Thesis Project Portfolio

Empirical Model Relating Chloride Loading Density and Conductance for Prediction of Galvanic Corrosion

(Technical Report)

Models and Simulations as Boundary Objects in Infrastructure Construction and Maintenance

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Trevor James Eggleston

Spring, 2023

Department of Materials Science and Engineering

Contents of Portfolio

Executive Summary

With the rapid growth of global computing power and mathematical knowledge, modeling of physical systems has become a cornerstone of modern engineering practice. Such models may take several forms, from simulations and predictive modeling to see how systems evolve, to quantification models in which some system parameter is calculated when supplied other information. In any case, computational models provide a low-risk sandbox for engineers to optimize their solution by applying many different environmental, material, and loading variables to their systems and seeing the effect of said variables. Besides the obvious technical uses of engineering models, models also serve an important social function by acting as a mediator or communication tool between engineers and nontechnical professionals. The technical thesis describes a model created to relate two important variables for corrosion and verification experiments performed to test its effectiveness. The sociotechnical thesis provides a case study to establish the role of models in public infrastructure projects involving many diverse parties, such as politicians, engineers, government workers, and NGOs. These projects are coupled in that they seek to demonstrate that models may benefit organizations both by allowing for increased technical capability and by enhancing communication between different organizational components.

The technical component is an investigation and development of a correlation model in which chloride loading density (CLD) may be determined from relative humidity (RH) and conductance (G) data in the context of corrosion in outdoor environments. CLD is an important parameter for predicting corrosion rates, as these rates tend to increase with chloride ion concentration by virtue of higher electrolyte conductivity. In order to create a model that reflects realistic surface wetting at high RH due to NaCl deliquescence, laboratory data of conductance

as a function of relative humidity at 30ºC was examined for known CLD values. Hysteresis-like loops were observed in the graph of $G(RH)$ as RH increased and decreased periodically, and the drying (decreasing RH) halves of these loops were isolated. For low CLD values, a logistic function was fit to data in the drying regime and the coefficients corresponding to the best fit were noted. For high CLD values, the linear region of the drying curves were fit to a line and the x-intercept was recorded. For each case, the parameters were then correlated to the known CLD value. Finally, experiments were conducted in an outdoor environment by applying a known CLD to the same sensors as those from the laboratory tests and measuring G, RH, and temperature. The goals of these experiments were to both verify our model's accuracy and to examine the effect of temperature and other environmental effects on conductance for a given CLD.

The sociotechnical component is a case study of models being used as agents of support for engineers when having designs approved by management or government agencies in public infrastructure projects. Frequently in projects of this nature, nontechnical professionals are primarily concerned with minimizing costs and maximizing public support. The priorities of engineers, typically being in design safety and effectiveness, sometimes come into conflict with those of the project planners and those who control budget allocation. In this case, models can act as boundary objects that mediate the two parties by simulating the effect of implementing or not implementing a particular design solution. This gives engineers a more potent argument in favor of their priorities for the project. To establish that this indeed a real role that models play in public infrastructure, a case study of the London congestion charge was performed. Here, simulations played a heavy role in the establishment of the congestion charge in central London through the interactions of the public, think tanks, engineers, politicians, and bureaucracy. Once

the social, political, economic, and technical background of the congestion charge was examined thoroughly, Actor Network Theory (ANT) modified by the notion of boundary objects was applied to critically examine what role simulations played in this case. Through this analysis, models were established to have the capacity to act as mediators between technical and nontechnical professionals in infrastructure projects.

The technical project concluded with a successful model predicting CLD using the x-intercepts from the linear-fit method. However, the isothermal conditions presented by the lab data proved insufficient for fully predicting CLD from conductance and relative humidity data in a complex real environment, as evidenced by our experiments. By using our procedure for the outdoor experiment to collect more data, the modeling approach used here could be used to more accurately quantify CLD from temperature, conductance, and relative humidity data. Additionally, the sociotechnical project successfully extended prior work of describing models as boundary objects by identifying a specific example of how models act in this way in public infrastructure. Further, it was shown that ANT provides a useful framework for thinking about the mechanism by which models fill this role, despite the complexity of this system. Future work could reinforce the research done here by examining other cases in which models act as boundary objects using the same ANT framework. Other sociotechnical frameworks could also be applied and examined, potentially giving more ways of thinking about this particular system.