ABSTRACT

Concrete structures, including normal reinforced concrete and pre-stressed concrete constructions are the backbone of the modern civil infrastructural facilities. Such concrete structures are susceptible to damage due to numerous factors such as degradation of materials, adverse environmental conditions, overloading etc. To avoid the possibility of failure, such existing concrete structures need continuous monitoring to detect any impending damages at the earliest so that strengthening and repair works can be initiated. One such popular approach is the vibration-based damage detection technique where damage sensitive global dynamic responses, like natural frequencies, mode shapes etc. can be used to locate and quantify damages. The research work presented in this thesis used the correlation between the experimental modal testing observations and finite element modelling to subsequently update and estimate the stiffness loss of reinforced concrete beams and slabs, as well as prestressed concrete beams. The beams and slabs have been quasi-statically loaded in laboratory to induce incremental damages and dynamic measurements were undertaken between each loading and subsequent unloading cycles. An inverse eigen-sensitivity algorithm has been implemented in a weighted least square sense to minimize the discrepancies between numerical and experimental data. A spatial damage index was introduced, quantifying stiffness variations along the length of the structure to help localize damages and also to determine its severity. The results demonstrated a strong correlation between numerical predictions of damages and physical observations, including the formation of cracks. The technique was found to be resilient even when faced with sparse modal data or limited access to parts of the structure, facilitating extension of the proposed methodology towards practical structural applications. The major contribution of the research work is the prediction of impending cracks, which were proved experimentally during subsequent incremental loading. The application has been limited at present to laboratory scale small beams and slabs. The method offers a non-destructive and reliable means of condition assessment of concrete structures throughout their service life, thereby supporting the maintenance and reducing the risk of impending catastrophic failures.

Keywords: *Experimental modal testing, natural frequencies, mode shapes, Finite element model updating, Reinforced concrete beams, Post-tensioned concrete beams, Reinforced concrete slabs, Damage detection.*