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Structural Health Assessment of Bridge

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***Abstract*—The aging of structures subjected to adverse environmental conditions, earthquake, heavy wind load, mechanical vibration, fatigue, flutter effects and accident etc may lead to damage in the structure. The damage generally begins at the material level and under a particular loading scenario it progresses to component and system level. If the existence of damage in unmonitored and unnoticed, it will lead to undesirable stresses or deformations. This will affect the present or future performance of the structure leading to functional problems and ultimately a catastrophic failure. Hence, the early assessment of structural damage is one of the major challenges in existing bridges. In India, most infrastructure are aged and are still being used despite the deterioration and associated damage. Moreover, the structures are being subjected to earthquakes, bomb blast, mechanical vibrations, and operational fatigue conditions. In such cases, conditions monitoring of these structures is an area of prime concern. The structure under such conditions are to be immediately evaluated and precautionary measures needs to be implemented to avoid catastrophic failures and minimise the down time. The failure of Civil Engineering structures like bridges, buildings etc., More often results in a large number of causalities as well as social and economic problems. Hence, the health monitoring of a structure is an emerging research field to provide a potential to assess the safety and integrity of structures.**

***Keywords* —**

I. INTRODUCTION

The aging of structures subjected to adverse environmental conditions, earthquake, heavy wind load, mechanical vibrations, fatigue, flutter effects and accidents etc, may lead to damage in the structure. The damage generally starts at the material level and then under a particular loading scenario it progresses to material and system level. If the existence of damage is unmonitored and unnoticed, it will lead to undesirable stresses or deformations. This will affect the present or future performance of the structure leading to functional problems and ultimately a catastrophic failure. Hence, the early assessment of structural damage is necessary in existing bridges.

The early damage assessment helps in real time monitoring and reporting of bridge structures. Also, it reduce the down time and helps to evaluate the safety, reliability and prevent thecatastrophic events. The knowledge of the condition of the bridge structure is necessary to take affirmative decisions on its further use for the purpose it is intended.

The proposed research includes selection of one of the NE region bridge which requires the structural health assessment. The scaled down model of the selected bridge truss will fabricated and numerically validated. Then the acquisition of a vibration signals from the bridge truss model subjected to moving vehicle load corresponding to scale factor. The signals are acquired through wireless sensor network and studied with feature extraction technique to identify the damage, if any. The measured acceleration response in time domain and frequency domain are analyzed through pattern recognition *and*wavelet transform techniques, enabling the automated structural health monitoring system for a structure. Further this study can be extended to the real bridge under consideration at NE region.

II. REVIEW OF STATUS OF RESEARCH AND DEVELOPMENT IN THE SUBJECT

2.1 International Status:

Structural monitoring refers to instrumenting civil engineering structures with sensors that aid in analyzing the performance of these structures under ambient wind or earthquake loading. Civil structures were embedded with structural monitoring systems to predict performance in earth quakes and strong winds (Johnson 2001). SHM has enabled analysis of structures in regions of high seismic activity and have aided in suggestions for better design. Structural monitoring systems are also used extensively in predicting the life of long-span bridges. Many bridges such as Akashi Takyo and Tatara bridges are instrumented with sensors in Honshu, Japan (Tamura 2001). Dynamic response of these structures obtained using data collected from the sensors are further used to compare the results predicted using numerical models (Wond et al 2001). Having condition based maintenance in place of a scheduled maintenance will reduce repair cost of structures which is normally as high as 4% of construction cost (Bergmeister 2000). For better transmission of signals from remote locations, low-cost wireless sensing units are designed which embeds in itself, statistical time series damage detection algorithms (Lynch et al (2003). Recently smart sensing technologies such as fiber optic sensors are being widely used to monitor the health of civil engineering structures, Sun et al (2010). Modifications to be incorporated for improving structural integrity aiding in long term risk management is provided by structural health monitoring techniques (Savage W U(2001).

2.2National Status:

In India, most infrastructures are aged and are still being used despite the deterioration and associated damage. Moreover, the structures are being subjected to earthquakes,

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bomb blasts, mechanical vibrations, and operational fatigue conditions. In such cases, condition monitoring of these structures is an area of prime concern. The structures under such conditions are to be immediately evaluated and precautionary measures needs to be implemented to avoid catastrophic failures and minimize the downtime. The failure of civil engineering structures like bridges, buildings, etc., more often results in a large number of casualties.

Hence, the health monitoring of a structures is an emerging research field to provide a potential to assess the safety and integrity of structures. The natural frequencies of the structure are utilized to identify the damage in the structure (Patil and Maiti, 2003). However it was observed that, the changes in natural frequencies due to variation of environmental conditions can be significant more than that due to actual damages (Aktan et al. 1994).Dhivya and Hcmalatha (2013) presented an early alarm system for the structure subjected to earthquake using wireless health monitoring system. Though, the presence of damage was identified after earthquake, the location and magnitude of damage were yet to be explored. Sundaram et al. (2013) discussed about the disadvantages and limitations of wired and wireless SHM systems and their applications to civil infrastructures. Sindhu and Nirrrnala (2015) presented an overview of continuous wireless SHM of a structure using accelerometers and piezoelectric sensors. They suggested the extension of the work to transmit the data wirelessly for remote monitoring of structures such as high rise building and bridges

2.3 Importance of the proposed project in the context of current status:

The structures, especially bridges built many years ago, lose their strength over a period of time. In the field of bridge engineering, though the design codes specify the use of safety factors and various other measures which ensure that the built structures are safe and last for the desired period of design time, still damages are observed. This is because during this design period the structure experiences various external disturbances such as strong winds, operational excitations or earthqua.kes. This may lead to minor damages such as cracks which bridges may withstand or sometimes these may be extreme which may eventually lead to collapsing of these bridges. Even if there are not many extreme external disturbances over years, the condition of the bridges can deteriorate which may generally go unnoticed. In any of the above cases, it is necessary to identify and monitor the condition of the load carrying capacity and strength of the bridge to prevent any severe damages to the structure as a result of the accumulation of the minor damages over years. The collapse or damage especially in the bridge structure can lead to huge losses in terms of human and economy. The repair after a collapse is a tedious and time taking task which renders the bridge inoperable for a considerable period of time. Monitoring and repair of the bridge on regular interval on the other hand can save a lot of and time and human loss. Thus all the bridge structures need a continuous monitoring and evaluation in regular basis, with repairs and rehabilitation whenever required. This is where the structural monitoring comes into importance and very useful in the current day scenario. Structural health monitoring though not a new process, but in recent years studies have been performed to improve the accuracy and reliability of the process. In economic terms, constant maintenance costs and reliability of a structure are more of a benefit as compared to increased maintenance cost during damage and low reliability for bridge structures. This structural health monitoring emerges as an efficient, reliable and economical approach to monitor the structural health and repair damage early and maintain the structures strength for a long period of time and prevent unforeseen catastrophic damages.

III. WORK PLAN:

3.1 Methodology

(1) Scaled bridge model for response prediction:

Ascaled model of existing bridge truss in NE region will be made using RPtechnology using steel members. It will be instrumented with accelerometer sensor at critical location.

(2) Simulation of damages:

The bridge truss model will be subjected to arbitrary excitation using moving vehicle loads scaled down as per model. Its vibration response will be recorded using wireless data acquisition system. Further, the damages will be introduced artificially at different elements of truss and the time history of its response to arbitrary excitation will be recorded. A data base will be created depending on the number of damages simulated.

Alternately, the database with various damage conditions will be simulated usingnumerical model of the bridge structure. Excitation forces similar to those experienced by experimental test structure will be induced on the numerical model and the corresponding response of the structure with various damaged conditions will be extracted. This will greatly reduce the experimental cost and time involved in creating a training data base. For this approach the numerical model updating of the undamaged structure with that of experimental model is very important.

(3) Instrumentation and data acquisition:

The accelerometer sensors will be used for sensing vibration at different critical locations of the bridge truss model. Accelerometers will be in turn connected to the signal conditioning unit and time domain vibration signals will be captured continuously through wireless data acquisition system. Time domain signals for each of the damage cases along with that of healthy bridge will be captured, which forms the raw data for further processing.

(4) Raw Data Processing

The raw vibration data is past processed so as to obtain feature vectors using different feature extraction techniques

The feature vectors serve as input to machine learning algorithms such as Artificial Neural Network /Support Vector Machine, which will be capable of classifying the damage in the building.

(5) Damage Assessment

Further, assessment of the location and amount of damage in the bridge truss is made using wavelet transform and pattern recognition techniques.

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An automated structural health monitoring system will be developed tocontinuously track the condition of the structure subjected to moving vehicle load.

The results obtained above will be compared with an alternative approach and their efficiencies will be compared. The same raw data, responses from the experimental studies will be used to obtain the Frequency Response Function (FRY). The damage assessment will be carried out with useful features like natural frequencies, modal information extracted from the FRF employing evolutionary algorithms.

3.2 Time Schedule of activities giving milestones through BAR diagram

Activities	Months					
Literature survey	1-6	7-12	13-18	19-24	25-30	31-36
Fabrication of scaled bridge truss model using RP technology or using steel frames.						
Numerical simulation of the bridge model for validation and data generation.						
Instrumentation of the building model with wireless accelerometer sensors.						
Generating various element damage scenario in the bridge truss model and vibration data acquisition						
Post processing the vibration data. Feature Classification using machine learning techniques						
Validation: Comparison with numerical model and validation of the damage assessment results.						
Research Report with outcomes						

3.3 Suggested Plan of action for utilization of research outcome expected from the project.

Future Plan:

The research study conducted on scaled down model of NE Region Bridge can be extended to structural damage assessment of the real scale bridge at the site. Further, the same technique can be adapted to all the important bridge strictures in NE region.

- Title of Project: "Characteristics and modeling of tornado-induces wind loading on low-rise buildings"
- Role: Research Collaborator from India for the Project, Other Colaborators: Tonji University, China and Tokyo Polytechnic University, Japan
- Duration: Jan 2015-Dec 2018.
- FundingL: Funding for International Travel, Overseas Stay and Conducting Wind Tunnel Experiments
  Other details: First set of experiments were conducted in June 2015, as a visiting research at Tongji University, Shanghai, China
- Partial results were communicated as a paper to 8th International Colloquium of Bluff Body Aerodynamics and Applications which was presented at North Eastern University, Boston.

<u>*Research Interest*</u>

- Fluid – Structure Interaction
- Wind Effects on Structures
- Condition Monitoring and Machine Learning studies on Wind Turbine Gear Boxes
- Vehicle Aerodynamics

<u>*MEMBERSHIP IN PROFESSIONAL BODIES*</u>

- Life Member of Indian Society for Technical Education (ISTE)
- Associate of Institution of Engineers (India) (AIE)
- Life Member of Tribology Society of India (TSI)
- Life Member of Indian Society of Wind Engineering (ISWE)

<u>*Journals/Bulletins*</u>

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