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CASE STUDY OF STRUCTURAL HEALTH MONITORING IN INDIA AND ITS BENEFITS

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Abstract — In today's modern world, the development is at its peak. Due to increasing development, thousands of new buildings, tunnels, bridges, expressways, and many challenging and complex structure are being made day by day for suiting the increasing needs of people. The development is also seen in the new materials and techniques used in construction methods. Due to this increasing construction of vast structures, the analysis of structures has also become a major challenge as maintaining the integrity of the structure is of utmost importance. Traditional methods of structure analysis are not much beneficial and are not sufficient enough. Structural health monitoring (SHM) is a great development in the analysis of the structures for damage detection and determination of cracks and defects present in the structure. SHM system improves the safety and reliability of the structures; reduce maintenance costs and also helps in extending the useful life of the structures. Still the practical applications of this method are not much used and are still behind in the civil sector in India.

***Keywords*:** SHM, damage detection, cracks

1.0 INTRODUCTION

India is full of old heritage monuments, buildings either owned by state government or people. These heritage buildings are still standing despite of several hundred years and the environmental conditions. It is a remarkable sign of integrity.

Despite these old buildings in India, the high rise buildings and other complex structures are also being made day by day. Monitoring safety and health conditions of these structures is very important as these structures like huge monuments, shopping malls, hospitals, schools etc have a large amount of people gathering. Any failure in these structures will harm hundreds of people at the same time.

Dams are also huge complex structures which involve various complex design, construction, maintenance process. Failure in these dams would cause a great amount of loss to economy and also to thousands of peoples. So monitoring the health conditions of dams is utmost important.

Qualitative and non-continuous methods have long been used to evaluate structures for their capacity to serve their intended purpose. Nearly about the 19th century railroad wheel-tappers have used the sound of a hammer striking the train wheel to evaluate if damage was present.[1] The current method of damage inspection include visual inspection and localised experimental methods. All of these methods requires the area which is to be inspected, is accessible. In relation to this limitation, there is shortage of highly experienced inspectors and also inevitable delay of time in-depth structure analysis. As a result, need for development in damage detection methods for complex structures has risen.[2]

The shift from simple experimental observation to Structural Health Monitoring has been driven by two factors: on the one hand, by the consequences led by degradation of modern construction materials and functional obsolescence onto infrastructure economics and, on the other hand, by the availability of cheap, effective and durable innovative instrumentation and hardware/software tools to accomplish complex data acquisition and signal processing functions.[3]

Structural health monitoring (SHM) is a process of finding the accurate conditions and performance of the structures. SHM is a great development in the field of civil sector. It provides Permanent continuous, Periodic or Periodically continuous recording.

of representative long terms. The information/data received from SHM systems strength and modal parameters over short or would then be used for repairs or rehabilitate and to maintain the safety of the structure. [4]

2.0 STRUCTURAL HEALTH MONITORING(SHM)

2.1 WORKING OF SHM

Working of SHM is same as the human nervous system. In human nervous systems, there are number of nerves connected to controlling part of human body (brain) and as soon as we feel pain in any part of our body, the nervous system sends signals to the brain. Likely in SHM systems, sensors act as nervous systems which are connected to the main controlling unit of data processing and decision making.

Responses are recorded from the detecting system and are distinguished as:

1. Physical- temperature, humidity
2. Mechanical- strain, cracks opening, stress load
3. Chemical- carbonation, chloride or sulphate penetration [4]

The data received from the sensors shows the type of response like physical, mechanical or chemical and then the measures are taken to correct or repair the type of damage recorded.

The engineering structural health concept encompasses four distinct subsets:

1. Sensor allocation and measurements,
2. Structural identification,
3. Damage or degradation detection, and
4. Decision making. [5]

The total process includes these four sub processes for identification, location and severity of damage and for determining the remaining life of the structure inspected.

2.2 SHM TECHNIQUES

SHM techniques are basically divided into two categories:-

- Global dynamic technique
- Electromechanical impedance technique

2.2.1 GLOBAL DYNAMIC TECHNIQUE

In this technique, the structure which is to be tested is subjected to low frequencies excitations, either harmonic or impulse and the response vibrations such as velocity, displacement and acceleration is recorded. Initial mode shapes with corresponding natural frequency is then compared with healthy state data and the severity of damage is determined. The damage present in the structure affects the modal parameters like modal frequency, modal damping and mode shape. The damage incurred also affects the structure parameters.[6]

The basic drawback of this technique is low sensitivity to incipient damage.

2.2.2 ELECTROMECHANICAL IMPEDANCE TECHNIQUE (EMI)

It is an ultrasonic technique and one of the most attractive methods used for monitoring. In this technique, PZT (leadzicornate-titanate) transducers are embedded on the structure which is to be monitored. PZT transducers are basically made up of piezoelectric materials exhibiting electromechanical coupling characteristics. These are called smart materials, which have ability to communicate between two domains. [7]

PZT transducer acts both as a actuator and sensor. It uses high frequency range excitation, so vibrations from outside environment like vehicles and wind will not have a significant effect on the EMI technique. The main advantage of this method is that it can detect internal damage at a relatively low cost. [8]

2.3 USE OF SHM IN STRUCTURES OF INDIA-CASE STUDIES

2.3.1 MONITORING OF OLD HERITAGE TEMPLE

Bhand deval temple is situated in Arang tahsil Raipur district, Chhattisgarh. It is a heritage temple which was built in 9^{th} century AD under the rule of Haihaya dynasty.

The monitoring method adopted in this temple is Rapid visual screening which is based on seismic intensity, building type and damageability grade. Geo coordinates are Lat 21degrees 11 minutes and 43 seconds North and Long.81 degrees 58 minutes 10 seconds East.

Popularly known as Bhand Deul, this temple is dedicated to Jaina section as evident from three beautiful images of Tirthankaras in kayotsarga pose installed in the sanctum. [9]

2.3.2. NAINI BRIDGE (2001-2004)

The Naini Bridge is part of the Allahabad bypass, crossing the Yamuna River just upstream the intersection to the Ganges River. The Bridge is owned by National Highway Agency of India (NHAI), designed By COWI A/S and constructed by a JV of Hundai and Hindustan Construction Company. The Structural Health Monitoring System for the bridge was also designed by COWI A/S and contracted by Devcon Infrastructure Private Ltd (DIPL).

The most parameters to monitor was defined to the traffic loads in order to assess the frequency of overload, settlement measures of the pylons and movements of pylons for design verification of creep assumptions for the bridge. The SHMS was designed to be operated from local control room approximately 750 from site by remote control from NHAI in Delhi. [10]

2.3.3. SIGNATURE BRIDGE IN DELHI

It is new cable-stayed bridge under construction across river Yamuna in Wazirabad, Delhi. This bridge will have total span of 675m, with a main span of 251m. It will carry four lanes of traffic in each direction. Its dramatic inclined steel pylon, with a height of 154 meters, and elegant stay cable design, will make it a particularly attractive and imposing addition to the Wazirabad skyline.

The bridge will be equipped with a sophisticated structural health monitoring system, supplied by a joint venture of Mageba India, Mageba Switzerland and Vienna Consulting Engineers. [11]

The system is intended to fulfill these major purposes:

- Structural health monitoring and damage detection;
- monitoring of weather loading (e.g. temperature, storms); and
- Earthquake monitoring [11]

2.4. BENEFITS OF SHM

2.4.1 Increased safety

Advancements of new technologies have made greater impact on public safety. SHM systems include sensors, data processing tools and data acquisition which helps in providing digital information about structures indicating their health conditions.

SHM helps in finding out whether the structure is able to withstand further excessive loading or whether the building is going to collapse or not. All these information helps us in finding out the useful life of the structure and also to maintain public safety by maintaining the integrity of the structure.

Traditional methods of visual inspection tools help in scheduled inspection of the structure but SHM helps in continuing monitoring of the structure. Continuing monitoring helps in constantly monitoring the health conditions of the structure. [12]

2.4.2 Cost efficiency

Maintaining structural integrity of structures for longer period of time reduces demolition and rebuilding cost. SHM can also greatly reduce long-term and short-term costs related to structural maintenance.

Additionally, SHM technology reduces need to halt profitable operations for large scale safety inspections, and to perform unnecessary maintenance on structural components that are still in good condition. All this helps in maintaining economic benefits for business and industry. [12]

2.4.3 Time saving

Time also plays a major part in comparing SHM with the traditional methods of damage detection. The scheduled detection test takes a greater amount of time to check the faults or damage and if in depth checking is done, ample amount of time is wasted. But in SHM, the sensors give immediate results and also time used in rebuilding the degraded structures would also be saved by continuous monitoring of structure and providing immediate remedy or repair work at early stage only.

2.4.4 Assurance of quality

The quality of structures can also be maintained by using SHM systems. Installing SHM systems at early stage of construction of structure can help in maintaining the quality of the structure.

It can help us in quality check of the structure at every stage of construction and also after the construction is finished.

Quality assurance is another very important factor in maintaining the safety of the structure. If the quality standards are in the desired proportion, then the structure is termed as safe.

3.0 NEED OF SHM IN INDIA

Between 2010 and 2014, a total of 13,178 people lost their lives in accidents where structures whether the building or the flyovers or any other structure have fallen.[13]

Seven incident of structures collapse happen every day. States in which this incident occur time to time:

Table 1: Deaths corresponding to different states

STATES	DEATHS IN NUMBER
Uttar Pradesh	2065
Maharashtra	1343
Andhra Pradesh	1330
Madhya Pradesh	1176
Tamil Nadu	1154
Gujarat	1067

Between 2010 and 2014, the collapse of residential buildings caused a total of 4,914 dying and this accounts for about 37.3 per cent of the total number of deaths.

The data of collapse of structure is categorized into five categories-residential building, commercial building, bridges, dams and others.

The collapse of other structures resulted in deaths of 6,233 people and this accounts for 47.3 percent of the total deaths.

A total of 1,610 people died in collapse of the commercial buildings. A total of 124 and 297 people died in collapse of dams and bridges respectively and this accounts for 3.2 percent of the total deaths.[13]

By looking at these numbers, we can take an idea that how failing of the structures is affecting the lives of people and it also shows the carelessness and the irresponsible behavior in the construction and maintenance of the structures. This all is costing the lives of innocent people.

Therefore, implementing SHM systems is of utmost importance for large-scale buildings to secure structural and operational safety and to issue early warnings on damage or deterioration prior to costly repairs or even catastrophic collapse. Long-term SHM of high-rise buildings is very helpful in understanding the building conditions under abnormal loading conditions and ensuring the safety for whole-life cycle. It provides the most authentic information for assessing structural probity, serviceability and reliability.

Many seismologists have said that "earthquakes don't kill people, buildings do". This is because most deaths from earthquakes are caused by buildings or other human construction falling down during an earthquake. Structural collapse is responsible for 75% of deaths in earthquake. In earthquake, majority of damage is done by falling of structures and measure should be taken to make buildings earthquake resistant by using high quality aggregates, by good and strong reinforcement and continuing monitoring of the structure. SHM helps in analyzing the structure for damage and also shows data which helps in verifying the characteristics adopted in wind and seismic design.[14] By this we can determine whether the structure is going to withstand any future unexpected vibrations or not.

India is a developing nation and it is very important that the country is enlightened and aware of its infrastructure. India is adopting certain SHM techniques, but they are very basic and their results are not very effective and can be better with new technologies like sensors based SHM, Wireless SHM, SHM software. [15]

SHM systems are not much used by people because they are not aware of these new technologies and also some does not adapt it because of high installation cost. So, in order to make people use of this system, government should made it legal for the construction of public structures and also the high rise buildings which are more prone to catastrophic conditions in the future. Government should make awareness plans so that more and more people will be informed about SHM system and its benefits. India

shall have an Indian Standard Code for Structural Health Monitoring and it has to be made mandatory for upcoming and previous structures.

4.0 CONCLUSION

Ageing of structures is inevitable; we cannot stop the structures to age. Structures start losing its strength gradually with age. Phenomenon like carbonization in steel and creep, fatigue in concrete starts appearing after certain period of time of excessive loading, harsh environment conditions etc. All this damage to the structures can be prevented to a certain limit by making changes in designing method but cannot be eliminated. Analysis of structures is a great method to find out the faults and damage in the structures. Traditional methods of scheduled inspection are becoming obsolete and outdated with time as they are time consuming and also not much efficient. SHM systems are a great development in analyzing the structures for every type of defects. It is a method of continuous monitoring of the structure and also very efficient.

In India, applications of SHM are not practically used in civil sector. One of the main reasons behind this is general awareness of SHM technology among the people. People are not aware of this new technology for damage detection and also there is a great misunderstanding among people that SHM systems are expensive! They do not understand that this is only a onetime expense only the installation cost is high and also by using SHM system, the scheduled inspection is not needed.

Other reason is that government has not made it legal. There is no rule for using SHM as a mandatory element in the construction. Government should make some rules regarding compulsory use of SHM systems in the construction process especially in huge public structures as number of failing structures is increasing day by day and this collapsing and failing of structures is leading to deaths of thousands of people in different parts of the country.

For making a safe and reliable environment for the people of our country our government should consider the more and more use of SHM. These little steps will lead our country to greater heights and also one step closer to known as developed country.

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