Piezoelectric materials have so far proven their efficacy for both energy harvesting and structural health monitoring (SHM) individually. Piezoelectric ceramic (PZT) patches, operating in $d_{31}$-mode, are considered best for SHM. However, for energy harvesting, built up configurations such as stack actuators are more preferred. The main objective of this research was to explore the possibility of employing the same piezo sensor for SHM as well as energy harvesting on real-life civil structures such as bridges. Experiments have been carried out in the laboratory environment to measure the voltage and the power generated by PZT patches in surface bonded as well as embedded $d_{31}$ configurations. In embedded form, the PZT patches have been considered in the form of concrete vibration sensor (CVS), operating in the normal axial strain ($d_{31}$) mode. This packaged sensor (CVS), which is composite in nature, has better compatibility with the surrounding concrete and can withstand the harsh conditions typically encountered during casting. Analytical models have been developed based on Euler Bernoulli’s theory for a beam under harmonic vibrations, using which the voltage output of a PZT patch, either surface bonded or embedded (CVS), can be determined duly considering the effects of shear lag and other losses associated with the bonding layers. Beam structure has been considered for modelling as well as lab experimentation owing to the energy harvesting potential offered by real-life bridges. Utilization of the same patch for energy harvesting as well as for SHM through a combination of the global vibration and the local EMI techniques has been experimentally demonstrated. The strength gain and the fatigue characteristics of the real-life sized RC beam have been duly investigated via the embedded CVS in laboratory. The experimental observations have been found to match with theoretical predictions. The performance of the CVS is compared with
surface-bonded PZT patch. The typical measured output power from a piezo sensor $10 \times 10 \times 0.3$ mm has been determined to be in microwatt range.

Optimum parameters of PZT patches have been arrived at by performing detailed numerical investigations. A comprehensive parametric study to investigate the effect of various parameters such as PZT geometric parameters, adhesive layer thickness and bond stiffness, which is otherwise difficult to perform experimentally, has been done. A numerical model has been developed for a real-life sized simply supported beam instrumented with (a) surface bonded PZT sensor (SBPS), and (b) embedded PZT patch in form of concrete vibration sensor (CVS), and coupled field analysis has been performed for the two configurations through finite element method (FEM). The results have been compared with the existing analytical model as well as the experimental data and the comparison has been found satisfactory. Effect of varying load resistance across the PZT patch on the close circuit power generated by the patch has also been investigated. The investigations show that a piezo thickness lying between 0.3 mm and 1 mm ensures maximum yield for SBPS. For CVS, the thickness above 1 mm is somewhat more beneficial. In addition, covering the SBPS with a layer of epoxy is also beneficial.

A real-life flyover with span of length 25 m has been numerically modelled to estimate the dynamic strain levels and hence, the power that could be produced in real-life structures. The numerical study predicts a yield of 2.2 $\mu$W from a typical city flyover. This aids to quantify the gap between the voltage generated by the PZT patches under specific conditions in lab environment and corresponding to the strain levels produced in real-life structures. Harvesting potential of the structural vibration energy by PZT sensors during idle time is experimentally
demonstrated and this concept has been extended to eight real-life bridges across the world, based on the validated analytical model. Effect of losses such as mechanical loss, dielectric loss and shear lag loss, on the real-life structure have been duly considered. Computations show that the power yield could range anywhere from less than a microwatt (RC bridges) to over 25 µW (steel bridges). These figures correspond to power densities over 30 µW/cm$^3$ and 800 µW/cm$^3$, respectively. The study reveals that the PZT patches could harvest enough energy in reasonable time in the idle state so as to enable intermittent operation of SHM system. Typically, it could take only a couple of seconds to scavenge enough energy to power commercially available A/D converters.

Proof-of-concept demonstration of normal plate type piezo in axial strain mode in place of commercial expensive transducers for energy harvesting from real-life civil structure has been the original aspect of this study. It is expected that the outcomes of this research will pave way for dual use of the ordinary piezo patch in SHM as well as energy harvesting.