Impactful Resilient Infrastructure Science and Engineering (IRISE)

-Project Scope of Work-

(FY 2022-23 (IRISE Year 5) Annual Work Program)

SUMMARY PAGE

Project Title: A novel methodology for structural optimization of bridge decks against corrosion

Person Submitting Proposal: John C. Brigham

Proposed Funding Period: 10/01/2022 - 09/30/2024

Project Duration: 24 months

Project Cost: $ 175,600.80

PennDOT Work for Hire? No

Project Title: *A novel methodology for structural optimization of bridge decks against corrosion*

Problem Statement: A major problem for transportation infrastructure is the degradation of structural concrete in bridge decks, which is currently estimated to cause an annual cost of $8.3 billion for mitigation and rehabilitation in the US. Corrosion is significantly accelerated by the application of deicing salts during winter months. Moreover, the presence and evolution of micro- and macro-cracking in the concrete promotes faster ingress of chloride ions from the surface to the rebars. As a result, corrosion shows prominent non-linear traits that often necessitate replacing the entire deck, if mitigation measures are not put in place. The complex interactions between the mechanical degradation and percolation of different aggressive chloride ions, therefore, necessitates frequent visual inspections and drives up the maintenance cost of the systems. In recent years, several corrosion mitigation strategies have been proposed, many of which have included changes to the material components of the concrete. The adoption of such mitigation strategies brings challenges in the evaluation of new design and maintenance paradigms, as the long-term efficacy of the new materials has not been identified yet. Therefore, more research is needed to quantitatively assess the technical and economic benefits associated with different corrosion mitigation strategies.

Project Objectives: Our objective is to create and deploy a novel toolset for the prediction of corrosion based on the structural features of a selected bridge deck. To do so, we will first create physics-based numerical models for the prediction of corrosion in reinforced concrete decks, by means of the Dual Random Lattice Modeling approach recently developed by Dr. Alessandro Fascetti. We will embed this new modeling framework in an optimization framework to develop new best practices for bridge deck corrosion mitigation and guide both the design of new systems and the operational maintenance of existing ones. The ultimate goal of the research is to identify the complex interrelationships between the temporal and spatial frequency of salt application and the corrosion mitigation strategies in place. Then, this new information will be combined with reliability-based optimization to provide guidelines for the operational control of bridge decks subject to corrosion mechanisms.

Project Scope: The project will focus on analyzing the existing solutions to bridge deck corrosion. Furthermore, the project will provide new insights into the effects of micro- and macro-cracking in concrete on the different types of commonly-used mitigation strategies, which include the use of sealants, polymeric coatings, and/or different types of reinforcing steel (galvanized, martensitic MMFX or epoxy-coated bars). We will analyze the effects of different types of salts (sodium chloride or calcium chloride) and construct numerical models to predict the concentration of chloride ions throughout the deck. Different scenarios obtained from the reliability-based optimization may provide new insights into the most effective prevention measures, as well as novel capabilities for advanced structural optimization based on the prediction of the rates of corrosion in the deck.

Outcomes of this work will provide quantitative measures for: 1) the effectiveness of combining different mitigation strategies for extending life span and reducing corrosion rates, and 2) practical guidelines for the optimal design and adoption of corrosion-resistant measures, based on the specific structural features of the examined bridge.

Task Statements:

The objectives of this project will be realized through the completion of the following tasks:

Task A – Review of Current Practice:
Review of current practices and analysis of deicing salt application patterns (frequency, quantities and specific salts used). Identify the conditions most commonly associated with sections vulnerable to corrosion, including exposure patterns (as related to the deicing salt application), as well as dimensions, original construction materials, and mitigation strategies.

Task B – Corrosion Modeling Framework:
Construction of modeling framework and simulation of corrosion by means of meso-scale coupled mechanical-diffusion models. The framework will account for typical geometries, materials, and exposure/mitigation conditions, as identified in Task A.

Task C – Corrosion Model Validation:
Validation of the model created in Task B to estimate the *in situ* rates of corrosion for a representative set of sections. Validation will be performed for the processes of diffusion and mechanical damage for both separate and coupled scenarios.

Task D – Optimal Design Algorithm:
Development and evaluation of a multi-objective optimization approach that includes uncertainty (i.e., variations in performance of materials and exposure conditions). The optimization will produce a series of mitigation designs based on Pareto optimality with respect to cost and corrosion damage rate, account for given structural design constraints, and incorporate the physical model developed in Task B. The optimization will incorporate surrogate modeling to account for expense of optimization with uncertainty.

Task E: Final Report
Final report containing recommendations and guidelines for best practices for corrosion mitigation.

Deliverables:

1. Task A - Literature review of existing technologies and available recommendations for mitigation of bridge deck corrosion, 6 months from the Notice to Proceed date.
2. Tasks B and C - Coupled mechanical-diffusion model, 15 months from the Notice to Proceed date.
3. Task D - Optimal design algorithm, 21 months from the Notice to Proceed date.
4. Task E - Draft Final and Final report and recommendations and guidelines, 22 and 24 months from the Notice to Proceed date.

Key Personnel:

<u>Principal Investigator:</u>

John Brigham

Other Key Staff:

Alessandro Fascetti

Other Personnel:

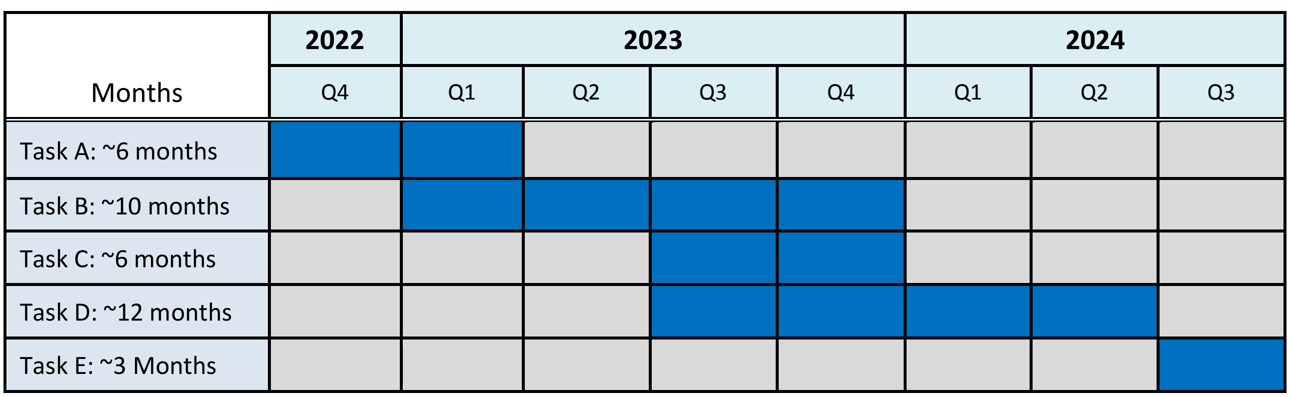
Grad Students:

1x Graduate Student

Proposed Person-Hours by Task:

Team Member	Task A	Task B	Task C	Task D	Task E	Total
Key Project Team Members, Estimated Hours Per Task						
John Brigham	23	57	34	69	17	200
Alessandro Fascetti	23	57	34	69	17	200
Graduate Student	317	792	475	950	238	2772
Total	363	906	543	1088	272	3172

Schedule:



Budget: The total project cost is $175,600.80.

Acknowledged By:

John C. Brigham, Ph.D.
Principal Investigator