IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Development of Integrated Smart Sensing System for Structural Health Monitoring**	
Project Number	**IMURA1004**	
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IITB Head of Dept (Name, Email, Phone)	Prof. Deepankar Choudhury, dc@civil.iitb.ac.in	*Full name, email*
IITB Department:	Civil Engineering	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
(Please nominate JUST ***one.*** *For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research 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	*Artificial Intelligence and Advanced Computational Modelling*
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	*Sustainable Societies*

The research problem

Indian Standard (IS) on Plain and Reinforced Concrete Code of Practice [1] considers a design life for reinforced concrete structures as 50 years, while the Canadian Highway Bridge Design Code [2] considers a service life of 75 years for newly constructed bridges. During the service life of a structure, the concrete is quite often exposed to the aggressive environment that causes deterioration. This results in a significant reduction in its service life, bringing about a hazardous condition and, in few cases, may result in catastrophic and fatal damage to property and lives. The National Crime Records Bureau [3] statistics reported that a total of 13,178 people lost their lives between 2010 and 2014 in accidents where buildings, flyovers or other structures have failed/collapsed. The study further reported that the collapse of residential buildings caused 4,914 fatalities between 2010 and 2014, which accounts for about 37.3 per cent of the total number of deaths.

Another major reason for structural collapses before their design life is the unrealistic loading conditions assumed at design stage. Although engineers have a good understanding of how individual structural elements respond in controlled loading applications, there is lack of understanding of the magnitude or nature of the applied loading in real building scenarios or its behaviour under an unexpected catastrophic event. A study published in MEICON [4] point out the ludicrous magnitude of imposed loads that exist in commercial buildings and how inadequate our understanding is of the imposed-loads acting on the structure that could cause unexpected catastrophic failures.

While there is a need to re-assess our design philosophy and increase the service life of structures, it is equally paramount to protect our older constructions. The architectural heritage is a pillar of societal identity and among the most strategic global economic assets, making its preservation a commitment towards future generations. Several factors such as pollution, poaching, uncontrolled urbanization, unchecked tourist development and in few cases armed conflict, earthquakes and other natural disasters, pose major problems to World Heritage sites. In the year 2018, two heritage monuments in India which were more than 200 years old collapsed after a spell of rain [5]. In January 2021, the eastern front wall of the hustle castle which was constructed in 15th century by King Henry III, and belongs to English Heritage, collapsed after a storm impacted the southern England [6]. Moreover, the World Heritage Committee has recently listed 53 properties which have been included on the List of World Heritage in danger in accordance with Article 11-4 of the UNESCO Convention [7]. Although there are none listed in India, there is one structure each listed in United Kingdom (Liverpool – Maritime Mercantile City) and United States of America (Everglades National Park). The management and the security of infrastructures, in particular the heritage structures, require periodic or continuous structural health monitoring, maintenance and conservation.

The proposed research will be focused upon analysing the monitoring capabilities of smart fiber reinforced polymer (FRP) bars with embedded Fiber Bragg Grating (FBG) sensors and will lead to the progressive accomplishment of further phases of the research.

REFERENCES

[1] Bureau of Indian Standards, "IS 456, Indian Standard Plain and Reinforced Concrete Code of Practice," 2000.

[2] CSA, "Canadian Highway Bridge Design Code," Ontario, Canada, 2006.

[3] Rakesh Dubuddu, "Between 2001 & 2015, an average of 7 people died per day in Collapse of Structures including Buildings," *National Crime Records Bureau, Factly*, pp. 1–8, 2019.

[4] MEICON (s.d.), "Mythbusters [online]," *Avaiable at www.meicon.net/mythbusters*.

[5] The Times of India, "Two Heritage Monuments Collapsed after Spell of Rain," *TNN*, Mumbai, Aug. 07, 2018.

[6] J. Brooke, "Henry VIII's Hurst Castle wall Collapses in Lymington," *BBC News*, Lymington, 2021.

[7] UNESCO, "List of World Heritage in Danger," *World Heritage Centre*, 2017. https://whc.unesco.org/en/danger/ (accessed May 21, 2021).

Project aims

The over-reaching goals of the proposed project are as follows:

- To document past and present research available on State-of-the-Art structural health monitoring (SHM) techniques for various infrastructure systems. To further systematically review the techniques and algorithms involved in Fiber Bragg Grating (FBG) based Fiber Optic Sensor (FOS) technology and its application in SHM of ancient and new infrastructures.
- To experimentally examine the efficacy of smart fiber reinforced polymer (FRP) bars with embedded FBG sensors in evaluating the long-term performance of new as well as partially-distressed and dilapidated concrete members.
- To develop a custom-built SHM system using a combination of FOS, optical interrogator, IoT, 5G network using the data retrieved during the laboratory experiments.
- To further apply and demonstrate the usefulness of the new algorithmic approach to accumulate data retrieved from the optical interrogators and other IOT based sensors to create a single unified platform and subsequently make it comprehensible to the end-user using a mobile application.
- To subsequentially publish the research findings and share knowledge with a wider community (e.g., cloud-based SHM systems in peer-reviewed journals such as Security Journal of United Kingdom).
- To propose appropriate guidelines for smart-bars to be included in the national and international standards and to further outline what is needed to go forward in implementing a long-term SHM programme in real-life structures using the system developed and validated in the laboratory.

Expected outcomes

The outcomes from the present research will result in an architectural framework of integrating the information collected from smart-bars (with embedded FBG sensors) installed within the structure. Subsequently, the research will utilize IOT to create a conducive environment to implement real-time SHM system and make it comprehensible to the end-user, visible in his mobile application with the data presentation in the form of simple holograms and charts. This level of preparedness is paramount for real-time field applications of SHM systems which will replace the old and obsolete methods of inspection and monitoring and also protect the integrity of our heritage structures.

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.

It is quite common nowadays to hear about smart-watches or health-tracking devices that can detect the human health condition on a real time basis. Popular smartwatches detect heartbeats by projecting a green light on the skin, which gets absorbed by the blood. More green light being reflected is related to lower blood flow, which indicates that the heart-rate is in-between the beats. Based on this technique, the smart watch intimates the user regarding his/her health condition and if they need to see a doctor.

A similar concept of a health monitoring system for **sustainable smart housing societies** can be imagined which consist of a basic set of digital transducers (sensors) which are applied on infrastructures such as bridges and buildings. These sensors can be embedded/mounted on structural elements of the structure to be monitored. An optical interrogator can be installed close or within the structure which will serve the purpose of sending the optical signals to the transducers. The interrogators can be placed inside a leak-proof casing and used for data transmission to the operator of the system. The next most important component part of the system is the visual interface to process the accumulated raw data and to convert it into simple hologram and charts comprehensible to the end user. This integrated self-sensing system can allow the user to track the health status of the infrastructure through their smartwatches or mobile phones.

The proposed research enables a system for data-interpretation in real-time which will be visible to all the users in a smart-screen installed near the structure. Based on the inbuilt algorithms, the system will detect the levels of damages incurred within the infrastructure and send warnings to the user if the conditions of the structure become unserviceable; thereby making the infrastructure smart and sustainable.

The excellent sensing characteristics of the smart bar and the ease of implementation of the developed novel embedment technique indicates that the novel smart bar manufactured using the developed technique has a great potential to build a smart infrastructural society. Timely maintenance or rehabilitation of the infrastructures is possible with these smart bars resulting in a considerable long-term saving in life and economy.

The above vision of building a smart infrastructural society can be achieved through a two-fold process. Firstly, the ease of producing smart materials needs to be addressed efficiently to convince the manufacturers to adopt this technology in their production plants. The past study has unequivocally solved the first-fold of the problem by disclosing the technique to the manufacturer of normal FRP bar using a simple yet sophisticated model to convert any production line into a smart production line. Currently, there are no strict guidelines to monitor the health of a structure over its life-span. SHM of engineering structures should be a mandatory regulation for every construction to ensure the safety of the end-users. Thus, as a second step towards the development of a smart infrastructure society, it is crucial to introduce guidelines to use these smart materials as a built-in real-time data monitoring device for medium and large-scale infrastructural projects. This above-mentioned objective can be achieved by building a prototype smart-colony which would serve as an exemplar for the construction industry and provide sufficient data to include smart bars in the upcoming design codes and guidelines.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited *for the proposed project*

IITB:

Prof. Sauvik Banerjee

Prof. Ravi Sinha

Monash:

A/Prof. Colin Caprani

Prof. Wenhui Duan

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.

Master's degree in Civil Engineering with Specialization in Structural Engineering.

Prior experience in the areas of large-scale structural testing/structural health monitoring/Fiber Optic Sensor/Wireless Sensors and IoT.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Non-Destructive Testing of Materials
Fiber Optic Communications
Digital Signal Processing and its Applications

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Prof. Sauvik Banerjee, Department of Civil Engineering, IIT Bombay
Prof. W.K. Chiu, Department of Mechanical and Aerospace Engineering, Monash University

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Cloud Computing
Sensor and Sensor Networks
Next Generation Infrastructure
Modelling and Simulation