Building Smarter Cities via Intelligent Asset Management: South Carolina Case Study using IBM Maximo Application

Technology Transfer Activities

by

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Li Ai

Laxman KC

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Technology Transfer Activities

1 Outputs

This project introduced an improved load rating procedure utilizing digital twin technology. By using potentiometers, strain gauges, and fiber optic sensors to monitor a laboratory bridge slab, data related to crack evolution and strain during loading were obtained. Subsequently, calibrated three-dimensional finite element models representing different loading scenarios were produced, laying the foundation for a digital twin model of the bridge slab. The bridge slab model was then integrated into a bridge span to form the digital twin model of the actual bridge span for load rating tests. The digital twin model was calibrated with field monitoring data from potentiometers, strain gauges, fiber optic sensors, and drones, The digital twin model developed was applied to a bridge in Abbeville, South Carolina.

1.1 Output #1

One report has been submitted to C^2M^2.

The project also resulted in the following publications:

Journal Article:

1. Ai, L., K C, L., Elbatanouny, E., Henderson, A., &Ziehl, P. (Accepted on January 24). Assisting Load Rating Testing of Precast Reinforced Concrete Bridge Slab through Digital Twins and Field Monitoring Data. Journal of Testing and Evaluation.

2. K C, L., Ross, A., Ai, L., Henderson, A., Elbatanouny, E., Bayat, M., & Ziehl, P. (2023). Determination of vehicle loads on bridges by acoustic emission and an improved ensemble artificial neural network. Construction and Building Materials, 364, 129844.

3. K C, L., Tabassum, N., Ai, L., Cole, C., &Ziehl, P. (2023). Automated crack detection and crack depth prediction for reinforced concrete structures using deep learning. Construction and Building Materials, 370, 130709.

Presentation:

1. Ziehl, P., Ai, L., K C, Laxman, (2022, October). Surface Damage Imaging for Input to Load Rating of Bridges. In Emerging Methods for Surface Damage Monitoring and Imaging, Part 2 of 2. ACI Concrete Convention.

Poster:

1. K C, L., Tabassum, N., Ai, L., Cole, C., Comert, G., Huynh, N., &Ziehl, P. (2022), “Automated Inspection of Precast Reinforced Concrete Slabs in South Carolina”, C2M2 6th Annual Fall Conference, South Carolina, USA.

1.1 Output #2

The project developed an improved load rating method using digital twin technology. Specifically, it includes: (1) a method that uses a drone to detect bridge cracks and estimate the depth of bridge cracks, as well as the spacing of the cracks; (1) a 3D finite element model of the bridge span for load testing. The load testing process can be updated with field monitoring data. The University of South Carolina is working closely with IBM, Verizon and Luna Innovations to expand on the results of this project and meets weekly with representatives from IBM.

2 Outcomes

Bridges are important hubs in the transportation system. This project improved the load rating process for bridges. The project also developed a technology for using drone inspection and computer vision algorithms to detect and estimate crack depths as well as spacing. Both technologies are readily deployable.

2.1 Outcome #1

This project developed a digital twin-based load rating method, incorporating data from lab-monitored bridge slabs using various sensors. It involved creating a detailed finite element model and integrating it into a digital twin of a bridge span.

2.2 Outcome #2

This project develops an innovative automated framework for detecting cracks and estimating their depths using images captured by drones. The framework consists of three phases: in the first phase, surface crack detection using a binary convolutional neural network (CNN); and in the second phase, depth prediction using a combination of CNN and regression models (RF and XGBoost). In the third phase, the spacing between two cracks is estimated based on the visualization results of surface crack detection.

3 Impacts

3.1 Impact #1

The impact will be a significant enhancement in bridge maintenance, achieved through the implementation of a digital twin-based load rating method that integrates lab data with finite element models for precise structural evaluations.

3.2 Impact #2

The impact will be a substantial advancement in concrete structure maintenance, as it introduces an automated, drone-based framework for precise crack detection, measurement, and visualization, leading to more informed repair and maintenance strategies.