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Structural Health Monitoring and Assessment: A Review

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Abstract: ***Prime objective of the design of building structure is to protect human life, conserve properties and maintain functions. The performance of a structural system is considered as satisfactory if it fulfil the two criteria i.e. safety and serviceability. Structural health monitoring and assessment is the process of implementing damage detection and characterization strategy for engineering structures which involves health monitoring, operational evaluation, data feature extraction and statistical models development. This paper provides an insight of the various methods used in assessing and monitoring the health of civil structures.***

Keywords: Safety, Serviceability, Structural health, Damage detection, Dynamic response.

I. INTRODUCTION

Structures play a very vital role in sustaining the Nation building process. In the growing demand and increasing cost of rebuilding vital structures, maintenance of existing structures which are aged become very important. A civil engineer needs to ensure that the state of the structure must remain in the domain specified in the design, although this can be altered by normal aging due to usage by the action of environment and by accidental events therefore proper assessment, evaluation and technical diagnosis of structure is crucial to ensure public safety and economic usefulness of their functionality as a consequence of which we need to assess and monitor the health of the structure.[1] Structural health monitoring is the process of assessing the behaviour of structures and evaluating the performance of materials during the life cycle of the structures and involves the amalgamation of sensors, smart materials, data transmission, computational power and processing inside the structure.[2] The objective of structural health monitoring is to enhance the performance of existing structure, monitoring of structure affected by external forces and feedback loop to improve future design based on experience. The different ways of the detection of damage caused or to determine the health of a structure include visual inspection, use of non destructive testing, ambient vibrations etc. The present paper gives a review of research studies in the field of structural health monitoring and assessment and throws light on the methods of SHM.

II. LITERATURE REVIEW

According to Aditi Majumdar, Bharadwaj Nanda, Dipak Kumar Maiti and Damodar Maity in their paper Structural damage detection based on modal parameters using continuous ant colony optimization, at an initial level the damage can be determined through visual inspection but this technique has a limited capability to detect the damage, especially when the damage lies inside the structure and is not visible. So it is necessary to have an effective and reliable global damage assessment methodology for determination of damage state particularly in the regions which are inaccessible. [3]

According to a paper published by International journals of systems science Volume 31, 2000 - Issue11 authored by N. Stubbs, S. Park, C. Sikorsky & S. Choi non- destructive damage assessment methodology not only detects the damage but also evaluates the impact of the damage on the performance of the structure. This methodology involves two activities namely (i) periodic non-destructive damage localization and severity estimation; and (ii) the assessment of structural safety based on the results of the non-destructive damage detection. They observed that to fulfil the above two activities firstly the method to find out the changes in localized sectional stiffness properties like axial, bending and torsion from changes in dynamic properties such as mode shapes and frequencies of the pre-damaged and post-damaged structures is reviewed and then an efficient technique to directly assess the reliability of a structural system is developed. [4]

Bart Peeters, Johan Maeck and Guido De Roeck in their article on Vibration-based damage detection in civil engineering: excitation sources and temperature effects explained the idea of vibration-based damage detection which is to measure dynamic characteristics such as eigen frequencies, damping ratios and mode shapes on a regularly. The evolutions in the above characteristics show the state and deterioration of the structure.[5]

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III. THEORY AND DISCUSSION

A. *Structural Health Monitoring Methods*

1) *Visual Inspection Method:* The most traditional and the simple method of damage identification is the visual inspection method. One of the serious limitations of this method is that it affects the decision making process and resource utilization significantly. The foremost issue will be time interval that is the inspection frequency of visual inspection methods can be selected as per the requirements of the structure, environmental conditions and operational loads. It is important to note that the static assessment of the structure may not be sufficient enough to identify damages which are critical. Therefore a continuous monitoring is preferred. For example crack propagation cannot be captured by visual inspection methods. Second major issue is the interpretation of results of visual inspection method. It strongly depends on visual inspectors, their expertise and domain knowledge, their experience and training etc. So the results of visual inspection or subjective assignment which may be inadequate to compare with true assignment. Mainly this is due to the fact that visual inspection team may not be experienced. Second could be visual inspection guidelines used by different agencies may differ. So there are no set standard criteria for visual inspection. Third could be accessibility. It is very important to know that effective results of visual inspection depend on physical accessibility of the visual inspection team to the surface of prospective damage. If sufficient accessibility is not provided then internal irregularities ca not be interpreted from the results or reports of visual inspection method.
2) *Non Destructive Method Of Evaluation:* There are three major areas which can do non destructive evaluation as far as structural health monitoring is concerned:

a) Non destructive testing (NDT)
b) Non destructive evaluation (NDE)
c) Non destructive inspection (NDI)

All of these are very vital for structural health monitoring scheme as they become part and parcel of inspection methods. Sometimes they also become a part of continuous or intermittent health monitoring. They are essentially used to detect the structural failure or in sense local damage. The most important methodology being used is ultrasonic inspection which is the most commonly practiced in structural health monitoring.

B. *Basic Principle*

In an infinite solid medium elastic waves can propagate in two modes namely pressure waves (P waves) and shear waves (S waves). If the medium is bounded with rigid boundary then these waves reflect at the boundaries to form a complicated wave pattern. Alternatively there is guided waves which remain contained within the waveguide. The ultrasonic non destructive evaluation (NDE) essentially relies on elastic wave propagation and its reflection within the material. These wave field disturbances are caused due to local damage and any other defects that are present. On the other hand any disturbance caused to this wave field is an indication of presence of damage. This is how damage detection is done.

1) *Vibration Based Monitoring:* The procedure practiced for vibration based monitoring is as given below:

a) *Dynamic Response Measurements:* In the first step dynamic response measurements are done through data sensing and then the sensed data is transmitted thereafter it is analyzed. One the data is obtained it could be applied to the real time vibration system.
b) *Initial Characterization of the System:* In this the results can be achieved in two ways i.e., through static test and dynamic test. The data obtained from these tests is then utilized to prepare a baseline model.
c) *Continuous Monitoring:* From continuous monitoring one can achieve the vibration signature records, which can be useful in doing modal analysis for the structure which is functional. This modal analysis for the structure under operation will be different from the conventional characterization of the system based on which the baseline modal has been prepared. So based on this value the damage localization is achieved
d) *Updating Of Model:* The data obtained from initial characterization of the system and continuous monitoring is then put together to update the model. So based on the updated model further updating of the finite element model is done for analysis and based on which the performance evaluation of the system is done.

The performance evaluation will finally lead towards two issues capacity building capacity estimate of the structural system and service life prediction of the system.

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IV. CONCLUSION

Structural health monitoring and assessment enables us to update integrity of the structure if monitoring is done on a continuous basis and utility or functional value of the structure is enhanced. The foremost challenge in SHM industry is that to develop and demonstrate the health monitoring technology which can be useful to maintain the structural integrity with improved reliability and durability. Developing a technology itself, which suits the specific application problem, is one of the important and major challenge in the SHM. The second issue is compared to non destructive tests, unlike conventional entities; a single technology of health monitoring cannot be suitable for all applications that make it more challenging since it depends on various factors like material, component geometry and identifiable damage scenarios of a given structural system. Third is, outcome of the monitoring scheme should be reliable because sometimes it may trigger an unwanted maintenance which is expensive.

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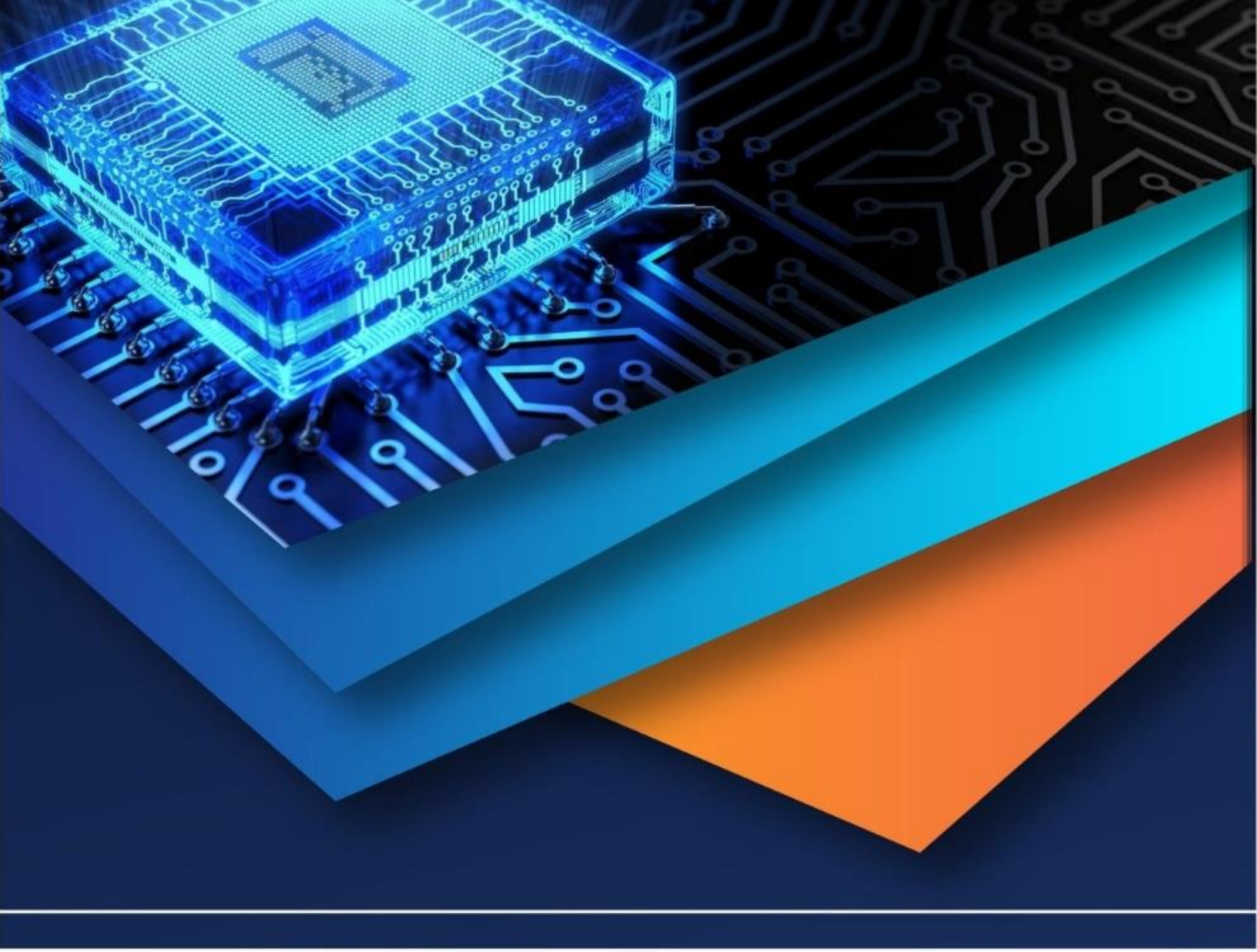

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