Finding an Empirical Relationship Between Chloride Loading Density and Conductance for the Prevention of Galvanic Corrosion in Real Environments

(Technical Paper)

Investigating the Environmental Impacts of Underwater Tunneling

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Humans have been creating bridges since the beginning of time. Something as simple as logs across a river made travel easier for prehistoric peoples. It was not until the early 1800's that humans had the idea to tunnel under these waterways. Having been completed in 1843, the Thames tunnel is the first tunnel constructed under a navigable river (Willis, 2018). Engineers completed this monumental task without the use of steel reinforced concrete to support the massive weigh of soil and water. As a result, the tunnel partially collapsed during construction in both 1827 and 1828 resulting in the deaths of six workers (Kuklewicz, 2021). This tragedy shows the importance of corrosion resistant materials when constructing an underwater tunnel and that is why this project aims to continue the understanding of corrosion.

The technical portion of this project revolves around finding if there is an empirical relationship between chloride loading density and conductance. In simple terms, this means uncovering how the amount of chloride affects the degree to which an object conducts electricity. Our research group will then verify this relationship using experimentation. The STS portion of this project will focus on the environmental impacts of underwater tunneling in the 21st century. This portion of the project will answer the question of whether underwater tunneling has a negative impact on the environment.

The first section of the STS portion will lay out the research question. I will discuss this question by breaking it down into sections containing the technology being examined, what the overarching research question is, and why that question is important. The second portion will discuss the relevant social groups and the third section will discuss what methods and

frameworks I will use during research. The STS portion will conclude with a timeline for the rest of the research and writing.

Both these questions relate to the concept of corrosion and become more relevant as large cities continue to grow with limited area available. The correlation between chloride loading density and conductance can help predict corrosion rates which is a beneficial metric when selecting materials for an underwater tunnel. I will first discuss the technical portion of this project followed up by the STS portion. The prospectus will end with a list of key texts used to explore the ideas presented in both the technical and STS portions.

Technical Topic: Determining the Chloride Loading Density in Real Environments for the Prevention of Galvanic Corrosion

Modern engineered structures have optimized cost, efficiency, and mechanical properties through multi-material systems. In the aerospace industry, lightweight materials such as aluminum alloys and carbon fiber reinforced polymers make up an airplane's structural components. Areas under greater stress use higher strength materials such as steel and titanium alloys (Prasad, 2017). When these two different types of materials are in electrolyte contact, galvanic corrosion can occur. This means there will be an increased rate of corrosion on one of the materials and a decreased rate of corrosion on the other material. Galvanic corrosion occurs as a result of many variables, most of which are currently understood and have documented relationships. One relationship which is not fully understood is that of chloride loading density and conductance.

Our capstone group is looking to discover this empirical relationship between chloride loading density and conductance. We will first use software such as Python to develop a machine

learning algorithm to help analyze experimental data which LunaLabs collected using the Acuity LS Sensor. Once the data has been analyzed, we will create a model which can explain the relationship between chloride loading density and conductance. Finally, we will run our own set of experiments using the Acuity LS Sensor to verify our model is accurate. If we establish a quantitative relationship between chloride loading density and conductance the impacts would be far reaching. This relation could lead to the creation of a finite element method model that can better predict the rates of corrosion. Benefits would include improved material performance testing methods, better informed material selection during design, and live condition monitoring and assessment. Fields such as marine infrastructure, offshore energy, automotive, aerospace, and more would all benefit from this model.

STS Topic: The environmental impacts of underwater tunneling

Underwater tunneling is the technology being emphasized in the STS section. There are two main types of underwater tunnels, immersed and bored (Gerbis, 2022). Builders create an immersed tunnel by dredging in the sea floor and then sinking pre-made tunnel sections into the hole. A bored underwater tunnel uses a boring machine to create a hole through the rock and soil under the waterline (Gerbis, 2022). Concrete linings support the weight and prevent the tunnel from collapsing after the boring machine has passed (Gaynor, 2021).

The overarching research question being investigated in the STS section is whether underwater tunneling has a negative impact on the environment. All construction methods have some sort of negative impact on the environment. According to an article published in the International Journal of Environmental Research and Public Health, “construction is not an environmentally friendly process. Buildings are responsible for over a third of global energy-

related carbon dioxide (CO2) emissions, accounting for roughly 33% of the total global CO2 emission" (Yao, 2020, Page 2). It would be beneficial to research whether underwater tunneling causes problems such as habitat loss, water pollution, and whether the construction causes species to leave the area.

The question of whether underwater tunnels cause environmental damage is extremely important when focusing specifically on habitat loss in the marine environment. According to scientists at the U.N. Convention on Biological Diversity, up to 150 species go extinct every day (Djoghlaf, 2007). This number equates to between 18,000 and 55,000 species every year.

Environmental damage has an impact on many different social groups. Policy makers who influence the way construction happens, people living near the construction site, as well as marine traffic are all impacted by underwater tunneling. I identified these three social groups due to their direct involvement or proximity to underwater tunneling. Policy makers have the ability to set forth rules and regulations that dictate underwater tunnel construction and maintenance procedures. The power bestowed upon these officials gives them the ability to influence the level of environmental damage that results from dredging and boring. Material transportation and clean up procedures are two important facets of a construction project that can lead to great ecological damage if they become mishandled. Second, those people who live near the tunnel construction site face adverse effects such as light and noise pollution as well as discarded construction materials on or near their property. A third social group affected by underwater tunneling are those businesses which rely on maritime passage ways for work. Building an underwater tunnel takes many years and can have the consequence of preventing shipping traffic or fishing vessels from passing by. The delay in maritime traffic can have an effect on other social groups not previously mentioned such as restaurants who depend on fish or consumers

who rely on container ships to bring goods from overseas. Discussing relevant social groups is important because it helps to emphasize the real-life people who face complications caused by environmental damage due to underwater tunneling. It is easy to brush off an issue that has no names or faces behind it but it is much harder to neglect those who can share their stories of how they were directly impacted.

Two STS frameworks that I will be using to help answer the question of whether underwater tunneling causes environmental damage are case studies and public policy analysis. Case studies are a valuable tool to find information relating to previous underwater tunnel construction projects. Info such as planning, pre-construction stages, construction stages, and post construction stages can be a valuable asset when determining if underwater tunneling causes environmental damage. Public policy analysis is also a valuable tool that can shed light on already existing policies that relate to underwater tunnel construction. The method I plan to use when looking for information on these topics is finding, reading, and synthesizing previous literature in order to come to a conclusion that answers the STS question.

Timeline is as follows:

March 15th: First Draft

April 15th: Polished Draft

April 15th through May: Review

Key texts for the STS topic

An important primary source text for reviewing current policies on underground tunnel construction is the OSHA handbook on underground construction (tunneling). This handbook is

not specifically for underwater tunneling but has important information pertaining to things such as air monitoring requirements and site control procedures. This information is also applicable to underwater tunneling when using the boring method and should help to answer some questions on how tunnel construction operates (OSHA, 2003).

Another important text is the Immersed Tunnels in the Natural Environment informational paper published by the International Tunneling and Underground Space Association. This text lists construction processes that need environmental considerations as well as a comparison between immersed and bored underwater tunnels. This paper will be useful when looking at the different phases of a construction project and how they impact the environment (Working Group 11, 2016).

A helpful resource when looking at the environmental impact of construction in general is the paper titled “Evaluating the Environmental Impact of Construction within the Industrialized Building Process: A Monetization and Building Information Modelling Approach.” This paper gives important information on the CO2 emissions of construction as well as a breakdown of energy usage for each section of the construction life cycle (Yao, 2020).

A fourth valuable resource is the paper called “Large undersea tunnels and the progress of tunnelling technology.” This paper breaks down the advancement of tunneling technology as well as some of the problems that can occur during the digging process. The type of things that can go wrong are important when writing about the environmental impacts underwater tunneling can have (Eisenstein, 1994, Pages 283-292).

Bibliography

Djoghlaf, A. (2007). *Secretariat of the Convention on Biological*. CBD International. Retrieved October 28, 2022, from https://www.cbd.int/doc/speech/2007/sp-2007-05-22-es-en.pdf

Eisenstein. (1994). Large Undersea Tunnels and the Progress of Tunneling Technology. *Tunneling and Underground Space Technology*, *9*(3), 283–292.

Gaynor, A. (2021). *How a Tunnel Boring Machine (TBM) Works*. EquipmentandContracting.com. Retrieved October 27, 2022, from http://publish-it-online.com/publication/frame.php?i=705526&p=30&pn=&ver=html5

Gerbis, N. (2022, August 24). *How do you build an underwater tunnel?* HowStuffWorks Science. Retrieved October 27, 2022, from https://science.howstuffworks.com/engineering/structural/build-underwater-tunnel.htm

Kuklewicz, S. (2021). *1828 tunnel flood*. The Brunel Museum Thames Tunnel. Retrieved December 14, 2022, from https://thebrunelmuseum.com/1828-tunnel-flood/

OSHA, Underground Construction (Tunneling)1–28 (2003). Washington, D.C.; U.S. Department of Labor.

Prasad, N.E., & Wanhill, R.J. (Eds). (2017). *Aerospace Materials and Material Technologies: Volume 1: Aerospace Materials* (Vol. 1). Springer.

WG11. (2016, June 30). *Immersed Tunnels in the Natural Environment*. ITA Activities. Retrieved October 27, 2022, from https://about.ita-aites.org/publications/wg-publications/1398/immersed-tunnels-in-the-natural-environment

Willis, M. (2018). *How the Thames Tunnel Revealed London's Class Divide*. JSTOR Daily. Retrieved October 28, 2022, from https://daily.jstor.org/thames-tunnel-revealed-londons-class-divide/

Yao, F., Liu, G., Ji, Y., Tong, W., Du, X., Li, K., Shrestha, A., & Martek, I. (2020, November 13). *Evaluating the environmental impact of construction within the Industrialized Building Process: A monetization and building information modelling approach*. International journal of environmental research and public health. Retrieved October 27, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7698002/#:~:text=However%2C%20construction%20is%20not%20an,CO2%20emission%20%5B3%5D