MPC-450

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Project Title:
Using Building Information Modeling to Track and Assess Structural Condition

University:
Colorado State University

Principal Investigators:
Rebecca Atadero, Assistant Professor
ratadero@engr.colostate.edu
970-491-3584

Caroline Clevenger, Assistant Professor
Caroline.Clevenger@colostate.edu
970-491-7963

Mehmet Ozbek, Assistant Professor
mehmet.ozbek@colostate.edu
970-491-4101

Research Needs:
As asset management for bridges and other transportation structures progresses, an important challenge that must be addressed is the need to systematically determine the effect of damage/deterioration on structural performance, including issues related to safety and serviceability. Currently, bridges are primarily inspected visually and inspection findings are recorded using the AASHTO CoRe elements for use in bridge management programs such as AASHTOware Bridge Management (formerly Pontis). Although inspection findings are recorded by element type, the location of the damage on the element is not recorded. Without information on location, the ability to determine and document the significance of damage is limited. For example, a large corroded region on the flange of a simply supported steel girder would be of much greater concern if it were located near the middle of the span where the bending moment is high, than if it were located near the end of the span where moments are low. The need to track location information in order to assess the implications of damage to bridge performance is not a new revelation (e.g. Estes and Frangopol, 2003), but modern software tools are emerging that can enhance our ability to collect, store and use this type of information.

In a related issue, externally bonded fiber reinforced polymers (FRP) are increasingly being used as a repair technique for bridges, particularly reinforced and pre-stressed concrete bridges. FRP is applied in thin sheets, and can cover fairly large portions of some bridge elements. MPC Project 340 considered the performance of externally bonded FRP after eight years in service on the Castlewood Canyon Bridge in Colorado (Atadero, Allen, and Mata, 2013). This project showed that regions of FRP are prone to debond from the concrete surface for reasons other than excessive loading such as environmental conditions and perhaps application techniques. As FRP becomes more common in the field, it becomes important to have means to record and track the condition of these debonded regions (i.e., location information) in order to 1) better understand the sources of initiation and rates of progression of debonding, and 2) to be able to assess how the debonding is affecting structural condition. Understanding FRP debonding is another situation where it is important to track damage with regard to specific locations on structures. For example, if 5% of the total area of FRP is debonded, but this area is distributed throughout the total bonded region in many small areas, this would be much less concerning that a situation where all 5% was concentrated in a single critical location.

In both cases, a means is needed to record and store the location and extent of damage/ deterioration on bridge elements and to provide a platform for analysis of the recorded damage. Such a tool could be used to assess the actual condition of the structure or element. Building Information Modeling (BIM) offers a great deal of promise to support the creation of such a tool(s). The three-dimensional (3D) interface of BIM software creates a platform that enables engineers to visualize and explore geometric relationships virtually and in real-time. The real power of BIM, however, comes from the association of databases (for example, information about loads, tributary area, reactions, moments, shears, and beam sizes) with 3D information, allowing previously unavailable queries, filters and analysis. Specifically, organizing data within three dimensions allows for software analysis that incorporates and relates locational information, creating new opportunities for data storage, manipulation and output. Finally, interoperable capabilities that support data transfer between BIM software and existing analysis programs (for example, Revit Architecture and Robot Structural Analysis) can further support accurate and automated data analysis. In sum, significant opportunity exists to use BIM models to transform structural asset management of bridges and a wide range infrastructure facilities (Clevenger, Ozbek, Fanning and Mahmoud, forthcoming).

Research Objectives:

The goal of this project is to demonstrate the feasibility of using BIM models to store detailed data from bridge inspections (particularly with respect to location and extent of damage), and to develop a preliminary analysis tool that can operate on the enhanced data stored in the BIM model to provide assessments of structural condition.

The objectives of this research are to:

1. Collect detailed data on bridge condition from a real bridge and show how this data can be input and stored in a BIM model of the structure.
2. Develop a demonstration analysis tool that can take the information stored about element condition and assess the effect of recorded damage on structural performance (in terms of strength, for example). This demonstration tool will operate on a specific type of bridge element – likely the girders or deck.
3. Identify the future research and tools needed to make the process of storing bridge inspection results in BIM practical for state DOTs.

Research Methods:

This project will take a demonstration approach to addressing the first and third research objectives. A real bridge will be identified with assistance from the City of Fort Collins. A BIM model of the bridge will be created or adapted in BIM software. A detailed inspection of the bridge will be conducted and results will be input into the BIM model. Through this process the feasibility of storing bridge inspection data in a BIM model will be explored, and current limitations on the applicability of BIM to this purpose will be identified.

The second research objective will be addressed analytically with a final demonstration on the BIM model of the real Fort Collins bridge. A specific type of bridge element will be selected for consideration – likely girders or the deck. Possible damage/deterioration modes will be identified for the element. For each damage mode literature review, structural analysis and assumptions will be used to create a model to predict how the type, extent, and location of damage affects structural capacity. These models will be used to create a demonstration analysis tool that can analyze information stored in the BIM database to estimate the impact of damage on performance of the structural element. Finally, the analysis tool will be used to assess the relevant elements of the real bridge, and results of the tool will be compared to more detailed traditional analysis techniques.

Expected Outcomes:
This project will add to the growing body of examples on the use of BIM to store data relevant to the operation and maintenance of a variety of infrastructure types. It will identify important areas for further research to facilitate the adoption of BIM technology in bridge and infrastructure inspection and asset management. The project will also develop an analysis tool demonstrating how the data stored in BIM can be used to enhance the assessment of structural condition.

This project represents fairly early steps in a long process, but ultimately, as the techniques studied in this project develop and mature, they will greatly enhance our ability to collect, store, analyze and use bridge inspection data. Long term effects include greater accuracy in bridge condition assessments leading to better management planning, and a greater understanding of bridge deterioration processes made possible through the collection of more detailed data.

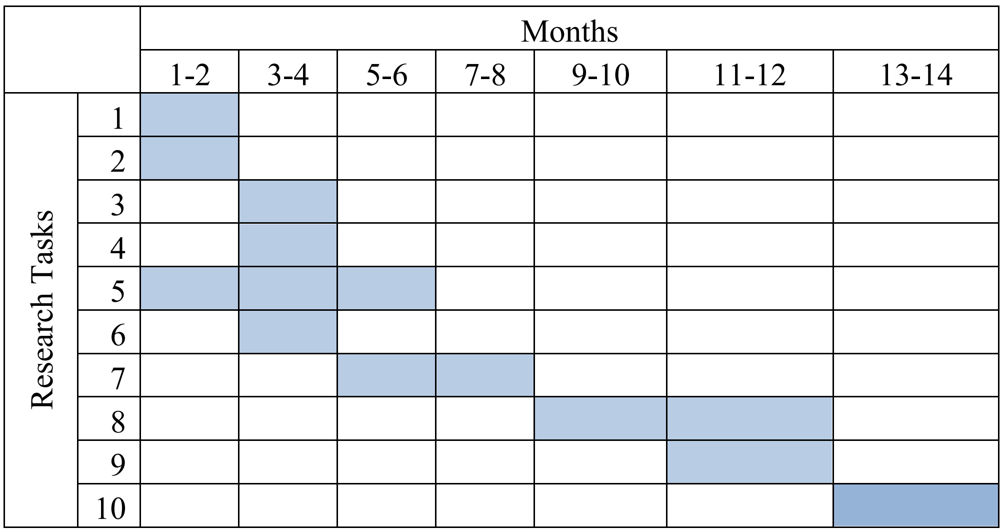
Relevance to Strategic Goals:
This project addresses the Strategic Goal: State of Good Repair. MAP-21 is requiring states to develop performance based and risk based plans for asset management. Carefully evaluating the performance of or risk associated with individual bridges requires the ability to take bridge inspection results and use them to determine the condition of the bridge.

Educational Benefits:
A graduate research assistant will be hired to conduct the research described in this proposal.

Work Plan:
The specific tasks below will be completed as part of this project.
1. Assess BIM functionality and determine means to store inspection results in BIM models.
2. Work with the city of Fort Collins to identify a demonstration bridge.
3. Create a BIM model of the bridge. This model may be based on actual or representative data.
4. Conduct a thorough inspection of the bridge and input inspection data to the BIM model.
5. Identify challenges associated with the use of BIM, especially those encountered during tasks 1 and 4, and propose areas for further research.

6. Select example bridge element for analysis tool (this may depend on the type of damage on the demonstration bridge).
7. Identify damage modes relevant to the bridge element selected in task 6 and create models to relate the location and extent of damage to structural condition (strength).
8. Use models created in step 7 to write an analysis software tool (or interoperable interface) that will support analysis of the data in the BIM model to assess structural condition.
9. Demonstrate the functionality of the analysis tool using BIM model data from the real bridge test case.
10. Disseminate project findings through final report, journal publications and a TLN webinar.

The project timeline is presented below.



Project Cost:
Total Project Costs: $62,690
MPC Funds Requested: $ 36,000
Matching Funds: $ 26,690
Source of Matching Funds: Faculty Time and Effort and Faculty Start-up Funds

TRB Keywords:
Inspection, Bridges, Performance

References:
Atadero, Rebecca A., Douglas G. Allen, and Oscar R. Mata. *Long-Term Monitoring of Mechanical Properties of FRP Repair Materials.* MPC-13-253, North Dakota State University - Upper Great Plains Transportation Institute, Fargo: Mountain-Plains Consortium, 2013.

Clevenger, Ozbek, Fanning and Mahmoud, *A Pilot Case Study to Evaluate the Potential Impact and Benefit of Adopting and Implementing BIM on Bridge and Infrastructure Projects.* MPC-413, North Dakota State University - Upper Great Plains Transportation Institute, Fargo: Mountain-Plains Consortium, forthcoming.

Estes, A.C. and Frangopol, D.M. (2003). "Updating Bridge Reliability Based on Bridge Management Systems Visual Inspection Results." *Journal of Bridge Engineering*, 8(6), 374-382.