Executive Summary, Technology Transfer, and Research Readiness Level Assessment

Prototype System for Implementing the Ultrasonic Guided Wave Method on the Field

Research Objectives

The ultimate goal of this project was to make the previously developed innovative testing method, namely the use of the leaked ultrasonic guided waves for the early detection of multiple flaws in reinforced concrete bridge decks, more practical and field-application ready. Following objectives were accomplished:

1. Developed a suitable attachment for the transmitter to the rebar
2. Evaluated the system hardness and durability in the field in terms of adhesives/attachments as well as the effect of vehicular vibration/impact
3. Developed recommendations for the location of the transmitter and receivers on actual bridge decks
   - •The best locations for the transmitter for common issues
   - •The best locations for an array of receivers for common issues
4. Validated the results and benchmark the method on the field

Research Benefits

- This method presented the opportunity for a relatively low-cost and simple to interpret non-destructive evaluation technique that can be utilized in-house by NDOT, eliminating the need for multiple NDT techniques to detect different types of flaws
- This method presented an opportunity to make improvements in the maintenance protocol for bridge decks
- Increased safety and health of reinforced concrete bridge decks
- Reduced maintenance cost on infrastructure over time

Background

Reinforced concrete bridge decks are highly susceptible to deterioration, mainly due to corrosion of the rebars and the subsequent propagation of issues. According to Federal Highway Administration (FHWA 2014), 145,890 out of the 610,749 highway bridges (24%) in the U.S. are structurally deficient. Yunovich et al. (2001) states that corrosion and delamination accounts for approximately 40% of all bridge deck repair costs; and Cui et al. (2010) identify the highway bridge corrosion related repair costs to be around $8.3 billion, with $2 billion of this just for the repair of bridge decks. Given such high costs, NDOT personnel informed the PI that the philosophy in Nebraska is to add an asphalt overlay to bridge decks based on age (i.e. when they are 10 years old) as a precaution. While this is a safe approach, it comes at a cost and it could be avoided, if there were better nondestructive evaluation (NDE) methods that can detect problems earlier. Many NDE methods can detect issues only after the defects are of significant size, and most NDE methods are good in detecting only one type of flaw.

Conclusion

This report presents the latest improvements in a recently developed nondestructive testing (NDT) technique for early detection of various flaws such as corrosion, delamination, and concrete cracking in reinforced concrete (RC) bridge decks. The method, named Ultrasonic Guided Wave Leakage (UGWL) method by the developing authors, involves use of internal steel reinforcement (rebar) as a wave guide for transmitting ultrasonic waves through the system and the measurement of leaked energy at the surface of the concrete. This report builds upon the progress made in the previously published phases of the project (M029 and M066) and aims to further explore the capabilities and practicality of the proposed NDT method. Specifically, efficient coupling of the sensors to the reinforcement and to concrete, durable embedment of sensors in field conditions, detection of corrosion development, benchmarking with half-cell potential (HCP) and chloride level tests, and suggestions for optimal sensor arrays are explored via laboratory and field testing. Results show that with careful placement of sensors and data interpretation, onset and progression of localized corrosion can be detected, which will be useful in developing deterioration models for RC bridge decks in the future. Results show that the UGWL results match well with chloride level tests and HCP testing predictions for potential for corrosion. For field applications, an angled seat made of fast-setting Hydrocal gypsum cement is recommended and it is projected that the optimal angle of attachment is 33 degrees or less from the vertical axis.

Principal Investigators

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Final report is available:
HERE

NDOT Recommendations Based Off of Research Project

Since this research project was a feasibility study showing that is possible to use Ultrasonic Guided Wave method on the field. Since this technology is still evolving, the Bridge Division is focusing in other technologies to detect defect on waterproof and asphalt overlays. Bridge Division can see that this technology could provide to test the long/short term life cycle of patching materials.

- *As provided by Fouad Jaber, Lead TAC Member*

Technology Transfer

PUBLISHED JOURNAL PAPERS AND THESES/DISSERTATION

- Garcia, E. V. C. (2016). Identifying the onset, type, and location of deterioration in reinforced concrete using ultrasonic testing. PhD Dissertation. Department of Architectural Engineering, University of Nebraska-Lincoln.
- Garcia, E., Erdogmus, E., Schuller, M., & Harvey, D. (2017). Novel Method for the Detection of Onset of Delamination in Reinforced Concrete Bridge Decks. Journal of Performance of Constructed Facilities, 31(6), 04017102.
- Garcia, Eric, Erdogmus, E., Schuller, M., & Harvey, D. (2019). Detecting Onset of Different Types of Flaws in Reinforced Concrete. ACI Materials Journal, 116(1). https://doi.org/10.14359/51710962.

PUBLISHED WEBINARS/PRESENTATIONS

- Tran-SET webinar "Innovative Technology, Techniques, and Processes in Transportation Infrastructure Inspection" https://www.youtube.com/watch?v=S5tv2MrbeEY&feature=youtu.be

JOURNAL PAPERS SUBMITTED FOR REVIEW

- Erdogmus, E. , Garcia, E., A. Amiri, Schuller, M. "A Novel Structural Health Monitoring Method for Reinforced Concrete Bridge Decks Using Ultrasonic Guided Wave Leakage," INVITED submission to the Infrastructures Journal, Special Issue Non-Destructive Testing and Evaluation (NDE&T) for Civil Infrastructures. (Submitted on 5/21/2020)

IN PROGRESS JOURNAL PAPERS AND THESES

- Amiri, A.S. (2020). A Comparison Between Ultrasonic Guided Wave Leakage And Half-cell Potential Methods In Detection Of Corrosion In Reinforced Concrete Structures. Master's Thesis. Department of Architectural Engineering, University of Nebraska-Lincoln.
- Amiri, A.S., Erdogmus, E., Richter-Egger, D. "A Comparison Between Ultrasonic Guided Wave Leakage and Half-Cell Potential Methods in Detection of Corrosion in Reinforced Concrete Structures," in preparation for submission to Sensors Journal.

Research Readiness Level (RRL) Assessment

RRL 2

Level 2: Applied Research/Proof Concept – Lab Level

-Research/Technology developed in a laboratory environment. Integration of components

This brief summarizes Project SPR-P1 (19) M086
"Prototype System for Implementing the Ultrasonic Guided Wave Method on the Field"
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