Framework of Internal Damage Identification in Inhomogeneous Medium Interweaving Wave Scattering Model and Deep Learning

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$ 122,000

Assesing internal damage identification using WSM

Various environmental conditions and loading forces may cause our infrastructure material, concrete, and HMA to deteriorate. Internal vertical cracks and internal reflective cracks (e.g., subsurface cracks) perpendicular to concrete surfaces are the most common, challenging, and critical types of infrastructure damage. Consequently, these extensive damages result in material property degradation, reinforcement corrosion, and even structural failure. Thus, effective detection of the cracks must be executed in a timely manner for better service life prediction and to monitor structural conditions at an early stage. There are recent advances in the study of surface-opening vertical crack detection (e.g., nonlinear diffuse ultrasonic waves, guided waves, and transmission energy). Despite these efforts, these studies for surface opening crack not internal damage, may present certain limitations and challenges for more in-depth understanding and monitoring of "internal" cracks. These internal reflective cracks commonly occur in many other infrastructures such as airport runway, pavement, and pipe, under the overlay caused by stress concentration at the bottom of the overlay. The project's overall goal is to advance understanding of a wave scattering model (WSM) of an internal vertical reflective crack in inhomogeneous material (IHM) leveraging deep learning.

Problem Statement

Various environmental conditions and loading forces may cause our infrastructure material, concrete and HMA to deteriorate. In particular, internal vertical cracks, particularly internal reflective cracks (e.g., subsurface cracks) (e.g., subsurface cracks) perpendicular to concrete surfaces, are among the most common challenges and critical types of infrastructure damage. Consequently, these extensive damages result in material property degradation, reinforcement corrosion, and even structural failure. Thus, effective detection of the cracks must be executed in a timely manner for better service life prediction and to monitor structural conditions at an early stage. There are recent advances in the study of surface-opening vertical crack detection (e.g., nonlinear diffuse ultrasonic waves, guided waves, and transmission energy). Despite these efforts, these studies for surface opening crack not internal damage, may present certain limitations and challenges for more in-depth understanding and monitoring of "internal" cracks. In particular, these internal reflective cracks commonly occur in the airport runway, pavement, and pipe, under the overlay caused by stress concentration at the bottom of the overlay. PI recently studied an analytical model to identify the internal reflective crack with various numerical integration methods to improve the analytical solution validated through FE simulations and experimental study. This approach provides an accurate depth-to-crack distance by using the relation between scattering energy, so-called wave response variation (WRV) and crack geometry. However, huge challenges in this effort of the analytical modeling for identifying are to reduce the gap between the nonlinear analytical and numerical WRV model and experimental WRV result.

Objectives

The overall goal of this study is to advance understanding a WSM of an internal vertical crack in inhomogeneous material (IHM) leveraging deep learning. This approach will enable to achieve the following objectives: 1) to develop unique experimental and numerical databases for physics-based integrated modeling for complex wave scattering by an internal vertical crack and material inhomogeneities; 2) to advance ML methodologies that can validate the scattering behaviors in objective 1, to develop a WSM, and to enhance the model's prediction accuracy in IHM; 3) to verify and analyze the framework with the experimental results

Intended Implementation of Research

The team plans to support a total of two Ph.D. students and one Master's student under this project. At least two underrepresented populations will be involved in this project. The students in Transportation Group will have an opportunity to synthesize literature and current practice in sensor utilization and to develop the evaluation tool. The student in Structure Group will learn sensor design and development for implementation. All the students will engage with city planners and stakeholders to get feedback and technical advice on the decision-making process and to arrange field implementation. The implementation phase of the project will consist of outreach and educational activities, including to: 1)elaborate a short document aimed at transportation agencies and practicing engineers detailing research findings; 2)present research results from the project in technical meetings; 3) develop of online-learning materials (YouTube videos and webinar).

Anticipated Impacts/Benefits of Implementation

While most previous research efforts have challenges with limitations to identify and estimate these damage due to complex wave scattering and various environmental factors, the proposed project addresses the need for reliable damage evaluation and framework. With the help of a damage evaluation framework leveraging unique experimental data and physics ML or deep learning, this research can realize broader impacts by leading efficient and effective transportation planning and operation in Region 6. Understanding current practice in the evaluation and monitoring of transportation infrastructure capabilities is critical in achieving the expanded transportation aspects. The proposed project contributes to providing innovative strategies for assisting investment in new sensors, data collection, and structural performance assessment using deep-learning technology and next-generation visualization technology.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.