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STRUCTURAL HEALTH MONITORING SYSTEM FOR BRIDGES AND HIGH RISE BUILDING

Mhatre Rajesh Tanaji
research scholar North East Frontier Technical University

DR Awari Mahesh Babu
Professor, Department of Civil Engineering ATRI
Parvathapur, Hyderabad

ABSTRACT

As more advanced materials and technology become available, the designs of structures not only get more ambitious but also more complex. This is due to the fact that buildings are rising higher, bridges are having longer spans, and structural designs are getting more difficult. In light of these improvements, there is a rising need to provide not just cost savings in terms of maintenance but also a safer environment for by minimising structural failures. This should be done in order to meet the growing need for both of these things. The various historical structures in India, each of which has its own distinct style, is a fair indication of the rich cultural and historical legacy of the country. These structures have been built to an exceptionally high level, and as a result, they have withstood the test of time. However, due of their historical value, it is of the utmost importance to analyse the present condition of health of these structures in order to guarantee that the right safeguards are taken before it is too late to do so. Accelerometers, electrostatic gyroscopes (ESGs), and piezoelectric patches (PZTs) were the three varieties of sensors that were tested on beam constructions for this investigation.

KEYWORDS: *Structural, Health, Monitoring*

INTRODUCTION

Old heritage monuments are scattered across the entirety of India, and a significant number of these buildings are owned either by the state government or by the people. Despite the passage of several hundred years and the deterioration caused by the surrounding environment, these historic structures have retained their integrity. It is an extremely compelling evidence that one is being truthful. New high-rise buildings and other sorts of complex structures are being built there on a daily basis, despite the fact that India is home to a large number of historic buildings that date back thousands of years. Since a large number of people congregate in these structures, such as enormous monuments, shopping malls, hospitals, and schools, among other types of structures, it is extremely important to monitor the safety and health conditions of these structures. Examples of these structures include the following: In the event that any of these buildings were to collapse, the lives of dozens, if not perhaps hundreds, of individuals would be put in jeopardy. Dams are not only extremely difficult structures to build, but also include a broad array of complex processes throughout their design, construction, and ongoing maintenance. If these dams were to break, it would not only do a huge amount of harm to the economy, but it would also have an impact on the lives of thousands of people. For this reason, keeping a close eye on the physical condition of dams is of the highest significance.

SHM is an abbreviation that refers to the technologies of structural vibration control and structural health monitoring. These technologies are primarily concerned with the stability of building structures. The major purpose of SHM is to discover whether or not any structural damage has occurred and to locate the precise site of it. This is performed through the use of a method referred to as feature extraction, which entails applying statistical pattern recognition to the data that was measured. The damage that was caused by environmental pressures has to be repaired; otherwise, it will get worse over time and might eventually lead to the collapse of the entire system. If this damage is not repaired, it will become worse over time and could lead to the collapse of the entire system. When it comes to figuring out the structure's dynamics, dynamic factors like acceleration, velocity, and displacement all play an important role in the process. Knowledge of displacement is particularly essential when discussing bridges because of the nature of these structures. Not only is it difficult to put conventional displacement sensors on bridges, but once they are in place, these sensors are essentially worthless, particularly in the event that there is seismic activity. One more widespread method of sensing involves the application of global positioning system technology (GPS). Nevertheless, its utilisation is affected by a variety of issues, including cost, the cycling of satellites, electromagnetic noise, and unfavourable weather conditions. The laser Doppler vibrometer (LDV) is an additional choice; however, it does have a few drawbacks that stem from the installation process that it necessitates as well as the expense involved. The vast majority of acceleration and tilt measurements are performed with the assistance of accelerometers. This is because the accelerometer has a very easy structure, and it also does not need any kind of connected reference point to function properly. Due to the much greater costs associated with ordinary generic wired systems, wireless networks (WNs) have become an increasingly popular option.

Because the recorded acceleration signal from an accelerometer includes offset and low-frequency noise, it is impractical to integrate the acceleration signal directly in this case. Because of this, integrating the acceleration signal is much more challenging. Drifts could occur anywhere from the beginning to the end of the integration process due to the offset of an accelerometer as well as uncertain starting conditions. A drift-free numerical integrator was proposed as a possible solution in the cited source. During the design phase, the method for removing drift in the frequency domain was implemented into the system. The fundamental problem with these filter-like numerical integrators is that in order to stop drift, they are required to employ excessively high time constants. This is the only way to stop drift. Baseline correction is an alternative method that may be utilised, which has the potential benefit of preventing drift throughout the integration process. The fundamental problem with the baseline correction integrator is that the low-frequency noise was eliminated by making use of a window filter that had been constructed for a particular input signal. This is the root of the problem. As a direct consequence of this, it is not possible to use these integrators for online estimate. The observed acceleration signal is utilised by certain SHM observers in order to generate estimates of the vehicle's velocities as well as their current locations. On the other hand, the performance of an ideal integrator is not even remotely comparable to that of a filter with a large time constant.

In the process of assessing the soundness of the structural components of tall structures, vibration data are often put to good use. The damage is a reflection of changes in the structural characteristics, such as the stiffness and damping coefficients. On SHM, data mining was only used to a small subset of the research projects that were conducted. During the process of categorization, several methods were used to determine the modal characteristics of the structure. These parameters included the natural frequencies of the structure, the vibration intensity, and the damping coefficients.

Support vector machine, more often referred to as SVM, is a very desired technique of classification since it gives a hyperplane that indicates the greatest separation (or margin) between the two classes. This makes SVM a very attractive classification method. Because of this, the SVM is a very appealing classification strategy. However, in order to find a separation hyperplane, it is necessary to solve the quadratic programming (QP), which results in a significant increase in the amount of computing complexity. Moreover, in order to find a separation hyperplane, it is necessary to find a separation hyperplane, it is necessary to find a separation One technique for reducing the quantity of necessary training data is to make use of the geometric qualities of the support vector machine (SVM). SVM training now makes advantage of convex hull, which was not present previously. Within the realm of computational geometry, it is feasible to compute the convex hull for a finite collection of points by utilising any one of a number of distinct approaches. This is achievable for both closed and open surfaces. The Graham scan locates all of the vertices of the convex hull in the order that they are placed along its border by identifying the direction of the cross-product of the two vectors. This is done by calculating the direction of the two vectors. The convex hull may be discovered by employing the Jarvis march, sometimes known as gift wrapping, which involves doing angle comparisons and winding a thread around the point set. When dealing with an issue that has three dimensions, the divide-and-conquer tactic can be an effective way to address the situation. In order to streamline the process of finding solutions to issues, the incremental convex hull approach and the fast hull technique both require skipping over specific steps in the process. When a nonconvex loss function is utilised, a nonconvex support vector machine (SVM) is produced as a consequence.

OBJECTIVE

1. To studies Basic points Of Structural Health Monitoring
2. To study on The Precepts That Guide Structural Health Monitoring

Basics of Structural Health Monitoring

A approach that is comparable to the way in which an illness or pain is treated and controlled by the human body is used to assess the structural health of a building. This method is called the "health monitoring system."

If we were to equate the human body to a construction, it would be something like this: The nervous system is able to recognise when a person's body is in an unhealthy state and will alert the brain when it does so. This occurs whenever the nervous system senses an injury or trouble with the person's body. These signs let the person know that there is an issue with their health. A person becomes aware that he is unwell and makes the decision to visit a doctor in order to halt the progression of the sickness before it becomes more severe. It is possible to view the sensors and the acquisition system as performing the functions of the nervous system and the brain in a manner that is interchangeable between the two. The structural expert functions as something of a physician for the structure; after hearing the remarks, they create recommendations for how the problem could be repaired in the future.

The responses that are included inside the structure are the most important components. Responses that may generally be quantified can, in the vast majority of instances, be divided up into the following categories:

I. Mechanical: load, strain, deformation, displacement, opening of cracks, stress, and displacement

II. The physical aspects, including temperature, humidity, and pore pressure

III. Chemical: chloride penetration, sulphate penetration, pH, carbonatation penetration, rebar oxidation, and steel oxidation.

SHM's physical diagnostic tool is a combination of a wide variety of sensing devices and auxiliary systems, including but not limited to:

i. Sensory system

ii. Data acquisition system

iii. The information and data processing system

iv. The Method of Communication

v. Damage detection and modelling system

Monitoring does not serve the objective of providing a diagnosis in any way. It is necessary to carry out a comprehensive inspection as well as any applicable analyses before arriving at a diagnosis and recommending a course of therapy for the ailment in question. In order to discover anomalous structural behaviours, the study of monitoring findings is carried out in line with algorithms that have been defined in advance. The efficiency of monitoring is not only dependent on the functioning of the monitoring system that is being used, but also on the algorithms that are being utilised for the purpose of monitoring.

Structural Health Monitoring Stages

Structural health monitoring, also known as SHM, is becoming more essential in a range of study sectors, including aerospace, civil, and mechanical engineering, due to the fact that it is an efficient method for guaranteeing the structural integrity and safety of a building or other structure. This may be explained, at least in part, by the fact that SHM has had a meteoric rise in popularity over the course of the last several decades. SHM refers to the process of putting a plan into action in order to find damage in structures. This tactic employs a number of different sensing technologies, all of which are combined into separate hardware and software systems that are intended to record, log, and evaluate data in real time. SHM is an abbreviation for structural health monitoring, which is another name for it. The capability to monitor a structure and identify deterioration at the earliest possible stage provides support for maintenance programmes and accurate forecasts of the remaining life of the structure.

The identification of the problem is the first stage in the diagnostic procedure for damage in structural systems. This is followed by the characterization of the problem in terms of its location, nature, and degree of severity. According to this, a dependable SHM system is composed of the processes of damage identification listed below:

Level 1: Is there evidence of damage in the structure?

Level 2: Where exactly, in terms of coordinates, has the damage occurred?

Level 3: What kind of damage has been sustained?

Level 4: What kind of damage has been done and how severe is it?

Level 5: What is the estimation of the amount of remaining time that the structure will be in service?

Moving up the levels of evaluation results in an increase in the amount of knowledge one possesses regarding the state of the structure's health. However, this also results in an increase in the amount of effort that is required to acquire that knowledge, which is the concept that lies behind this hierarchy. Because of this, each of the different levels will have a certain set of requirements that must be satisfied, including the kind of sensors, the number of sensors, the types of damage monitoring methods, and the number of model parameters. The challenge lies in the development of SHM systems that are able to successfully respond to more than one level of damage identification, both in normal operating settings and after severe catastrophic occurrences such as earthquakes. This is a difficult task because it requires the creation of SHM systems that are able to successfully respond to multiple levels of damage identification.

The Precepts That Guide Structural Health Monitoring

The development of SHM over the course of the past twenty years has made it feasible to identify a few fundamental axioms or principles based on experimental research that has confirmed them. This has made it possible to progress the field. As a consequence of this, in order to have a successful practise in SHM, it is strongly recommended that one adhere to the following axioms:

Axiom number one: There is always going to be a defect or imperfection in a substance since that is just how things are. There are flaws in the atomic microstructure of every material, and these flaws may be seen with an electron microscope. These flaws might take the shape of voids, inclusions, or contaminants, depending on their particular manifestation. However, engineers have learned to work around and even accept the design challenges that develop as a result of the inherent faults in the materials that they utilise. This allows them to produce higher quality products overall.

Axiom II: In order to determine the extent of damage, it is required to do a comparison between two distinct states of the system, and each SHM technique requires a baseline system to function properly. The training set will be different depending on whether one is only pretending to detect damage or is actually acquiring detailed information about it (type, extension, location). As a consequence, the data set can either be based solely on normal conditions of the structure or on a combination of normal conditions and damaged conditions of the structure, depending on which option is selected. It has been stated that particular studies on SHM present data that contradicts this axiom; however, this is because of the vocabulary that was utilised in those studies; bringing this terminology to a common ground should clarify the reality of Axiom II;

Axiom III: Although it is possible to determine the existence of damage as well as its location by unsupervised learning, supervised learning is typically required in order to determine the type of damage that has been done and the level to which it has been done. Unsupervised learning is a type of learning in which algorithms are applied to data sets that only include instances of healthy structures. When it comes to this form of learning, the most important category of algorithm that is utilised is known as novel detection. When employing supervised learning, examples of both healthy and damaged structures are made available. As a direct consequence of this, discrete and continuous classification strategies, such as group classification and regression analysis, are utilised.

The inability of sensors to immediately evaluate risk is the subject of the fourth axiom. Feature extraction, which may be conducted via signal processing and statistical classification, is necessary in order to transform sensor data into damage information. This can be done in a number of different ways. Simplifying the process by which one must determine the relationship between a given damage state, denoted by the symbol D, and a given measured quantity, denoted by the symbol x, is the most challenging aspect of developing a SHM algorithm. This is because determining the relationship between these two variables can be extremely complex. This function, which is designated by the symbol f, is not known from the fundamental laws of physics; rather, it is something that needs to be learnt from the information that is gathered by the sensors.

Axiom IV-b: In the absence of intelligent feature extraction, the degree to which a measurement is susceptible to damage is inversely proportional to the degree to which it is sensitive to the various operational and environmental variables. This relationship holds true regardless of whether the variables in question are operational or environmental. For instance, the characteristics of a system that are found to be insensitive to changes in temperature are typically those that are located the farthest away from the peak of the frequency spectrum. This is because changes in temperature tend to have a linear relationship with the frequency of the system. This suggests that these qualities are also less prone to sustaining harm in the event that it occurs. The most important point that should be taken away from this axiom is that the features that may be deduced from the data that have been measured will rely not only on the type of damage that has to be identified, but also on an ambient variable and an operational variable. Because of this, it is desirable to create an algorithm in which the sensitivity of the reaction to other factors may be minimised, or at the very least reviewed and regulated, and the response is solely dependent on the amount of damage that has been sustained.

The duration and time scales connected with the beginning and progression of injury are responsible for determining the needed features of the SHM sensing system. This is the fifth and last axiom in the series. Damage may be the result of gradual accumulation over time (the period may extend over years), or it may be the direct result of a sudden one-time incident. Either way, damage can come about in either of these two ways. As a result of this, having an a priori quantification of the various time scales makes it possible for the sensor system to function in a more efficient manner by enabling the selection of the appropriate hardware components. This is because of the fact that having an a priori quantification of the various time scales is a prerequisite.

Axiom VI: There is a trade-off between the capacity of an algorithm to reject noise and how sensitive it is to damage. This ability is referred to as the noise rejection capability. In relation to axiom IV-b, the measurements that were gathered comprise both the influences of damage and the noise in the read response. The challenge is to distinguish the impacts that are brought on by each of the sources individually.

According to Axiom Number Seven, the level of damage that may be recognised from changes in system dynamics is inversely proportional to the frequency range of stimulation. This relationship holds true regardless of the type of stimulation. In the field of ultrasonic Non-Destructive Evaluation (NDE), the phrase "diffraction limit" refers to the smallest size of a flaw that may be detected as a direct result of the ultrasonic wavelength. This size is determined by the frequency of the ultrasonic waves. The phrase "diffraction limit" is often used in connection with this concept. According to this limit, defects of a size that is larger than half a wavelength or comparable to it can be detected. As a result of seeing this connection, it is evident that, for a given velocity, the wavelength will decrease as the frequency rises, which in turn means that the damage sensitivity will increase. This holds true even if the velocity remains the same. The equation denoted by the notation = vf describes the relationship that exists between the frequency, the wave phase velocity, and the wavelength. The relationship between the wavelength and the frequency may be expressed as the equation: vf =. In this sense, higher frequencies make it possible to detect even the smallest amount of damage more accurately than lower frequencies.

In accordance with Axiom No. 8, damage brings with it an extra level of complexity to every given construction. This idea may be immediately and easily grasped by just examining the fact that damage will cause a structural system, which was supposedly built to operate linearly, to start acting in a manner that is non-linear. This is the key to understanding this idea. Developing measurable measurements of complexity may be accomplished in a number of ways, one of which is by using the principles of statistics and signal processing to the data obtained from damaged and undamaged systems. One method for accomplishing this goal is to investigate and contrast the probability density functions of a measured response under damaged and undamaged structural circumstances.

RECENT ACCIDENTS DUE TO STRUCTURAL FAILURE

As can be seen in Figure 1.8 on December 2, 2006, a bridge that had been in use for about 150 years and was located in the vicinity of the Bhagalpur railway station in the state of Bihar in India collapsed. There were thirty fatalities and numerous others injured as a result of the incident. The investigation committee came to the conclusion that the bridge had reached the end of its life, and there was no monitoring done on the remaining strength and serviceability. It was also brought to everyone's attention that the bridge was in very terrible condition.

Fig. 1 Collapse of Railway Bridge near Bhagalpur

The dam in Val di Stava failed on July 19, 1985, which led to one of the biggest natural disasters that Italy has ever seen. The top dam failed first, which led to the failure of the lower dam as well. Both dams were destroyed. There was a discharge of over 200,000 cubic metres of mud, sand, and water into the Rio di Stava valley in the direction of the settlement of Stava at a speed of over 90 kilometres per hour. As a direct consequence, it led to the deaths of 268 people, the damage of 62 structures, and the collapse of eight bridges. The investigation group came to the conclusion that the dam had terrible maintenance, and there was very little room for error in its functioning.

As can be seen in Figure 1.9 on August 1, 2007, the main span of the foot bridge that was built in 1907 collapsed and fell into the Mississippi River as well as onto its banks. There were thirteen fatalities, and an additional one hundred or so persons were injured. It was discovered that the bridge was carrying additional dead weight as a result of the additional surface coating that had been applied during the restoration process. Unfortunately, the stress level was not evaluated after the additional surface layer was applied.

Fig. 2 Collapse of Bridge on Mississippi River

Flight CI 611 from Taipei to Hong Kong was supposed to be operated by the Boeing 747-209B B-18255 on May 25, 2002. The aeroplane broke up into several pieces while it was in flight, and as a result, all of the passengers and crew members perished. According to the conclusive findings of the inquiry (which can be read at http://aviation-safety.net), the accident occurred as a consequence of metal fatigue, which was caused by poor maintenance following a prior occurrence of tail hit in 1980. In the lower part of the aft fuselage, in close proximity to the outside row of the fastening rivets, there was evidence of fatigue damage. Multiple Site Damage (MSD) was discovered, and it consisted of a 15.1-inch through thickness major fatigue crack in addition to several smaller fatigue cracks. The scratching damage that was caused by the 1980 tail strike event was the initial cause of the 15.1-inch fracture as well as the majority of the MSD cracks. In addition, the analysis of the residual strength showed that the main fatigue crack, in conjunction with the MSD, was of sufficient magnitude and distribution to facilitate the local linking of the fatigue cracks so as to produce a continuous crack within a two-bay region. This was determined by the fact that both of these factors were sufficient in terms of both magnitude and distribution (40 inches). Ironically, none of the maintenance inspections performed on B-18255 were able to identify the inadequate structural repair that had been performed in 1980 or the fatigue fractures that had been steadily accumulating.

CONCLUSION

There are four components that make up comprehensive health monitoring of structures. These components include the existence, the location, the degree of the damage, and the remaining life of the building after the harm has occurred. Conventionally, several methods, as well as various kinds of sensors and hardware, are utilised for each individual element. The study effort that was done for comprehensive structural health monitoring and non-destructive evaluation only employing PZT sensors is included in this study. The conventional method is not only expensive and difficult to understand, but it also has a lower sensitivity and a lower degree of accuracy when predicting the site of damage. The fundamental purpose of this body of work was to establish a new method through the combination of local and global dynamic approaches in such a way that the final result is economical, sensitive, and easy to use, and that it only makes use of a single kind of sensor.

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