Embedded PZT Sensor Arrays for Comprehensive Local & Distributed Sensing of Concrete Structures

KID: 20220406

A low-cost, embedded PZT-based sensor that can be used for continuous monitoring of concrete after casting is developed. The embedded sensor can be placed inside the concrete and used for cure monitoring of concrete. The sensor also provides the capability of vibroacoustic detection for use in the structural health monitoring of concrete structures. The instrumentation, data collection, and processing algorithms for different applications have been also developed and tested. The sensing element in the sensor is a 20 mm Lead Zirconate Titanate (PZT) patch. A robust protection scheme for the sensing element ensures the long-term performance of the sensor placed inside the concrete. The embedded PZT sensor was evaluated for sensitivity to measurement and long-term stability when embedded inside the concrete. The sensor has also been tested for ruggedness in field use. A photograph of the PZT sensor is shown in **Figure 1**.

Figure 1: Embedded PZT-sensor

The embedded sensor sensitively monitors the local state of the material from the measured electrical response of the PZT patch. The electrical impedance (EI) measurements obtained from the embedded PZT are used to provide a local measurement of the material. The EI measurement depends on the dynamic response of the embedded PZT placed inside a medium. When placed inside the concrete, the measured EI response accurately provides a local measure of its stiffness. Continuous EI measurement accurately reflects the changes in concrete stiffness over time due to hydration. The interpretation of the signals from the embedded sensor requires an understanding of the coupled electromechanical response of the PZT surrounded by the concrete medium. A mechanics-based approach for interpreting the measured response and providing a realistic assessment of the material stiffness has been developed and calibrated using laboratory and field studies.

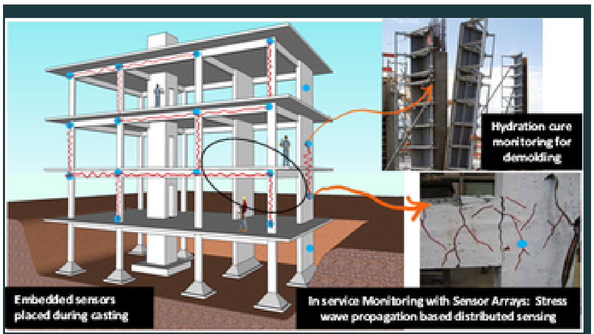

Figure 2: Embedded PZT sensor arrays for local & distributed sensing.

The sensor can be placed in concrete at the time of casting, and it provides information about the gain in concrete strength with time. Applications for determining the stripping time of the formwork are being developed that would be beneficial for the construction industry in terms of efficient use of forms, and speedy construction (**Figure 2**).

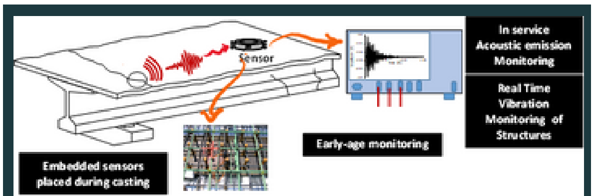

Figure 3: Embedded PZT sensors for continuous monitoring after casting and during service life of structure

Applications for assessment of concrete strength gain are being developed to assist the concrete construction industry in obtaining realistic in-situ strength assessment in concrete structures. Currently, such tools or sensors are not available. The successful development of this application will impact the current construction industry practices and lead to efficient construction. The embedded PZT sensor also provides the ability to monitor vibrations in the structure. Structural vibrations produced by the transient loads are detected by the sensors. The embedded PZT sensors detect the stress variations in the surrounding medium in the form of electric signals that can be digitized & analyzed. Additionally, the embedded PZT sensor can also detect stress wave propagation produced by small microcracks forming in the concrete. The embedded PZT sensor also provides the ability to monitor vibrations in the structure. Structural vibrations produced by the transient loads are detected by the sensors. The embedded PZT sensors detect the stress variations in the surrounding medium in the form of electric signals that can be digitized and analyzed. Additionally, the embedded PZT sensor can also detect stress wave propagation produced by small microcracks forming in concrete.

The PZT sensor provides acoustic emission monitoring capability for detecting damage in the material (**Figure 3**).

With an application of alternating current, the sensors can also be used to produce stress waves in the medium. Each embedded sensor can be used for generating and detecting ultrasonic waves. Pair of embedded PZT sensors can be used in ultrasonic wave-based monitoring of the concrete between the sensors (**Figure 2**). A spatial network of embedded sensors can be deployed in the structure to provide continuous monitoring of the structure (as shown in Figure 2). Each PZT sensor in the sensor array is used for determining the local state of the material through EI measurements. These sensors provide distributed sensing capability with ultrasonic wave propagation measurements. Additionally, over the life of the structure, the vibrations of the structure and acoustic emission can be monitored in a passive mode. The embedded PZT sensors, therefore, provide for comprehensive monitoring of a concrete structure immediately after casting and throughout its service life. Combining information about the local state of materials from the EI measurements with the ultrasonic wave propagation measurement and vibration and acoustic emission monitoring gives comprehensive information about the state of the structure. These PZT sensor arrays deployed for continuous, life-long monitoring of concrete structures can be used for asset management of concrete structures.

Dr K V L Subramaniam
Professor
Department of Civil Engineering,