Structural Health Monitoring and Its Remedies

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Abstract— **Over the last 50 years, a number of catastrophic bridge failures have called attention to the disrepair of national infrastructure systems and the need for structural health monitoring. For example, the I-35W Bridge in Minneapolis, Minnesota, catastrophically failed on August 1, 2007 without warning. In recent years, the bridge was rated as "structurally deficient" after annual inspections revealed corrosion, poor welding details, fatigue cracking in steel members and dysfunctional bearings considering the catastrophe of the I-35W Mississippi River. While no conclusions can yet be drawn as to the cause of the bridge's catastrophic failure. it is critical to implement a system to monitor the health of bridges and report when and where maintenance operations are needed. Therefore, it is important to have a systematic approach to monitor the health of a bridge. In spite of its promising benefits, structural health monitoring (SHM) is infrequently used in bridge applications. Bridge Structural Health Monitoring (SHM) has rapidly become one of the main interests in civil engineering field. Inexpensive and efficient SHM method utilizing.**

Keywords—Structural health monitering,remote sensor,provide remedies

I. INTRODUCTION

Structural health monitoring has attracted much attention in both research and development in recent years. This reflects continuous deterioration conditions of important civil infrastructures, especially long-span bridges. Among them, many were built in the 1950s with a 40- to- 50-year designed life span. The collapses and failures of these deficient structures cause increasing concern about structural integrity, durability and reliability, i.e. the health of a structure throughout the world. Currently, there are no foot proof measures for structural safety. A structure is tested for deteriorations and damages only after signs that result from fault accumulations are severe and obvious enough. When the necessity of such tests becomes obvious, damages have already exacerbated the system's reliability in many cases and some structures are even on the verge of collapse.

In general, a typical SHM system includes three major components: a sensor system, a data processing system (including data acquisition, transmission and storage), and a health evaluation system (including diagnostic algorithms and information management). The sensors utilized in SHM are required to monitor not only the structural status, for instance stress, displacement, acceleration etc.,

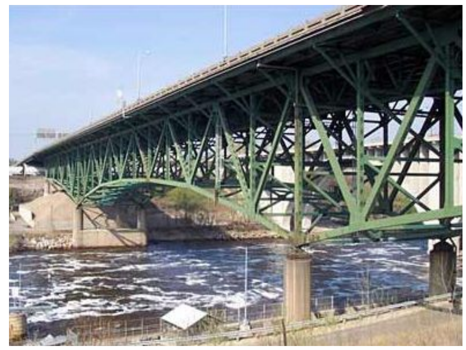

Figure . (Left) I-35W Bridge in Minneapolis, Minnesota; (right) catastrophic failure after collapse on August 1, 2007 (source: Associated Press, 2007).

Structural health monitoring is a non-destructive in-situ structural sensing and evaluation method that uses a variety of sensors attached to, or embedded in, a structure to monitor the structural response, analyze the structural characteristics for the purpose of estimating the severity of damage/deterioration and evaluating the consequences thereof on the structure in terms of response, capacity, and service-life (Housner et al. 1997, Karbhari 2005, Mufti 2001). The sensors obtain various types of data (either continuously or periodically), which are then collected, analyzed and stored for future analysis and reference. The data can be used to identify damage at its onset, to assess the safety, integrity, strength, or performance of the structure.

Components of SHM Systems

- As mentioned previously, structural health monitoring refers to subjecting the structure to static or dynamic excitations, continuous or periodic monitoring of the structure's response using sensors that are either embedded in or attached to the structure. New advances in sensor and information technologies and the widely use of Internet is making SHM a promising technology for better management of civil infrastructures. There have been many case studies worldwide in the past decade. While the specific details of each SHM system can vary substantially, SHM basically involves sensor and data acquisition, data transfer and communication, data analysis and interpretation, and data management. Thus a SHM system will typically consist of six common components, namely: Sensors and data acquisition networks;

- Communication of data;
- Data processing;
- Storage of processed data;
- Identification and interpretation); and
- Retrieval of information as required.

II Advantages and Benefits of SHM

- Improved understanding of in-situ structural behavior
- Early damage detection
- Assurances of a structure's strength and serviceability
- Reduction in down time
- Improved maintenance and management strategies for better allocation of resources

III Objectives

- Identification of most useful data and information to be collected.
- Identification of the types of structures/parts of structures where enhanced monitoring is needed and most promising.
- Deployment of the most promising technologies as demonstrations.
- Development of recommended revisions to the AASHTO condition evaluation manuals.
- Evaluation of current visual methods and recommendation of improvements.
- Development of automated data collection and reporting.
- Development of interpreting protocols and damage models using the data collected by the systems.
- Evaluation of cost/benefit of monitoring/assessment systems.
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- Study the implications of security and traffic management systems

IV Sensors

Selection of sensors

Once the structure and measurement metrics are identified, the first step for an effective SHM system is the selection or development of appropriate and robust sensors. Although the specific types of sensors selected for a project depend on several considerations, obviously the sensor must be able to measure the desired response parameter which will provide the information required for monitoring and analysis. For example, the measurement needs can be one or a combination of any of the following: strains, deformations, accelerations, environment (temperatures, moisture, pressure, etc), load, and other attributes of a structure Literature surveying had disclosed significant development in sensing technologies from conventional sensors of electrical resistance strain gauges, vibrating wire strain gauges, deflection transducers, accelerometers, anemometers, etc. to novel sensors of fiber optic gauges, etc. These sensors are commercially available, but many of them are not always suitable for SHM. For example, certain sensors are not appropriate for long term monitoring due to deterioration in sensor performance with time. Extreme care should be taken in the selection of the number of sensors and their location within the structure to ensure satisfactory performance.

Installation and placement of sensors

In addition to follow the instructions of sensor providers, great care should be taken during the design of the SHM system to ensure that sensors can be easily installed within a structure without substantially changing the behavior of the structure. The presence of sensor wiring, conduit, junction boxes, and other accessories needed to house the SHM system on site must be considered and accounted for during the design process. Experience has shown that while the embedded sensors themselves can be quite durable, poor durability or installation of the cable network and poor design of the data acquisition equipment for field environments can significantly reduce the functionality of the SHM system.

A detailed set of installation specifications should also be prepared for each type of sensor and data acquisition component that will be used. These specifications should detail the methods and techniques to be used for installing and configuring the sensors and data acquisition components, and a methodology for verifying that they are working correctly (i.e. testing and calibration of the sensors) . If the installation work is done by a general contractor, installation of all systems must adhere to the supplier's specifications, with appropriate instruction and supervision.

Wired connection by a lead cable or wire is sometimes subjected to electromagnetic interference (EMI) which can lead to errors in the measurement. The use of differential signaling techniques and properly shielded cables can sometimes mitigate the effects of EMI. Note that FOS technologies are not normally affected by EMI. In any case, extreme care must be taken during the construction process to ensure that sensor cables are not accidentally sheared off or otherwise damaged. Wireless connection is needed for some large structures where lead cable transmitted sensor signals might be corrupted by excessive noise, or where long lead cables are otherwise impractical. Wireless data transfer is currently more expensive than direct connections, data is typically transferred much more slowly, and the signals are not completely secure. However, it is expected that wireless communications will be increasingly used for SHM of very large structures in the future. Most sensor manufacturers offer data loggers (wired or wireless) with their sensor products. There are also manufacturers who only provide data loggers which are compatible with most commercially available sensors. This will be discussed in more details in Part 2 (current technologies).

Data Sampling and Recording

Experiences have shown that SHM data can easily become very large in quantity especially when the structure are extensively instrumented with a variety of sensors in a variety of locations, particularly in the case of continuous monitoring (Ni 2010). Therefore a well designed data acquisition algorithm-data sampling and recording, which captures an adequate (but not excessive) amount of data, is a very important component of a successful SHM system and will affect both the volume of stored data and the type of diagnostic information that can be obtained.

3 In setup the data sampling rate, a general rule is that the amount of data should not be so scanty as to jeopardize its usefulness, nor should it be so voluminous as to overwhelm interpretation (Mufti 2001). A low sampling rate leads to the former, and an unnecessarily high rate to the latter. Of course, in some cases, as in the case of dynamic testing (discussed later), high sampling rates are required to accurately measure the structure's response to transient loads. It is important to sample data at the appropriate rate for the type of testing which is being conducted. Decisions regarding appropriate sampling rates should thus be based on experience. For example, the data collected during continuous monitoring activities may be substantially compressed by recording only changes in readings or only data exceeding a specified threshold value. Another option is to only keep peak values of readings for each event, such as a heavy truck passing over a bridge.

Data Communication

Data communication refers to the mechanism of transfer of data from DAQ system to the location where they will be processed and analyzed (normally not on the bridge site). The communication of data is an important aspect of an effective SHM system, since it allows monitoring to occur remotely, and eliminates the need for site visits and inspections by engineers. Sometimes it is also possible to remotely control the DAQ system through proper monitoring software. Currently SHM systems transmit field data remotely, either through telephone lines or the internet, or using wireless technologies such as radio or cellular transmission (Han et al. 2004).

Data Processing and Analysis

This is the operational part of the process. The data is processed before it is stored in a database. Due to the many possible sources of error and uncertainty in the field, the data obtained by the various sensors in a structure are likely to contain extraneous information and noise that are of little or no use for the purposes of structural health monitoring.

One method for data quality assurance is to implement quality control at multiple levels of the signal path. At the level of the sensors and data acquisition hardware, a thorough initial calibration of the sensors and data acquisition hardware followed by periodic re-calibration of these components, verifying and ensuring the quality of the initial installations, are needed. Elementary data checks can also be programmed in the data acquisition software to automatically validate and process the data before it can be stored for later interpretation and analysis. The goal of intelligent processing is to remove this unwanted or redundant information. The various data management strategies should be able to eliminate unnecessary data without sacrificing the integrity of the overall system.

Sometimes a combination of data acquisition algorithms may be required so that only peak values are recorded as a general operating mode, and continuous data is recorded for discrete periods of time if a threshold value is exceeded. Selection of the most appropriate data acquisition algorithm is a critically important component of SHM as it will affect both the volume of stored data and the type of diagnostic information that can be obtained.

In more sophisticated systems, neural computing and artificial neural network techniques may be employed (McNeill 2004, McNeil and Card 2005). Artificial neural networks (ANNs) are basically statistical signal processing techniques that are inspired by the learning capabilities of biological systems. Similarly to their biological counterpart, ANNs have the capability to learn through experiences, rather than through explicit rules or procedures. This learning could be carried out in a supervised or unsupervised manner. Either case results in the system able to develop an internal model of the characteristic properties of a collection of the data. The internal data modeled stand for the physical response of a bridge due to its environment. This response is it in the form of strain, temperature, and acceleration measurements under normal operating conditions.

The specific nature of the learned model is dependent on the algorithm that is used to train the network and the quality of data that is made available. An algorithm is a set of rules or computational procedure for solving a problem. Should the network training data have sample inputs; the model will be capable of differentiating between similar varieties of such inputs in the future. In the absence of pre-labeled inputs, identifiable classes can still be incorporated into the learned model in cases where markedly distinguishable types of phenomena exist within the input data. Measurements that are consistent with the model will display low levels of novelty, while those which differ substantially from the model will produce high novelty value (McNeil and Card 2005).

In neural network, algorithms are designed to learn the characteristic patterns of the signals and identify only those patterns which can be classified as 'novel'. For example, on bridges with low to medium traffic volumes, particularly with respect to heavy trucks, the majority of signals produced by a continuous monitoring program will be small compared to the signals generated by heavy trucks. The latter is of more interest. Neural computing can be used to isolate the truck response as novel compared to all other responses and only this section of the data will be tagged for storage or further analysis. This can be conducted in an unsupervised mode by the monitoring computer such that no human input is required and the data management becomes automatic and efficient.

Storage of Processed Data

The processed data can then be stored for later use in structural health diagnostics. In some cases, the data could be stored for long periods of time, and it is important that, once retrieved, the data are easy to understand. Thus, the medium for storage of the data should be such that the data will be available for a period of many years without susceptibility to corruption. Obviously, the amount of memory required for storage can be very large in SHM applications with numerous sensors or higher data sampling rates, and care must be taken to ensure that sufficient memory is available to store all of the data which will be generated. It is also important to ensure that the data files contain enough information about the data so that anyone could interpret them. It is possible that the data collected could be used by an engineer many years in the future, so the data files should be logical and well-documented.

Developing appropriate algorithms for data quality assurance, processing and archival represents the major IT (information technology) related challenges in a SHM system. It is common to disregard raw data and store only processed or analyzed data, thereby decreasing the amount of space necessary for storage. Unfortunately discarding the raw data does not allow for reinterpretation at a later time. The result of this step is a database of measurements and a log of events.

Diagnostics and Prognostics

This is the most difficult step and also the most important component of an effective SHM system. Diagnostics involves further interpretation of the collected and processed data, analysis of the responses of the structure, and identifying if any of the foreseen damage or deterioration have occurred. Diagnostics is concerned with converting the data from monitoring to useful information about the response and health of the structure. This activity requires expert structural knowledge about the behavior of structures as well as an understanding of how that behavior may be affected by damage, deterioration or other changes in condition. The level of complexity of the analysis will change based on the needs of the monitoring program and the SHM system components. In a simple application, it may be sufficient to convert strain readings into stresses for assessment against critical limits such as yielding. The degree of sophistication can increase up to a point where artificial neural networks are required to determine the probability that a measured change in response readings indicates a specific damage type and location by a statistical comparison against a wide range of possible damage situations generated by parametric analysis using numerical models

In a long-term structural health monitoring application, the system should be able to interpret the measurement data, compare the result with some predetermined set of criteria, and execute a decision in an automated manner. The simplest example is to program a health monitoring system to issue an alert when the measurement data indicates that some behavior has exceeded a particular threshold value. The decision criteria should be thoroughly tested before it is implemented and must be rigorous enough to prevent the occurrence of false positives.

Retrieval of Data

When selecting data to store for retrieval, both the significance of the data and the confidence in its analysis should be considered. For example, for a static field test (discussed later), the volume of data generated is relatively small; therefore, both the raw data and the diagnostic information can be easily stored for retrieval. Conversely, for a dynamic field test, the volume of data generated is quite large, and therefore only the diagnostic information is stored. Of course, the overarching goal of structural health monitoring is to provide detailed physical data which can be used to enable rational, knowledge-based engineering decisions.

Preventive Measures.

- Increase steel
- Provide incLined member

- Provide alarm system
- Provide dampers
- Retrofitting
- Renewation of bridge

V Probable Conclusion:

- Through successful health monitoring, the life of a deteriorating bridge can be extended, and catastrophic failure events can be prevented. After analyzing the damage remedy can be applied based on the type of damage.
- Using SHM we can avoid the death ratio and accidental damage due to as unknown from dangerous situation.

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