DRISI

CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

Research Notes

Pavement

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Project Title:
Realtime monitoring of concrete strength to determine optimal traffic opening time TPF-5(471)

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Realtime monitoring of concrete strength to determine optimal traffic opening time PAV TPF-5(471)

Construction and field data from cradle to death from California test sections will provide valuable insights into the factors contributing to the overall long-term pavement performance in California.

WHAT IS THE NEED?

Fast-paced construction schedules often require accurate evaluations of concrete properties in early ages to confirm the traffic opening time with confidence as early as possible. Concrete strength and maturity tests are two commonly used current methods for determining traffic opening times. But these methods can be inefficient and expensive. For instance, the maturity test requires calibrations of the maturity coefficients for each different mix design. For this calibration, it is necessary to take additional sets of testing at different concrete ages. The strength testing of concrete beam or cylinder samples is very time consuming and sometimes provides variable results depending on the operators and due to the differences between laboratory and field conditions.

A new innovative nondestructive testing (NDT) method has been developed that enables an accurate and efficient evaluation of early age properties of concrete, including strength and stiffness, using electromechanical impedance (EMI) method with piezoelectric sensors. In preliminary studies, the project team has proved the feasibility and reliability of this innovative sensing technology for in-situ monitoring of concrete properties. One major benefit of this new test method is that it would save us cost and time by effectively and accurately measuring concrete properties without the need for creating mixture specific maturity curves for different mix designs.

WHAT ARE WE DOING?

The following tasks are proposed:

1) Develop field testing protocols to assess in-situ properties of concrete including the strength gain, elastic modulus (stiffness), and hydration behavior at any time period of interest.
2) Develop a user-friendly graphical user interface (GUI) for data interpretation.
3) Implement the smart sensing methods in all participating states through field testing and train state engineers to effectively use the sensing methods.
4) Provide guidance and specifications for use of the EMI sensors and measurement system based on data gathered nationwide.
5) Develop AASHTO ready specifications for evaluating the concrete properties using the proposed smart sensing technology.

WHAT IS OUR GOAL?

The goal of this pooled-fund study is to develop a field-ready application protocols for its practical implementation.

WHAT IS THE BENEFIT?

With participation in the proposed pooled fund study, Caltrans will have data on the best time to open concrete pavement to traffic. This will reduce construction time and delays due to road closures.

WHAT IS THE PROGRESS TO DATE?

Background:
On September 15, 2023, a construction project was undertaken along the Highway-50 Corridor. The pavement for this project consisted of a continuously reinforced concrete pavement (CRCP). Rui He (email: he566@purdue.edu), a PhD student at Purdue University, was on-site to install REBEL™ sensors along with dataloggers. The Caltrans engineering team prepared two standard concrete beam samples, each measuring 6 inches by 6 inches by 22 inches, in order to assess the strength development of concrete under various curing conditions. In total, nine (9) sensors were embedded, including three (3) in the pavement, three (3) in the on-site cured beam, and three (3) in the beam cured under laboratory conditions.

Sensing Results of Concrete Strength:
The sensing results and cylinder break results are presented in the Figure 1 below. Each prediction curve represents the mean value of three (3) sensors, which were generated using a proprietary machine learning (ML) algorithm to convert sensor output along with temperature profile into compressive strength. The team has observed discrepancies among sensor outputs, attributed to the inconsistent quality of the hand-made sensors and dataloggers at Lu's lab as well as intrinsic material inhomogeneity of concrete. Consequently, the post processed mean value of the sensing results in each beam (or pavement) was used as the result, a process similar to that outlined in ASTM C39 section 11.1.

As shown in Figure 1, the sensing results for two concrete beams (one cured on site and the other in the lab) closely align with that of cylinder break as per ASTM C39. However, the results of sensors that embedded in the pavement are substantially higher, as explained below.
The variance in sensing results among the beam and pavement can be rationalized by examining the temperature and maturity profiles presented in the Figure 2 and Figure 3. The maturity data of three concrete structures (lab cured beam, field cured beam and pavement) agrees with our sensing results, therefore validating our hypothesis that difference in strength between the pavement and cylinder was caused by the significant difference of thermal profile for pavement and beam.

In summary, we hope that this preliminary dataset has demonstrated the feasibility of using the REBEL sensor to directly measure the in-place strength of concrete structures at any given point of time. The mean values of sensing results are comparable to those obtained through cylinder testing and maturity testing within the same concrete structure. As explained earlier, all sensors and dataloggers were handcrafted in our research lab at this stage, leading to significant discrepancies among the three sensors. This issue can be addressed by implementing a standard manufacturing process. We are currently collaborating with manufacturing partners to ensure the quality and consistency of both the sensors and dataloggers.

IMAGES

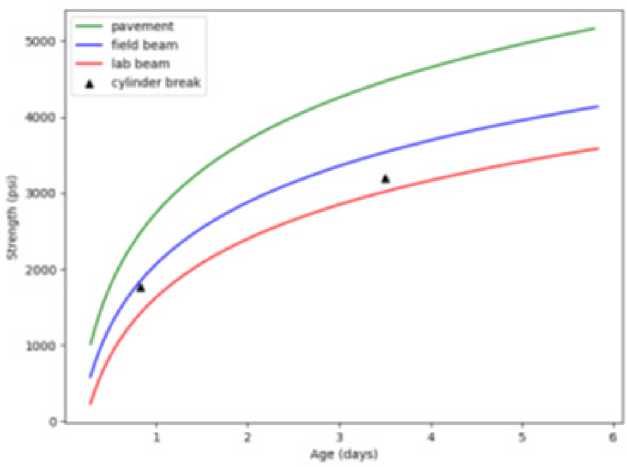

Image 1: Sensing results versus cylinder break

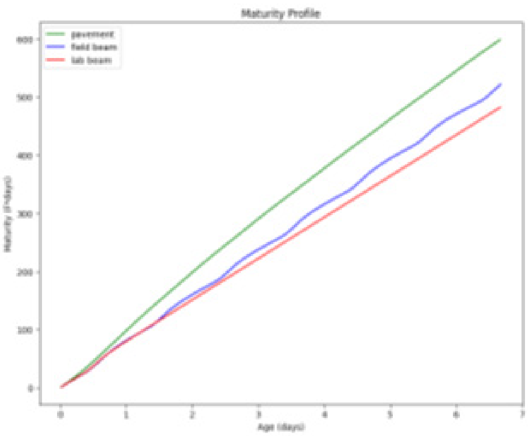

Image 2: Temperature profile

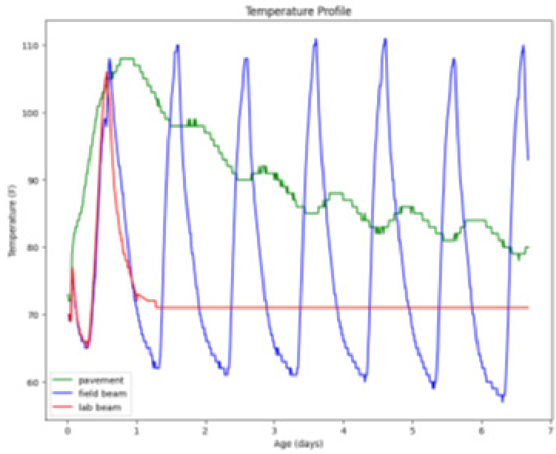

Image 3: Maturity profile