AN INTEGRATED APPROACH FOR STRUCTURAL HEALTH MONITORING

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CERTIFICATE

This is to certify that the thesis entitled '**AN INTEGRATED APPROACH FOR STRUCTURAL HEALTH MONITORING**" being submitted by Mr RAMA SHANKER to the Indian Institute of Technology Delhi for the award of the degree of **DOCTOR OF PHILOSOPHY** in Civil Engineering is a record of bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for the submission of the thesis, which is best of our knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted, in part or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

There is a phenomenal rise in construction activities in the field of civil engineering in the recent years. Major structures like buildings, bridges, dams are subjected to severe loading and their performance is likely to change with time. It is, therefore, necessary to check the performance of a structure through continuous monitoring. If performance deviates from the design parameters, appropriate maintenance is required. The life of a structure depends on initial strength and the post construction maintenance. It is for this reason that the necessity of structural health monitoring (SHM) is emphasized worldwide. There are several techniques to monitor the health of structures. These can be divided broadly into two types, global and local. The local and global techniques independently cannot monitor the health of a structure continuously in an autonomous manner. For example, the global technique, cannot determine incipient damage. The local techniques, being localized in nature, can identify damage only within a limited zone. Hence, a technique is required for structural health monitoring (SHM), which should carry out continuous monitoring of structure both locally and globally, should be sensitive and at the same time cost effective. The primary objective of this research work is to develop a new technique by integrating the global and local techniques based on piezoceramic sensors.

The global and the local techniques are studied to identify the advantages and drawbacks of each technique. It is found that the global dynamic techniques work only in low frequency range (typically < 200Hz) and can detect moderate to severe damage. However, global techniques do not detect hair line cracks which develop at an early stage. Opposite to this technique, a local technique called electro-mechanical

impedance (EMI) technique, which is based on piezo-electric ceramic (PZT) sensors; operates at higher frequency range and can typically detect damage at microscopic level. Damage can be detected at a very early stage by the EMI technique. However, the EMI technique typically fails to properly distinguish among severe damages. It is proposed to integrate EMI technique with the global dynamic techniques to take advantage of both the techniques

There are different types of sensors which can be used for SHM. In general, the performance of PZT sensor is better than other sensors and are also very cost effective. In this study, PZT patches have been used as sensors for both global and local level damages. In addition, the possibility of an embedded PZT sensor has been investigated. The PZT sensor is embedded in structure at the time of construction. It is successfully demonstrated that the embedded patch acts as sensors for both the global dynamic technique and the EMI technique.

Detection of incipient damage is quite critical for the challenging task for health monitoring of structures. In this study, through artificial damage created in the structures, it is found that the incipient level damage is very quickly detected by the EMI technique. For moderate to severe damages, the same PZT is capable of serving as the sensor of the global dynamic technique, and can suitably quantify such damages as well as locate them. Hence, PZT patches, which have so far been used largely with EMI technique, have been found suitable for global techniques in this study.

A simple low cost experimental technique has been developed to extract the experimental strain mode shapes of the structures. Experimental mode shapes extracted using the proposed technique require less interpolation and are obtained using a single PZT sensor. Resolution of measurement can be adjusted as per desired accuracy. The technique uses a surface bonded or embedded PZT sensor to extract the experimental strain mode shape directly. Damage ranging from incipient to near failure (severe) can be located and quantified using the EMI technique and the experimental mode shapes with desired accuracy. Incipient damage is located using extracted equivalent parameter from the admittance signature of different sensors. Moderate to severe damages are located using extracted experimental mode shape. Basic advantage of the combined technique is that location of damage can determined out with desired accuracy.

The conventional methods, which differentiate the damage as incipient, moderate and severe, are based on experience. A new algorithm has been developed to determine the severity of damage using experimental mode shapes. The basic advantage of the algorithm is that the severity of the damage can be computed in terms of the original stiffness of structure.

It has also been shown that by suitable integration of the global dynamic and the EMI technique with artificial neural networks (ANN), the issues of localization and quantification can be addressed more appropriately. Hence, the integration of these techniques leads to much more effective SHM and this forms the main contribution of the thesis.

TABLE OF CONTENTS

CHAPTER 3: SENSOR SYSTEMS FOR SHM