Thesis Project Portfolio

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

(Technical Report)

Who Holds the Power: An Investigation Into the Power Dynamics of the Energy Industry

(STS Research Paper)

An Undergraduate Thesis

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Executive Summary

The basis for the following undergraduate profile is a capstone project that does a technical dive into finding a low carbon cement alternative. The focus of the low carbon cement project was to adapt cement mixes and curing methods to use a waste material as the binder. In the long term, to ensure the financial and logistical ability of the project, there needs to be an understanding of where the waste material comes from, who owns it and who regulates it. The Science, Technology, and Society (STS) research project supplements the technical research being performed in the capstone project. This STS research project focuses on understanding the dynamics of the energy industry, an industry which is notorious for creating and having to dispose of dangerous waste. This waste can get into the environment and damage these communities. Understanding the dynamics of the energy industry gives a foundation on how to interact with similar industries when the supply chain for the low carbon cement would need to be established.

The capstone project focuses on an issue plaguing the construction world, the use of Ordinary Portland Cement (OPC), one of the largest contributors of carbon emissions. As the continued development of society is reliant on the construction and maintenance of infrastructure, cement cannot be phased out of use. An alternative method based on Roman cements has been created. Roman cements create minerals like aluminum tobermorite which provide similar as seen in OPC. These minerals can be created by curing pseudowollastonite (PWOL) at high temperatures under a pressurized CO_2 environment. The PWOL is used as the binder in concrete mix, with a low-molarity sodium solution as the liquid. The use of these materials will allow for a significant decrease in OPC use. However, synthesizing PWOL in the lab is time consuming and energy intensive. The goal of the capstone project is to develop a cement mix design that instead uses a waste slag as the binder. The waste slag in question is not pure PWOL but does have a large concentration of the mineral. The use of this material is extremely advantageous, as it requires no dollar cost to manufacture or procure and as a result also incurs no carbon emissions allowing for a cheaper material both in monetary and carbon costs. This capstone project has made large steps in creating a concrete alternative to pure OPC that is a marketable, scalable, and low-carbon building material. It was found that the optimal mix design has a large majority of the binder as waste slag and a small amount of the binder as OPC. This design is the most optimal as the inclusion of OPC allows for a smoother transition of the product to the market. First, it includes products already created in market, next, it allows for the cubes to cured multiple different ways which enables the mix to be adapted to fit within the bounds of the manufacturing facility. An additional chemical interaction is seen between the binders, which causes an increase in CASH formation – one of the precursors to tobermorite. Future work in this field will use the mix design developed and chemical interactions discovered to create the product that will be brought to market.

The STS research project focuses on the energy industry and coal. The baseline fuel in America is coal; the production and usage of it has shaped the growth of areas like Appalachia. The decommissioning of the coal plants is detrimental to these communities unless alterative jobs are implemented. However, to properly help these communities, their existence and culture must be understood, as well as the energy industry that shaped them. This research defines the relationships between the energy industry, the communities it serves and is in, and the regulating entities. The framework of actor network theory (ANT) is used to fully define these relationships. Each entity serves as an actor with defined interests and goals, then the network is defined by the financial and government dictated roles that each entity has. Through this research, the underlying power plays in the energy industry are discussed which will give direction to those implementing new energy sources, as well as fixing regulation to protect the environment. In addition, the values and needs of the coal communities are uncovered which will allow the addition of new jobs that would serve the community as well as the earth. The ultimatum of this research is to create a baseline understanding of the current state of the energy industry to benefit the future implementation of new energy sources.

The completion of both the technical capstone project and the STS research simultaneously allowed for a broader view of both subjects. The addition of the STS research to the technical research created a foundation for understanding the social implications of the project as well as possible routes for commercialization. Understanding the complex commercial relationships and regulatory bodies revealed what aspects of design are important for commercialization. Additionally, the STS research revealed the importance of the social implications of the technical design. Creating a design that could seamlessly mesh with the current industry would allow for less job turnover and turbulence during the transition. The use of waste material in the design removes the product from the environment and therefore creates a safer community. Simultaneously completing both projects created more value to each project individually and allowed for a more wholistic view on the social impact of what even just a year of work can do.