POSITIONING AND QUANTIFICATION OF CRACKS BY SENSORS USING ALGORITHMS

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Introduction:

A crack is a discontinuity or fracture in a material that can extend partially or completely through the structure. Surface cracks are the cracks which are visible to the naked human eye while as internal cracks cannot be assessed by visual inspection. These internal cracks are caused due to various reasons out of which few are overloading, shrinkage, chemical reactions, thermal stresses etc.

Detection of cracks is an important task in monitoring the health of the structure because as the cracks increase in width or propagate through walls of the structure which compromises the integrity of the structure. SHM makes our task easier and helps us in detection of cracks by using sensors like ultrasonic sensors, RFID tags or optical fibre sensors etc.Regular monitoring systems collect data continuously or at regular intervals over time, whereas NDT is typically performed at fixed intervals. Conventional monitoring systems are usually less expensive than NDT because they install sensors or gauges that can be automated and require little human intervention. This can result in significant savings over the lifetime of the structure or part.

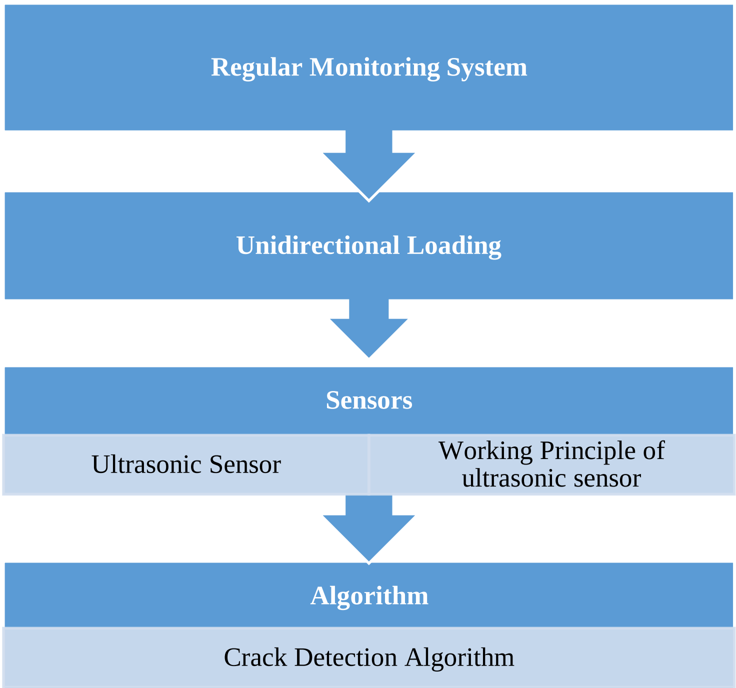
Objective:

- To localize the cracks in the structure to avoid the degradation of the structure, cracks can be identified at early stages of the deformation of the structure which helps us to increase the durability of the structure.
- To detect the position and quantifying of the cracks using sensors based on Fracture Mechanics, quantification of the cracks along with its position helps us to resolve any deformations at the earlier stage of the damage.

- To create the real time Regular Monitoring System to detect the cracks at early stages, whereas NDT helps us to detect cracks when there is visible deformation of the structure or over the fixed period of time.

Methodology:

In our project, we are conducting Compression Testing on structural members to evaluate their strength and integrity. This testing involves subjecting the structural members to gradually increasing loads in a single direction using a Compression



Testing machine (CTM). This allows us to measure the response of the material under compression and analyse its behaviour.

To monitor the structural integrity during the testing process, we are utilizing ultrasonic sensors. These sensors work by emitting sound waves at a frequency range higher than what the human ear can detect. The sensors consist of transducers that serve as both the transmitter and the receiver of the sound waves, similar to a microphone.

When the ultrasonic sensors transmit a signal, it is known as a pulse. As the pulse travels through the material, it encounters various interfaces, such as boundaries between different layers or cracks within the material. If there is a crack present, the pulse encounters a disruption in its path, causing it to reflect back as an echo. This echo is detected by the same ultrasonic sensor, which acts as the receiver.

To ensure accurate detection, we have placed ultrasonic sensors at different locations within each concrete cube. By doing so, we can capture the echoes from various angles and locations, which helps in accurately identifying the presence and location of any cracks.

In our project, we have chosen velocity as the primary parameter to detect cracks. Initially, we assume that the concrete cubes are homogeneous, meaning the material is consistent throughout. Under this assumption, we consider the velocity of the ultrasonic waves to be equal to the velocity of sound in the material. However, when a crack forms in the structure, the velocity of the ultrasonic waves traveling through the material is reduced.

By monitoring the velocity of the ultrasonic waves as they pass through the structural member, we can detect any reduction in velocity, indicating the presence of a crack. This change in velocity serves as an alert to the system, notifying us about the occurrence of a crack in the material.

By using this elaborate setup with ultrasonic sensors and monitoring velocity changes, we can effectively detect cracks in the structural members during Compression Testing. This information is valuable for assessing the structural integrity of the materials and making informed decisions regarding their strength and durability.

Results and Conclusion:

- We casted four concrete cubes of size (150x150x150) mm which underwent gradual loading under the Compression Testing Machine (CTM), the curing period for these cubes was 14 days.
- The concrete used for the casting of the cubes was of M20 grade which exhibited a strength of 26.67 MPa.
- The ultrasonic sensors were placed at different locations shown in the below figures in each of the cubes in order to assess the best placement position of the sensor to attain accurate results.
- The sensors were embedded during the casting of the concrete cubes. When the sensors were embedded in the concrete the initial condition is assumed to be homogeneous in nature even though coarse aggregates were present in the mix.
- The ultrasonic sensors react when the pressure is applied, while they react there is transition phase that takes place, the transition state is brittle to ductile. While we tested the concrete cubes, the transition phase took place from 490 kN to 525 kN. When the maximum load is applied, we attained constant readings. When the

pressure or the load applied is removed the sensors regains its original wavelength.

Cube 1 results

Time (sec)	Load (kN)	Crack Detected
0	0	Not Detected
36	490	Detected
51	500	Detected
60	510	Detected
95	520	Detected
120	530	Detected

Cube 2 results

Time (sec)	Load (kN)	Crack Detected
0	0	Not Detected
34	492	Detected
48	507	Detected
57	511	Detected
93	527	Detected
118	531	Detected

Cube 3 results

Time (sec)	Load (kN)	Crack Detected
0	0	Not Detected
42	476	Detected
55	488	Detected
63	497	Detected
97	510	Detected
128	525	Detected

Cube 4 results

Time (sec)	Load (kN)	Crack Detected
0	0	Not Detected
39	462	Detected
53	476	Detected
61	489	Detected
95	501	Detected
121	527	Detected

- Based on the above results, programme was developed to detect the cracks and was successful able to do so.
- To show the history of the cracks as well as the position of the cracks, we were successful able to develop a user interface (UI) using Visual Studio software.
- In conclusion, the crack detection methodology using ultrasonic sensors in compression testing proved to be successful in identifying cracks in concrete cubes. The embedded sensors accurately detected the presence of cracks, and the developed program effectively displayed the crack history and positions. This methodology offers valuable insights into the structural integrity and behavior of the tested specimens, aiding in the assessment of material strength and durability. With further refinement and optimization, this methodology has the potential to be applied in real-world scenarios for quality control and structural health monitoring of concrete structures.

Innovation of the project:

The innovation of this project lies in its comprehensive approach to early detection and quantification of cracks in load-bearing structures using sensors and algorithms. By incorporating ultrasonic sensors and IoT technology, the project revolutionizes crack detection by enabling the identification of internal cracks within concrete cubes, beams, and T-beams. This non-destructive testing method ensures minimal disruption to the structure while providing real-time monitoring capabilities.

The regular monitoring system implemented in this project ensures continuous surveillance of load-bearing structures. This proactive approach to crack detection allows for the identification of damage at an early stage, preventing the degradation of the structure and potential failure. By detecting cracks early on, engineers can implement timely interventions and maintenance strategies, safeguarding the integrity and safety of the structure.

The project's innovation is further highlighted by its ability to detect cracks that may be challenging to identify using conventional methods. Even when the crack depth is small or the structure is lightly loaded, the sensors and algorithms employed in this project can accurately detect and quantify the cracks. This capability ensures a more comprehensive assessment of structural health and facilitates targeted repairs and maintenance.

Overall, this project's innovation lies in its integrated approach, combining advanced sensing technology, algorithmic analysis, and real-time monitoring to detect, quantify, and monitor cracks in load-bearing structures. By providing early detection, precise measurements, and continuous surveillance, this innovative system contributes to safer and more durable infrastructure, minimizing the risk of structural failure and optimizing maintenance strategies.

Scope For Future Work:

The successful implementation of this project opens up exciting future scopes in the field of crack detection and monitoring in load-bearing structures, particularly in relation to beams and T-beams, as well as the regular monitoring of composite concrete materials like glass fibered concrete.

One potential future scope is to enhance the accuracy of crack detection by developing advanced techniques for accurately pinpointing the position of internal cracks within these structural members. This could involve the integration of advanced imaging technologies, such as tomography or acoustic emission analysis, which can provide detailed insights into the exact location and extent of the cracks. By combining these techniques with the existing sensor-based approaches, a more comprehensive understanding of the internal crack patterns can be achieved.

- Detecting the accurate position of the internal cracks in structural member namely beam and T beam.
- Quantification of the internal cracks formed in the structural members.
- Implementation of the regular monitoring system in the composite concrete materials like glass fibered concrete etc.