IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Integrity Evaluation of Reinforced Concrete Structures Using Ultrasonic Guided Waves**
Project Number	**IMURA0383**

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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(*Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

Define the problem

As the most widely used structural material in civil infrastructures, reinforced concrete is, however, vulnerable to the threat of deterioration, e.g. surface cracking, corrosion of steel rebar and debonding of reinforcement. Engineers continually seek new techniques to perform sustainable integrity evaluation of concrete structures while applying advanced materials, e.g. fibre reinforced polymer (FRP) composites to retrofit the degraded concrete structures. The reliability and durability of such retrofitting are, however, poorly understood because of the absence of reliable and robust methods to monitor and evaluate the structural integrity. In the last decade or so some techniques for reinforced concrete have emerged, e.g. acoustic emission-based, impedance-based and optical fibre-based techniques. These techniques, however, can only offer local measurement and very dense populations of sensors must be used for reinforced concrete structures.

On the other hand, novel structural health monitoring techniques have been developed on the basis of ultrasonic guided waves, which have already found their niches in other communities, particularly in aerospace industry, to achieve both global and local measurements with fewer sensors. However, many fundamentals need to be well understood before ultrasonic guided waves can become an effective and

reliable approach for integrity evaluation or health monitoring of reinforced concrete structures. The difficulties are mainly attributable to bulky and/or inhomogeneous nature of reinforced concrete structures, in particular the effects of reinforcing steel, aggregates, and FRP for the case of retrofitted concrete on stress waves. The interpretation of stress wave signals, with the prerequisite that multiple wave modes and components can be correctly recognised and differentiated, becomes a formidable task and success is usually achieved in a somewhat subjective manner. Studies are therefore necessary to understand the propagation characteristics of guided waves in reinforced concrete structures, together with the innovative development of sensor configuration, signal processing, feature extraction and identification for integrity evaluation.

Project aims

Define the aims of the project

This project aims to develop an accurate, efficient, and robust integrity evaluation technique for reinforced concrete structures using ultrasonic guided waves with the assistance of smart piezoelectric sensors. The specific objectives of this project are to:
(1) design compact piezoelectric transducers encased in short fibre-epoxy composite coatings to configure embedded and/or surface-mounted active sensor networks for wave actuation and acquisition;
(2) numerically and experimentally investigate the propagation characteristics of ultrasonic guided waves in rebar-reinforced and FRP-retrofitted concrete structures, and their interaction with typical defects, e.g. rebar corrosion and FRP debonding; and
(3) develop robust integrity evaluation algorithms for correlating damage signatures/structure degradation with corresponding wave features extracted from signals in concrete structures.

Expected outcomes

Highlight the expected outcomes of the project

This project entails fundamental but frontier techniques with immediate and wide-ranging applications. The direct outcomes are the knowledge and understanding of the propagation characteristics of ultrasonic guided waves in reinforced concrete structures, their interaction with defects (corrosion and debonding), the effects of aggregate distribution in concrete and interface interlocking between rebar and concrete, as well as the development and validation of innovative integrity evaluation algorithms with improved identification accuracy, efficiency and long-term robustness. The outcomes from this project will benefit much of critical civil infrastructure through obtaining new insights into the integrity status of large reinforced concrete structures. In the short term, the outcomes will allow damage to be located and quantified and casualty risks to be minimised; in the long term, they will ensure improvement in structural efficiency and extension of service life-span.

In addition, the design of piezoelectric patch transducers and the installation of active sensor networks addressed in this project will transform the design, operation and service not only of reinforced concrete structures in civil applications but also of other important engineering structures in aerospace, maritime and mining applications.

This project further provides a platform for research student training in both specific knowledge of stress-wave-based structural integrity evaluation and generic skills in signal processing and identification, which will benefit their future career development. Prospective cooperation with industry will also attract more students, contributing reciprocally to the development of the relevant areas.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

By designing compact piezoelectric patch transducers, investigating the wave propagation characteristics in reinforced concrete structures, articulating their interaction with defects, and developing new damage identification algorithms with the balance of identification accuracy, efficiency and robustness, integrity of concrete structures, in particular, the typical damage such as corrosion in rebar and FRP debonding can be evaluated and quantified. The engineering community will benefit from state-of-the-art knowledge about monitoring health status of reinforced concrete structures, and the general community will benefit from increased safety of critical civil infrastructure.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

The students should have the capacity and capability for independent scientific research. He or she should have the knowledge of mechanics of materials, structural engineering and reinforced concrete. He or she should also have the fundamental understanding of signal processing and basic programming skills with Matlab.