Utilizing Absorbed Heat from Concrete to Generate Clean Electricity

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There is a tendency of urban areas to be significantly hotter than nearby rural areas. One of the leading causes of this is due to the heat storing properties of concrete. However, with the Seebeck effect, concrete can be modified into modules for harnessing electricity. In this study, our team tested the effects on the thermoelectric and cost efficiency of different materials within concrete. To achieve this, our team curated 19 4.0 x 1.0 x 0.8 in. samples of concrete, each with different combinations of materials including Iron (III) Oxide, Fly Ash, Carbon Fiber, and Graphite Powder. Our data collection consisted of 4 trials: with copper end caps at 72° (C72), without copper end caps at 72°(N72), with copper end caps at 32°(C32), and without copper end caps at 32°(N32), where the samples had their maximum produced voltages between different time intervals measured. Our team found that hybrid samples or samples with less water yielded higher amounts of electricity and produced voltage at a faster rate after 5 minutes under the simulated environments. Our findings indicate concrete with lower concentrations of water and higher concentrations of iron oxide, carbon fiber, and fly ash were most effective.

Introduction & Background

THE URBAN HEAT ISLAND (UHI) EFFECT DESCRIBES THE TENDENCY OF URBAN AREAS TO BE SIGNIFICANTLY HOTTER THAN NEARBY RURAL AREAS. ONE OF THE LEADING CAUSES OF THIS EFFECT IS DUE TO THE THERMAL PROPERTIES OF CONCRETE. CONCRETE AND ASPHULT, CORNERSTONES OF URBAN DESIGN, ABSORB LOTS OF THERMAL ENERGY AND SLOWLY RADIATE IT INTO THE ENVIRONMENT (ZAFRA, 2025). NOT ONLY DOES THIS MAKE URBAN AREAS HOTTER AND MUCH WORSE TO LIVE IN DURING WARM SEASONS, BUT IT IS ALSO HIGHLY WASTEFUL ENERGY-WISE. OF COURSE, BUILDING SOLAR PANELS INTO SIDEWALKS AND ROADS WOULD BE IMPRACTICAL. THUS, BY UTILIZING THE SEEBECK EFFECT, A PHENOMENON IN WHICH A TEMPERATURE DIFFERENCE BETWEEN SEMICONDUCTORS CREATES VOLTAGE, CONCRETE CAN BE MODIFIED INTO MODULES FOR HARNESSING THERMOELECTRIC ENERGY. THERMOELECTRIC DEVICES ARE SUITABLE FOR THIS NEED, SINCE THEY EMIT NO CARBON DIOXIDE EMISSIONS AND HAVE NO MOVING PARTS (SINGH ET AL., 2021).

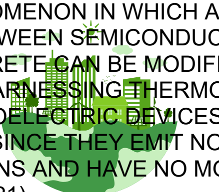

Figure 1. An artistic interpretation of clean energy being beneficial to a city.

Our objective in this study was to determine the most electric and cost efficient combination of fillers in concrete samples under a variety of environmental simulations.

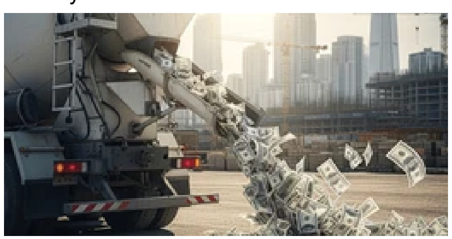

Figure 2. An artistic interpretation of money being wasted by the concrete industry through not utilizing the free electricity they could get. Image) used under license from Shutterstock.com

To achieve our objectives at hand, our team created our own concrete samples via wet curing in silicone molds. This totaled to 19 samples.

Figure 3. All samples with copper end caps, prepared for the C72 trial.

Materials & Methods

Figure 4. Materials in sample procurement.

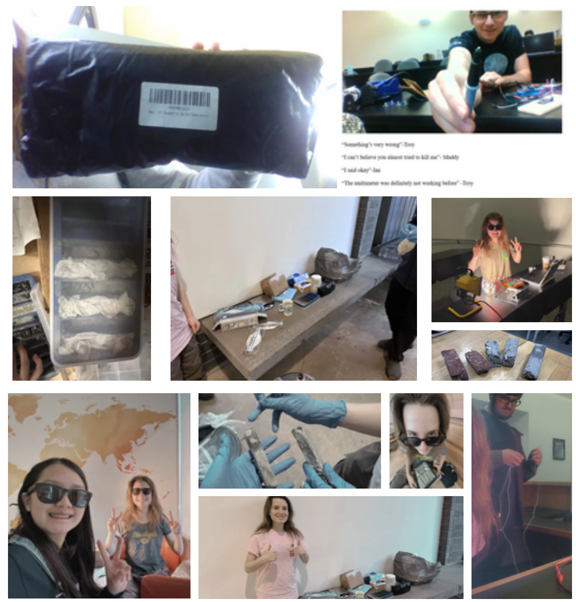

Figure 5. A collage of various parts of our project, featuring researchers and concrete evidence.

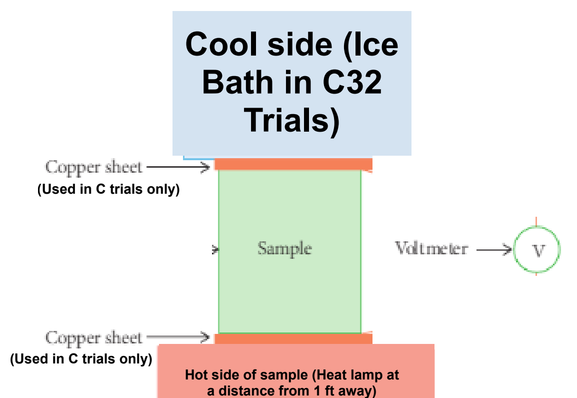

Figure 6. A diagram of our experimental set-up.

Results & Analysis

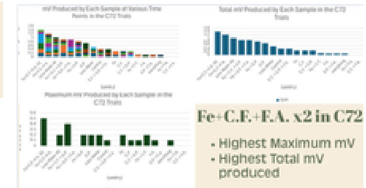

Figure 7. Pictured here are various charts for our C72 trials.

Figure 8. Pictured here are various charts for our N72 trials.

Figure 9. Pictured here are various charts for our C32 trials.

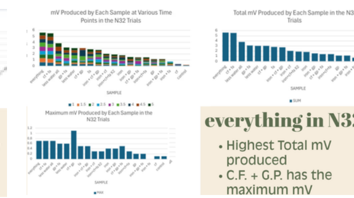

Figure 10. Pictured here are various charts for our N32 trials.

Figure 11. Pictured here are various charts summarizing all trials.

Ultimately, throughout all four trial sets, fly ash seemed most effective for generating voltage when paired with another conductor. Carbon fiber was found to be the most helpful, although graphite powder + fly ash was also optimal in the N72 trial.

Cost Analysis

Item	Total Cost	Amount/sample	$$$/sample
Cement	80lb for $5.96	60g	$0.01
Water	1000gal for $2	6.5tsp	$0.00
Iron Oxide (iron)	10oz for $11.99	1tsp	$0.20
Carbon Fiber (cf)	1lb for $40.48	1tsp	$0.88
Graphite Powder (gp)	4oz for $9.99	1tsp	$0.42
Fly Ash (fa)	1/4gal for $24.09	1tsp	$0.13
Superplastisizer	8oz for $12.59	1tsp	$0.26

Figure 12. A cost estimate for all materials used.

Sample	Cost
control	$0.27
less water	$0.27
iron	$0.47
cf	$1.15
gp	$0.69
fa	$0.40
iron + cf	$1.35
iron + gp	$0.89
iron + fa	$0.60
cf + gp	$1.57
cf + fa	$1.28
gp + fa	$0.82
iron + cf + gp	$1.77
iron+cf+fa	$1.48
iron + gp + fa	$1.02
cf + gp + fa	$1.70
everything	$1.90
iron+cf+fa (v2)	$1.48
less water all	$1.90

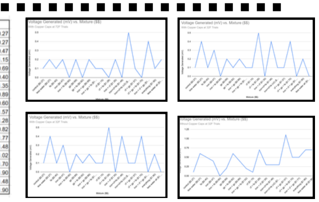

Figure 13: A cost estimate for all samples and charts comparing their output to cost ratio.

Discussion & Conclusions

Ultimately, throughout all four trial sets, fly ash seemed most effective for generating voltage when paired with another conductor. Carbon fiber was found to be the most helpful, although graphite powder + fly ash was also optimal in the C32 trial.

It was noted that samples with less water or more materials oftentimes seemed to produce a voltage much quicker than other samples in this study; thus we theorize that this is likely due to a reduced heat capacity in said samples. However, multiple cracks and potential weaknesses in samples were observed. Thus, we believe that there is a tradeoff between structural integrity and thermoelectric efficiency within concrete.

In further studies, we believe that it would prove useful to the field for there to be research on analyzing the concrete's strength and durability, using of stronger thermoelectric materials like Bismuth Telluride, testing the voltage in higher scaled samples, and creating apparatuses to use the voltage generated for civil applications such as street lamps.

Resources:

Zafra, M. (2025, July 1). The Floor Is Lava. Reuters. https://www.reuters.com/graphics/CLIMATE-CHANGE/URBAN-HEAT/byvrejywdpe/

Singh, V. P., Kumar, M., Srivastava, R. S., & Vaish, R. (2021). Thermoelectric energy harvesting using cement-based composites: a review. Materials Today Energy, 21, 100714. https://doi.org/10.1016/j.mtener.2021.100714

Li, W., Du, C., Liang, L., & Chen, G. (2025). Cement-Based Thermoelectric Materials, Devices and Applications. Nano-Micro Letters, 18(1). https://doi.org/10.1007/s40820-025-01866-2

Wei, T.-R., Guan, M., Yu, J., Zhu, T., Chen, L., & Shi, X. (2018). How to Measure Thermoelectric Properties Reliably. Joule, 2(11), 2183–2188. https://doi.org/10.1016/j.joule.2018.10.020

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