Progress Report #1

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COS120: Introduction to Research
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Objectives

For the past few months, we have completed research on the mechanics of the thermoelectric (TE) effect, the use of cement in TE devices, and how to measure TE properties. In addition, we have gained an understanding on how research is conducted and research papers are properly composed through reading and annotating relevant articles to our chosen field. Our objective for the following weeks is to refine our choices of materials used and devices used in experimentation, complete the order form for said materials and devices, and potentially begin setting up for our experiment.

Materials & Methods

From our research so far, we have concluded that we will be using the following materials:

- Portland Cement Mix
- Water
- Superplasticizer
- Graphite Powder
- Fly ash
- Fe_2O_3
- Cu_2O
- Chopped carbon fiber (If budget allows)
- 2 K-type thermocouples
- Multimeter
- Current source such as a battery
- Copper plates
- Heat Lamp
- Thermal Insulator Sheet

There will be two main apparatuses used in experimentation. One in which Seebeck coefficient will be measured, and one where thermal and electrical conductivity will be measured. The portland cement will be mixed with water, the conductive filler, and superplasticizer will also be added to create a more uniform distribution of conductive particles in the mixture. They will then be cured and then dried out to prevent interference during the drying process due to water acting as an ion carrier. The apparatus to measure Seebeck coefficient is shown below in figure 1. An insulated modified-cement-based sample will be placed between a heating and cooling element, and electrodes placed on each corresponding face of the sample. 2 K-type thermocouples will be used to measure the temperature at each end, and a multimeter will measure the voltage generated between the two electrodes.

The procedures of our experiment consist of measuring the Seebeck coefficient, thermal conductivity, and electrical resistivity of each sample type. To measure thermal conductivity and electrical resistivity, a cylindrical sample will be used, and a current source will be passed through the sample. The Seebeck Coefficient S [μV/k] can be found via the equation $S = V/\Delta T$.Electrical resistivity will be found with the equation $\sigma = \frac{1}{\rho} = \frac{RL}{A}$, where R is measured resistance in the sample, found via Ohm's law, L is the length of the sample, and A is its cross-sectional area. Thermal conductivity kappa will be found with the same equation used by Ji et. al. (2022), that is, $\kappa = (I*V*L)/(A*\Delta T)$, where I is supplied current, V is measured voltage, and ΔT is temperature drop between the electrodes. The dimensionless figure of merit ZT can be calculated as $ZT = S^2\sigma T/\kappa$, where T is absolute temperature (Li et. al, 2025).

Our research will have the possibility of safety risks. Some possible risks are burns from the heat lamp, as well as exposure to hazardous chemicals. To mitigate these risks, we will turn off the heat lamp while not in use, and wear personal protective equipment (PPE) while handling cement in a cautious manner. Our PPE will consist of gloves, safety goggles, lab coats and close-toed shoes. To prevent exposure to chemicals, we will store materials and chemicals properly according to its Safety Data Sheet (SDS).

Graphite powder, Carbon fiber, and Iron (III) Oxide are not considered hazardous by the OSHA Hazardous Communication standard. Fly ash, Portland cement, and Cuprous Oxide are, however. Fly ash may cause severe skin burns and eye damage, allergic skin irritation, respiratory irritation, or cancer. It should be handled outdoors in a well-ventilated area to avoid dust inhalation, though it can be disposed of normally. Portland cement has mostly the same hazards as that of fly ash. Cu_2O is very toxic to aquatic life. However, since our experiment will not use any aquatic life, similar precautions to the previous two will be followed. Skin contact and dust inhalation are to be completely avoided. Excess of these hazardous materials will be disposed of by sending it to the Prince William County Landfill Complex, which handles recycling of hazardous waste.

Data/Results

At the moment, we haven’t begun experimentation yet. As such, we do not have any measured data of our own. The following figures shown below are from various papers in our research so far. Figure 2 shows that in addition to enhancing the thermoelectric properties of cement, introduction of carbon fibers can enhance the strength of the cement as well. The same study (Ran et. al, 2024) also shows that fly ash is a viable filler for enhancing thermoelectric properties.

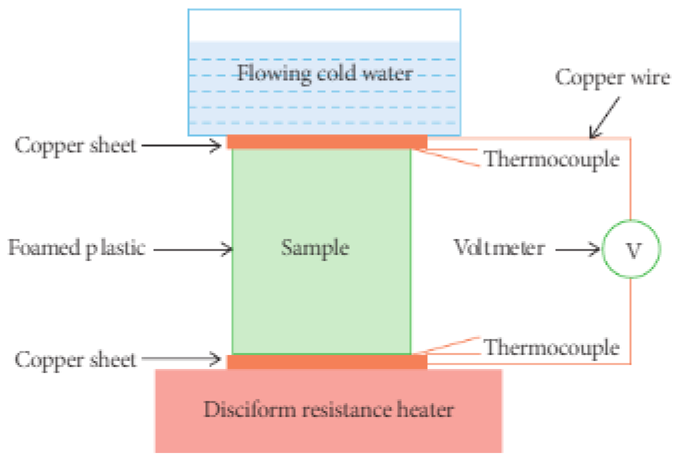

Figure 1. An apparatus for determining the Seebeck coefficient of the sample, as found in (Ji et. al., 2022)

Mix	Density (kg/m^3)	Compressive strength (MPa)	Tensile first crack stress (MPa)	Tensile strength (MPa)	Tensile strain capacity (%)
Control	1146 (5.7)	27.1 (1.3)	2.3 (0.38)	4.75 (0.20)	8.1 (0.31)
M−0.5–1	1003 (18.1)	23.8 (0.2)	3.02 (0.16)	4.34 (0.27)	10.67 (0.49)
M−1.0–1	1041 (7.3)	27.8 (1.1)	3.01 (0.01)	4.00 (0.04)	5.08 (0.42)
M−0.5–3	1028 (6.1)	25.2 (2.2)	3.02 (0.07)	3.91 (0.28)	4.93 (1.76)
M−1.0–3	1132 (13.1)	31.1 (3.6)	3.07 (0.49)	4.32 (0.56)	4.15 (1.59)
M−0.5–6	1111 (2.4)	30.4 (1.9)	2.99 (0.18)	4.23 (0.18)	5.67 (2.26)
M−1.0–6	1120 (6.4)	32.2 (1.3)	3.45 (0.09)	4.49 (0.19)	1.78 (0.17)
M−0.5–9	1131 (23.3)	33.4 (3.2)	4.03 (0.02)	5.83 (0.81)	6.43 (0.68)
M−1.0–9	1152 (29.4)	36.8 (2.8)	3.81 (0.52)	5.13 (0.49)	4.68 (0.75)
M−0.5–12	1126 (16.8)	30.3 (1.6)	3.07 (0.06)	5.04 (0.27)	7.89 (0.59)
M−1.0–12	1157 (46.1)	32.0 (0.3)	3.99 (0.52)	5.03 (0.47)	2.71 (0.37)
M−0.5–15	1082 (42.7)	30.2 (0.2)	3.03 (0.42)	4.58 (0.79)	4.51 (1.98)
M−1.0–15	1143 (17.1)	31.9 (0.8)	3.31 (0.31)	4.23 (0.14)	3.54 (0.61)
M−0.5–20	1151 (28.2)	31.2 (2.4)	3.15 (0.34)	4.05 (0.46)	3.32 (0.82)
M−1.0–20	1138 (38.2)	32.4 (1.5)	3.27 (0.40)	4.54 (0.56)	4.61 (1.37)

Figure 2. A table of mechanical properties of different mechanical samples. The mix names M-V-X represent length X (mm) at V percent volume. Found in (Ran, 2024).

References

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