# Strength Development Monitoring of Concrete Using Smart PZT Transducers

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ABSTRACT

The feasibility of electro-mechanical impedance (EMI) sensing technique, utilizing piezo-ceramic (PZT) patches, for online strength gain monitoring of early age concrete is investigated. An experimental study is conducted on PZT patch instrumented concrete specimens. The applicability of the EMI sensing technique for strength gain monitoring is discussed.

## 1. Introduction

Electro-mechanical impedance (EMI) based active sensing technique utilizing smart piezoelectric materials have been emerged as a potential tool for the implementation of a built-in online monitoring system for civil infrastructures [1]. In this study, the feasibility of the EMI sensing technique for the online strength gain monitoring of early age concrete is investigated. Smart piezo-ceramic (PZT) patches having high stiffness and piezoelectric strain coefficients ideally suited for monitoring concrete structures are used to sense the EMI signatures. Basic principle of the EMI sensing technique is to track an electrical impedance of the piezoelectric patch bonded onto the structure [1]. The PZT patch attached to the structure couples the mechanical impedance of the structure to the electrical impedance. Any change of the mechanical properties in a structure causes changes in the mechanical impedance, and also induces changes in the electrical impedance of the PZT patch bonded to the structure. In this study, this coupling property of the PZT patch is utilized for strength monitoring which is based on the measuring of the mechanical impedance.

## 2. Experimental Investigation

### 2.1 Experimental Setup

Concrete cylinder specimens with a diameter of 100 mm and a height of 200 mm, which is normally used for compressive strength evaluation, were prepared for this experiment in a total of 16 concrete specimens (1 for EMI signature acquisition and 15 for compressive strength tests) comprising of Type I Portland cement (C), water (W), well-graded washed sand (FA), and gravel coarse aggregate (CA).

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The mixing proportion of the concrete is 1:0.45:2.40:2.66 (C:W:FA:CA, ratio by mass of cement ) and the design strength is 21 MPa.  A size of 10 x 10 x 0.2 (*mm*) square PZT patch was instrumented on a cylinder specimen. The first testing was carried out at the age of 3 days in order to ensure full curing of PZT bonding adhesive. Compressive strengths were evaluated at the ages of 3, 5, 7, 14 and 28days.

### 2.2 Results and Discussions

Figure 1 (a) shows the average conductance signatures of the PZT at the ages of 3, 5, 7, 14, and 28 days corresponding to the days of compressive strength tests. It is obviously observed that the signatures gradually shift to the right and downward direction as the curing day increases. The magnitude and location of the resonant peak is reduced and shifted to the right direction. Increasing in the mechanical impedance (and hence strength) of early age concrete restrains the vibration of the bonded PZT and changes the resonant frequency of PZT-structure interaction system. This result verifies the feasibility of EMI sensing technique for strength gain monitoring. Compressive strengths were evaluated at the same test days and they are compared with the estimated resonant frequencies as shown in Figure 1(b). The estimated resonant frequency is shown to correlate very well with the compressive strength. This suggests that the resonant frequency may be used as a sensitive indicator to monitor the strength gain of concrete.

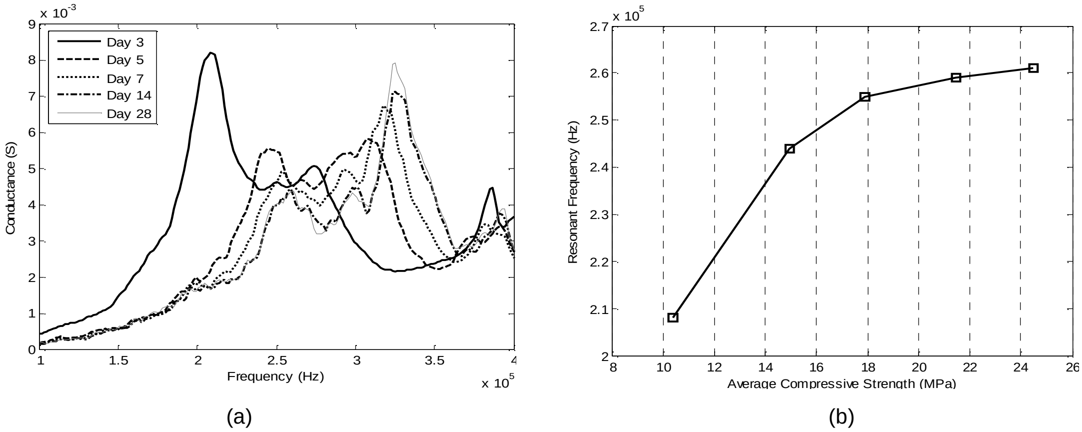


Figure 1. (a) Measured Conductance Signatures; and (b) Resonant frequency vs. Compressive Strength

## 3. Conclusion

The feasibility of the EMI sensing technique for strength gain monitoring of early-age concrete is presented in this study. According to the experimental results, it was observed that the EMI signature is sensitive to the strength development of early-age concrete.

### References

1. G. Park, H. Sohn, C.R. Farrar, and D.J. Inman, "Overview of Piezoelectric Impedance-Based Health Monitoring and Path Forward", *Shock and Vibration Digest*, Vol.35 (6), pp.451-463, 2003