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Steel Corrosion in Underground Transportation Infrastructure

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Introduction

Corrosion imposes a significant threat to aging American transportation infrastructure, including bridges, highways, railroads, and a multitude of subsurface structures such as metallic culverts, drainage pipelines, reinforced soil structures, and metallic deep foundation systems that support the nation's transportation network. The annual cost of corrosion for highway bridges in the U.S. is estimated to be between $6.3 and $10.15 billion. Corrosion of buried steel remains one of the most insidious challenges due to the uncertainty associated with its estimates. This uncertainty grows exponentially with time, making corrosion estimates in the long term challenging for transportation asset management, especially since buried steel structures cannot be inspected visually. Improving the industry's understanding of long-term corrosion and its ability to measure and predict it as underground soil conditions change can help engineers better estimate how long buried steel transportation structures will last. This knowledge is important both for maintaining existing infrastructure and for designing safer, longer-lasting structures in the future. Although researchers have learned a great deal about how individual factors affect soil corrosivity, there is still limited understanding of how these factors work together as soil conditions change over time. This research examined soil resistivity and corrosivity by studying several key factors that influence how buried steel corrodes.

Study Methods

Three studies were conducted as part of this research, which used new experimental and analytical methods: (1) experimental evaluation of soil resistivity in controlled, constant conditions using a newly devised experimental protocol to implement a comprehensive experimental program by varying one testing parameter at a time; (2) experimental evaluation of soil resistivity in controlled, variable conditions using a newly piloted experimental setup capable of capturing the variation in soil resistivity in a continuously varying environment; and (3) analytical evaluation of a curated digital database of field corrosion measurements and site parameters, which was used to devise a supervised machine learning prediction model capable of predicting corrosion of underground steel with a prescribed uncertainty tolerance. Overall, the studies involved in this project combined controlled experiments and data analysis to better understand how soil conditions influence corrosion in buried steel.

Findings

Three studies were completed and documented in this report. Following is a summary of each study and its main findings:

- Element-Scale Soil Resistivity Testing in Controlled Constant Conditions. This experimental study evaluated soil resistivity in controlled, constant conditions to explore how different soil properties affect corrosion. The results of the testing program showed the potential of the experimental approach to provide the necessary data to develop empirical prediction models for soil resistivity. The influence of each parameter was evaluated separately to discover how each one influenced results. Soil resistivity was observed to decrease with increasing soil moisture, chloride content, sulfate content, acidity, alkalinity, and soil temperature.
- Element-Scale Soil Resistivity Testing in Controlled Variable Conditions. This pilot evaluated soil resistivity in controlled, variable conditions. The results suggest that this experimental method can capture how soil resistivity varies in more realistic conditions that resemble what happens in the field. This information can help improve models used to predict corrosion in buried steel structures.
- Analysis of the NBS Romanoff Corrosion Dataset. This data analysis evaluated the corrosion of buried steel using advanced data science methods. Researchers compiled and cleaned a large historical dataset from the National Bureau of Standards' Romanoff corrosion study and used it to train a machine-learning model. The model was designed to predict corrosion in underground steel and was tested to ensure it could perform reliably across different sites.

Policy Recommendations

The research supports several policy and professional practice recommendations for managing underground steel transportation infrastructure. Design and asset management guidelines should explicitly account for time-varying soil conditions, rather than relying on single-point or conservative corrosion assumptions. Transportation agencies are encouraged to incorporate soil resistivity measurements and site-specific environmental data into corrosion evaluations and service-life predictions. The use of data-driven prediction tools, such as the validated machine-learning framework developed in this study, is recommended to quantify corrosion risk with defined uncertainty for both existing and new structures. Specifications and design manuals can be updated to better reflect the combined effects of moisture, chemistry, and temperature on soil corrosivity, supporting more targeted corrosion protection strategies, improved material selection, and risk-based maintenance and replacement planning. Together, these changes could help agencies better manage corrosion risk, extend the service life of underground infrastructure, and reduce costly failures.

About the Principal Investigator

Amr M. Morsy, PhD, PE, is an Assistant Professor in the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. His research focuses on geotechnical infrastructure deterioration and asset management.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2523

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