Condition Assessment of Structure Using Piezo-Ceramics Smart Material

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Abstract- *At the time of construction, it is impossible to ensure about uniform quality and strength at every section so, there is variation of strength from various section to section. Structure can be considered as damage free up to certain limit, but if it is beyond limit due to excessive loads which results into damage. Damage is defined as a change to the material and geometric properties of the structural system including changes to the boundary condition and system connectivity, which adversely affect the performance structure as a whole beyond a threshold. The ultimate failure strength of the material, component or system is its maximum load-bearing capacity. When this limit is reached, damage in the materials occurs, and its load-bearing capacity is reduced permanently, significantly and quickly*

I. INTRODUCTION

1.1General

At the time of construction, it is impossible to ensure about uniform quality and strength at every section so, there is variation of strength from various section to section. Structure can be considered as damage free up to certain limit, but if it is beyond limit due to excessive loads which results into damage. Damage is defined as a change to the material and geometric properties of the structural system including changes to the boundary condition and system connectivity, which adversely affect the performance structure as a whole beyond a threshold. The ultimate failure strength of the material, component or system is its maximum load-bearing capacity [22]. When this limit is reached, damage in the materials occurs, and its load-bearing capacity is reduced permanently, significantly and quickly [10].

1.2 Structural Health Monitoring

- Structural health monitoring (SHM) is a process in which determining the presence, location and severity of damages and the remaining life of structure after the occurrence of damage. This term is usually referred to all aerospace, civil and mechanical engineering infrastructure [11].
- Damage identification is the basic objective of SHM. There are mainly four levels in damage identification (Rytter, 1993):
- Level 1: Determination that damage is present in the structure
- Level 2: Level 1 plus determination of the geometric location of the damage
- Level 3: Level 2 plus quantification of the severity of the damage
- Level 4: Level 3 plus prediction of the remaining service life of the structure
- SHM involves periodically observation of the structure. In long term SHM, the output of this process is updated to provide information regarding the ability of the structure to perform its function in light of the inevitable aging and degradation which results from operational environments [11]. After extreme events, such as earthquakes or blast loading, SHM is used for quick condition screening and aims to provide real time and reliable information regarding the integrity of the structure (Doebling et al., 1998).

1.3 Non Destructive Evaluation

- Non destructive evaluation (NDE) of concrete has historically been a niche discipline within civil engineering and a process carried out by an individual operator in the field to evaluate the extent of known or suspected flaws within a concrete structure. NDE techniques such as Ground Penetrating Radar, Ultrasound, and Eddy Current methods depend heavily on the expertise and diligence of the operator to maintain accuracy and are prone to producing sparse, subjective data. For these reasons, NDE methods such as eddy current methods, ultrasound, and ground-penetrating radar (GPR) are typically called upon by governing agencies and only to identify the extent of known defects or defects suspected to be present [27].
- Concrete NDE techniques have shown the potential to reliably identify many forms of structural deficiency including poor material quality, poor consolidation,

insufficient cover (thickness of protective concrete layer over reinforcing steel), and subsurface cracking and delamination due to damage. The application of such methods for quality control purposes, however, requires spatially dense, exhaustive data collection performed in an irrefutable manner suitable for holding construction agencies responsible for the product they produce [29]. The list of NDE methods that have successfully been applied to concrete structures is incredibly long and is growing every day [30]. While one of the main goals of the development of the automated system was to create a system capable of expansion to include new NDE instruments, a review of a myriad of potential instruments to be included in future research is not necessary for comprehension of this work [25].

II. ADVANTAGES

SHM using PZT have been effective in making online assessment of a structure. The main advantage of SHM being,

- Large coverage area of inspection (global).
- Coverage of inaccessible areas of the structure.
- Rapid inspection without disassembly.
- Adjustable frequency range for interrogation for various size/types of damage SHM is most suited for health monitoring of plate and shell type structure with limited extension to thin walled beams, stiffeners and other parts of airframes [27].
- Structural Health Monitoring (SHM) requires PZT transducers for both excitation and sensing of elastic waves to interrogate the structures in order to detect, locate and characterize defects and damage [23].

The PZT generate both symmetric and antisymmetric mode simultaneously. The sensor-actuator approach enhances the control over the damage-sensitive feature being extracted from acquired signals. A conventional ultrasonic probe excites and senses waves indirectly through the interaction between activated guided waves and structural surface, whereas a PZT element excites and senses the waves directly through in-plane strain coupling. There are two possible ways to utilize piezoelectric materials [29]. First, piezoelectric materials can be used as sensors (direct effect). Second, piezoelectric materials can be used as actuators (converse effect). Piezoelectric (PZT) sensors used to generate Lamb waves can be used as both exciter and receiver which provides the very important benefit of having the capability of controlling the input excitation [34].

III. LIMITATIONS

- A PZT patch is sensitive to structural damages over a relatively small sensing zone ranging from 0.4m to 0.2m only, depending upon the material and geometrical configuration.
- This technique is unable to assess overall structural stability.

IV. OBJECTIVES AND SCOPE OF THE WORK

- To study the theoretical and technological developments in the field of structural health monitoring and non destructive evaluation.
- Damage assessment of aluminum plate, and concrete cubes is covered by PZT patches.
- Non destructive evaluation all specimen with the help of regression analysis.
- To calculate changes in different parameters of signature which is depend upon stiffness and damping coefficient.
- To check response for humidity condition.

V. PIEZOELECTRICITY AND PIEZO ELECTRIC MATERIALS

- Piezo electricity is the effect of interaction between electrical and mechanical systems. it occurs in certain type of anisotropic crystals, in which electrical dipoles are generated upon applying mechanical deformations. The same crystals also exhibit the converse effect, that is, they undergo mechanical deformations when subjected to electric fields. This phenomena was discovered by Pierre and Paul-Jacques Curie in 1880. Particularly working of structure with piezo electric patch was studied. That's why these things were discussed in detailed manner as follows. [27]

The prinicipal commercially available piezoelectric materials are

1. Piezoceramics, such as Lead ZirconateTitanate(PZT).
2. Piezopolymers, such as PolyvinvylideneFluoride(PVDF).

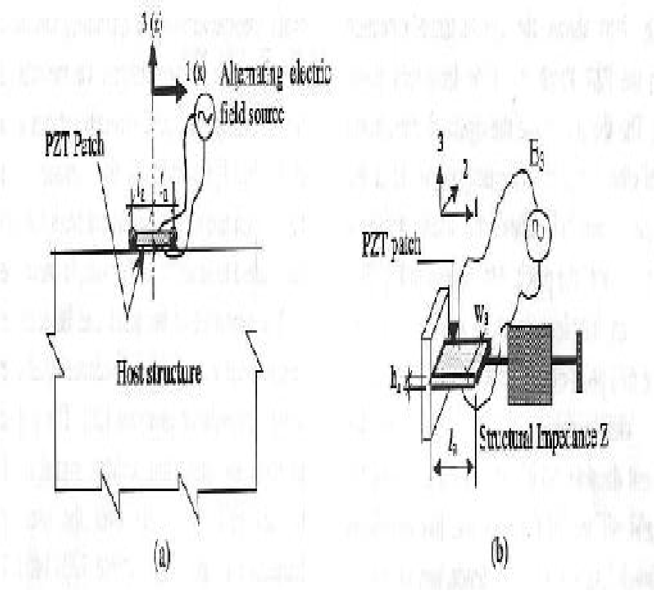

Fig. 3.3 (a) A PZT bonded to the structure (b) Interaction model of one half of PZT and host structure.
(Source :Bhalla and Soh[10] (2002)).

From fig. 3.3 it is observed that fundamental relation between host structure and PZT patches**.**

VI. PRINCIPLE AND METHOD OF APPLICATION

1. The structural response in turn modulates the current flowing through the PZT i.e. affects the electrical Admittance. The electrical admittance is therefore is a unique function of the mechanical impedance of the structure at the point of attachment[38].
2. Any variation in mechanical impedance will alter the electrical admittance, which can be used as an indicator of damage. A frequency range is selected for extracting conductance as a function of frequency. This is called conductance signature[37].
3. The conductance signature is recorded for the healthy structure as a bench mark. At any subsequent state, when structure health is required to be assessed, the procedure is repeated. If any change in signatures is found, it is an indication of damage[22].

Table 3.1 Averaged key parameters of PZT patches found experimentally[10]

Physical Parameter	Value
Electric Permittivity, ε^{T}_{33} (Farad/m)	1.7785×10^{-8}
Peak correction factor, C	0.898
Stiffness	5.35×10^{-9}
Mechanical loss factor η	0.0325
Dielectric loss factor δ	0.0224

VII. CONCLUSION

1. Conventionally, surface bonded PZT patches are used to monitor the health of structures. There are several difficulties like protection from harsh environment and external wiring associated with the surface bonded PZT patches, hence PZT sensor has been protected with plastic fibre in structure at the time of construction. It is successfully demonstrated that protected sensor acts well in both dry condition as well as in humid condition.
2. Apart from detection, damage ranging from incipient to near failure (severe) can be located and quantified using the proposed technique. Incipient damage can be located using extracted equivalent parameters from the PZT signatures. Basic advantage of proposed technique is that location of damage can be predicted with desired accuracy. Once the damage is located approximately, its exact location can also be traced accurately.
3. Severity of damage has been quantified in term of original stiffness using the proposed technique. Conventional methods fail to differentiate the damage in terms of higher grade of concrete from moderate to severe damage due to higher strength of concrete and aggregate size.
4. This technique useful for calibration of piezo-ceramic transducers for damage assessment of concrete. In the frequency range 10-30 kHz, stiffness was found to reduce and the damping increase with damage progression. This enabled the calibration of the piezo-impedance transducers in terms of damage severity and can serve as a practical empirical phenomenological damage model for quantitatively estimating damage severity of concrete.
5. A new experimental technique was reported for determining the in situ concrete strength non-destructively using the Lamb wave principle. The new technique is much superior than the existing strength prediction techniques, such as the ultrasonic techniques. In addition, the paper demonstrated the feasibility of monitoring curing of concrete using the EMI technique, which was found to share a sensitivity much higher than the conventional NDE techniques.

6. The signatures are at the same time highly prone to deviation by humidity. Plastic fibre is experimentally shown to be a sound material for protecting PZT patches against humidity. In the case of aluminium plate it is observed that 5% of fall in signature occurred in humid condition as compared to dry condition. In case of steel plate, very negligible change is occurred in signature of humid condition, in this work it is clearly observed that damages at incipient, moderate damage, severe damage from change in strength, damping coefficient, damping ratio. In case of hollow beam it is observed that 4% changes in baseline signature in dry condition as compared to humid condition. Lamb wave theory clearly observed incipient ,moderate, severe damages for these section.
7. The new developments reported here could improve SHM/ NDE, using the Lamb wave technique, for a wide spectrum of structural systems.
8. Over the last three decades, a number of studies have been reported to replace the visual inspection by some sort of automated method, which enable more reliable and quicker assessment of the health of the structure. The idea of smart structures is thought to be an alternative to the visual inspection methods. Because of their inherent 'smartness', the smart materials such as piezo-ceramic patches exhibit high sensitivity to any change in environment.

VIII. SCOPE OF THE FUTURE WORK

The work presented in this dissertation may be used as basis for future work suggested below.

1. The present study may be extended for the non destructive evaluation of beam and column by mode shape analysis due to limitation of sensing zone of PZT patch.
2. With the help of smart material which are embedded in concrete structure continuous health monitoring of structure can be possible.
3. Research in area of smart structures can be handled at an ease with finite element modelling. The conductance signature patterns for various types of damages and for damages which cannot be studied in laboratory can obtained by FEM.
4. In this the studies have been conducted on model structures. It is recommended that the studies may be extended to real life structures such as buildings.

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