnal stress, and how to account for its effects in future design to improve infrastructure resilience.

Introduction

- Thermal properties of soil is becoming important, as planet warming increases, correlation between ground temperatures and soil mechanical properties in relation to civil infrastructure, continues to be emphasized.
- Knowing the subsurface material's ability to conduct heat allows a better understanding of likelihood and magnitude of thermal straining in surface and subsurface structures.
- As of now there is limited research on the thermal properties of soil specific to Florida. There are also changing variables which increases variation of these properties as well.
- We will be looking at limestone cores collected from the Avon Park geologic formation in Levy County, Florida, near the surface and down to 45 ft. In addition, soil (cohesive and non-cohesive) from the panhandle and central Florida regions will be collected and measured.
- Thermal conductivity is the result with greatest importance to this experiment, it is the essential property that controls heat flow.

Methods

- Used an electric drill to drill a hole into limestone sample cores. This step was skipped for samples that were too brittle. If the core was long enough, drilled a similar hole on the other side of core as well.
- Used the TLS-100 thermal needle which is a device that measures thermal conductivity by sending heat to the sample through the needle and measuring the response it receives when the heat is ceased.
- Moisture content was taken for samples of box 1 and 2 (Figure 2 and 3 respectfully.)

Figure 1. TLS-100 connected to needle used in experiment

Results

Gulf Hammock Rock Mine Hole No. B-4A	Depth (ft)	Thermal Conductivity (W / m-k)	Thermal Resistivity (m-k / W)	Temperature (C)
Sample 1	8.000	1.626	0.615	20.4
		1.638	0.610	18.8
	9.117	1.320	0.757	18.9
		1.360	0.734	17.5
Sample 2	11.646	1.340	0.746	18.5
		1.309	0.764	18.3
		1.266	0.790	18.1
Sample 3	11.000	1.009	0.990	17.2
		1.016	0.984	16.9
	11.521	0.681	1.468	19.6
		0.705	1.418	17.9
Sample 4	12.708	0.836	1.196	20.5
		0.857	1.166	18.5
	12.000	1.018	0.982	19.8
		1.059	0.944	17.8
Average:	10.745	1.136	0.944	18.580
Standard deviation:	1.816	0.302	0.269	1.101
Coefficient of Variation:	0.155	0.266	0.285	0.059

Table 1. Results for box 1 of limestone samples

Gulf Hammock Rock Mine Hole No. B-4A	Depth (ft)	Thermal Conductivity (W / m-k)	Thermal Resistivity (m-k / W)	Temperature (C)
Sample 5	42.604	0.897	1.115	19.6
		0.910	1.099	18.5
	43.438	1.600	0.625	19.9
		1.653	0.605	18.2
Sample 6	44.604	1.571	0.637	19.1
		1.567	0.638	18.7
		1.567	0.638	18.5
Sample 7	46.260	1.394	0.717	19.4
		1.417	0.706	18.8
	47.000	1.171	0.854	20.5
		1.197	0.835	19.9
Sample 8	47.111	1.445	0.692	19.7
		1.442	0.693	19.6
		1.450	0.689	19.4
Sample 9	47.854	1.735	0.576	19.4
		1.714	0.583	19.5
		1.712	0.584	19.7
Average:	47.854	1.438	0.723	19.318
Standard deviation:	2.016	0.258	0.165	0.605
Coefficient of Variation:	0.042	0.179	0.228	0.031

Table 2. Results for box 2 of limestone samples

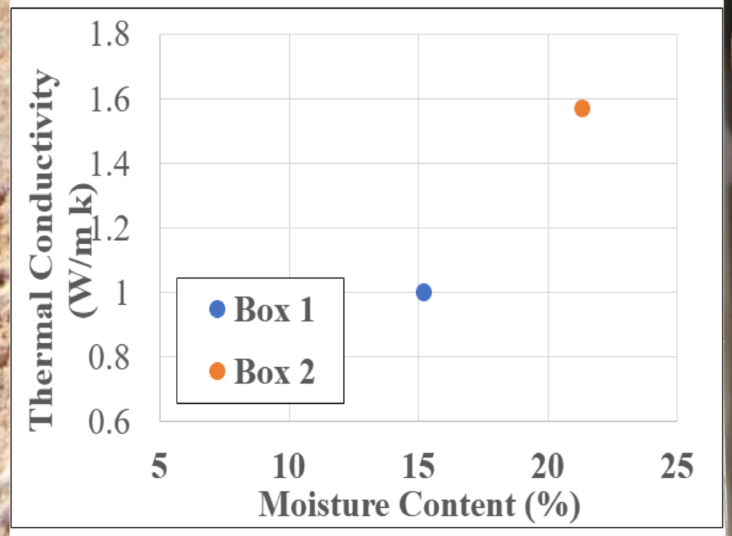

Table 3. Moisture content from Limestone Samples of Box 1 and Box 2

Figure 2. Box 1 of limestone samples

Figure 3.Box 2 of limestone samples

- The depth, shown in column two of the table, ranged from 8 ft to 47.854 ft with box 1 being closer to the surface than box 2 samples.
- Measured thermal conductivity had an average of 1.136 (W / m-k) for box 1 and of 1.438 (W / m-k) for box 2 limestones.
- For samples drilled on one side, three tests were taken while samples drilled on both sides had 2 tests taken per side, this was to ensure reliability of the results gathered in experimentation
- Moisture content showed variation between boxes with shallower samples having a lower moisture content than samples from the box with a deeper depth.

Conclusions

Soil is a very broad category containing variables that make even the same kind of soil significantly different. Limestone can be found on numerous continents of the world and still samples from the same limestone source can vary in properties. Some variables that affect thermal properties include mineralogy, density, moisture, porosity, temperature, and organic matter content. (Logsdon et al. 2010.)

Values obtained for thermal conductivity of the limestones had some variability which can be explained by any of the several variables listed above. Sample depth showed to affect thermal conductivity as the average was 0.302 (W / m-k) greater for samples from box 2 with a lower depth. This is due to the increased density and deceased porosity for these samples as they get compacted over time. Box 2 also contained greater moisture content which, along with increased density, showed a positive correlation with the thermal conductivity.

Extensive literature reviews were conducted to compare our results. They showed that thermal conductivity can vary significantly between limestone with the lowest being limestone sourced from Turkey, 0.60 W/m-k, (Yaşar et al. 2008), and the highest being a dolomitic limestone from India, 6.12 W/m-k, (Rao et al. 2022). Measurements by (Nuszkowski et al. 2018) taken of Florida limestone showing carbonite limestone having a thermal conductivity ranging from 1.2-5.3 (W / m-k) and dolomitic limestone ranging from 1.8-5.2 (W / m-k).

The rock from the Avon Park formation is limestone and dolostone with gypsum infill. It is identified as having calcite with aragonite to dolomite ratio greater than 1:1. The gypsum has a thermal conductivity around 1.2 (W/ m-k), this could be the result in the lower thermal conductivity measured here in comparison to pure calcite and dolomite. The darker colored limestone indicates more aragonite expressing how minerology affects thermal properties.

References

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