Thesis Project Portfolio

The Commercialization of Low-Carbon Cements through Calcium Silicate Carbonation of Industrial Waste

(Technical Report)

Too Close to the Sun: Have We Taken Carbon Offsets Too Far?

(STS Research Paper)

An Undergraduate Thesis

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Executive Summary

Introduction

Climate change links the technical work completed for the capstone project and the research work completed for the science, technology, and society (STS) research paper. The technical work described in this paper concerns development of a “carbon-negative” concrete building material. The material will sequester more carbon dioxide than it emits throughout the lifetime of its creation. It hopes to mitigate the effects of climate change by replacing traditional ordinary Portland cement (OPC) concrete, which emits one kilogram of carbon dioxide per one kilogram of concrete and is responsible for 8% of global carbon dioxide emissions. The STS portion of the project describes the effectiveness of carbon offsets, in an attempt to understand why they have become so popular and how they actually help reduce carbon emissions. In understanding more about how carbon offsets work, the paper hopes to understand how they can be used more effectively with other carbon emission-reducing strategies to reduce climate change effects.

Technical Summary

The capstone portion of the research focused on developing a life-cycle carbon-negative building material. The research was a continuation of previous work completed by the lab group that worked to understand how pseudowollastonite (PWOL) could be combined with granite aggregate, sodium hydroxide solution, and carbon dioxide (along with heat) to create calcium-silicate-hydrate gels which mimic the strength of traditional concretes. The PWOL was used as the binder, and the sodium hydroxide solution was substituted in lieu of water. The capstone project continued this research by utilizing waste materials from a metal processing plant that are high (> 50%) in PWOL. The use of waste materials significantly reduces the carbon footprint of the concrete.

Many experiments were conducted over the course of the year. Much of the experiment design was spearheaded by either interest from the research group about how different materials and ratios affected the compressive strength or chemical composition of the concrete or by the industry partner who provided insight into the scalability and marketability of the product. The brunt of the research focused on the addition of small amounts of OPC to the waste slag. Different percentages of OPC were included in the mix to try to both increase the compressive strength as well as increase the viability of certain curing methods, such as curing the concrete while immersed in water (a traditional technique that does not work with PWOL-based materials). Since OPC releases a lot of carbon, however, a “golden” amount of OPC had to be found to maximize strength while maintaining carbon negativity.

The project resulted in numerous data that will be published. This data hope to inform future and continued research into PWOL and waste-material-based concretes.

STS Paper Summary

The STS paper focuses on carbon offsets. It details how they came to be, what they are, how they work, and how they’ve evolved over the years. It then discusses, through the lens of a technological fix, the issues with carbon offsets and how they are currently used. These issues are societal, immense, and without an immediate, obvious solution (as is the case for technological fixes).

The paper uses data from different carbon offset programs to illustrate the systematic and behavioral repercussions of carbon offsets. Large-scale systematic issues lead to exploitation of the system by its users for individual profit instead of using it for its intended purpose of reducing emissions. Individuals using carbon offsets may be induced, upon paying for the offset, to emit more overall due to the feeling of accomplishment that results from having helped the environment.

Conclusion

Working on both of these projects exposed me to a wealth of information about climate policy. The end product for our capstone will ultimately be more expensive to implement that sticking with current traditional methods, so we had to consider government subsidies that companies may receive. It was interesting in general to see how all these actors interact with each other and to see how the needs of Ash Grove cement conflicted with the needs and abilities of the research team. In the same vein, it was interesting to see how all the entities involved with carbon offsets interacted with each other—both projects involved such large complex systems that it was cool to see how they all worked together.