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Bridge Health Monitoring System

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Abstract: *In developing countries like India there is strong focus on national infrastructure .New bridges are build every year. The maintenance of these bridges is many times overlooked. And the present systems use complicated and high cost wired network and high maintenance optical fiber system. So the main objective behind this project is to build a cheap bridge health monitoring system for developing countries.*
Keywords: *Bridge health monitoring system(BHMS), Accelerometer, Anemometer, Load Cell, LM35*

I. Introduction

Bridges are continuously subjected to destructive effects of material aging, widespread corrosion of steel reinforcing bars in concrete structures, corrosion of steel structures and components, increasing traffic volume and overloading, or simply overall deterioration and aging. These factors, combined with defects of design and construction and accidental damage, prompt the deterioration of bridges and result in the loss of load carrying capacity of bridges. The condition of heavily used urban bridges is even worse: one in three are classified as aging or unable to accommodate modern vehicle weights and traffic volume. Therefore, a significant number of these structures need strengthening, rehabilitation, or replacement, but public funds are not generally available for the required replacement of existing structures or construction of new ones.

Bridges can suffer structural deterioration due to aging, misuse or lack of proper maintenance. Among the many factors which have led to the unsatisfactory condition of bridge structures, one factor that has been neglected is the unsatisfactory inspection and monitoring of existing structures. The most common objectives for monitoring a bridge are to obtain quantitative data about the structural behavior in order to confirm design assumptions and to provide real-time feed-back during construction (especially true for new bridges), and to evaluate the real current condition of the bridge and allows the engineers to take informed decisions about their future and to plan maintenance or repair actions (especially for existing bridges). In the later, the monitoring system is used to increase the safety of the structure and provide early warning of an acceleration of the known degradations that are being monitored. And the application of SHM to existing bridges to perform a controlled lifetime extension of the bridges with known problems has greatly increased in recent years.

There are many bridges in Japan and China which are very advanced as compared to the monitoring systems in Konkan. So our aim is to develop a system that is reliable, cheap and more efficient for Indian bridges. This system will not only be useful for the railway bridges but also for the road bridges, foot bridges.

II. Literature Survey

Some failures are sudden and catastrophic, and some failures just take their time. Structural Health Monitoring (SHM) can be very helpful in serving as an alarm system for preventing both types of failures. Bridge Engineers need scientific tools which can give quick information about the health of a bridge. Such instrument shall supplement the periodical manual inspections. But when failures happen with any kind of structure there is loss of human lives, money and many more, most of the times. For example, during the bridge construction boom of the 1950's and 1960's, little emphasis was placed on safety inspection and maintenance of bridges. This changed when the 2,235 foot Silver Bridge at Point Pleasant, WV, collapsed into the Ohio River, on Dec. 15, 1967. 46 people were killed.

Hence to ensure the safety of bridges, the Bridge Health Monitoring System was introduced. Some of the existing technologies/methods for Bridge Health Monitoring System are as described.

1. Bridge Health Monitoring System on Konkan Railway

Konkan Railway Corporation Ltd. has procured one such equipment namely BRIMOS Recorder. This equipment records the vibrations of the structure under ambient conditions and gives a frequency plot (vibration signature). It has been the endeavor of the Bridge Engineers to search for an effective tool which can give a warning to the inspecting official (pending detailed inspection) in the form of an indicative parameter. Konkan Railway has procured one such system from Austrian Company namely, BRIMOS Recorder. It is portable equipment weighing about 16.5kgs which can be moved easily from bridge to bridge and carry out the recordings

All elastic members when exited will vibrate with certain natural frequencies. These natural frequencies are a function of their stiffness's. These natural frequencies can be monitored over a period of time (called the vibration signature) and any shift towards the lower end of spectrum indicates reduction in stiffness of the structure. The Engineer can then direct his efforts for detailed inspection along with necessary instrumentation for such bridges where reduction in stiffness beyond certain permissible limit is detected.

The equipment is user friendly. The instrument can be set up even on the foot path of the bridge with the help of leveling screws. Each recording takes about 5 minutes and the instrument can store data for about 40 recordings. The data can be transferred on to permanent storage devices such as personal computer and the vibration signature (frequency plot) can be viewed /analyzed and stored for future reference.

2. Bridge Health Monitoring System on Akashi Kaikyo Bridge, Japan

Akashi Kaikyo Bridge is not only famous for world longest suspension bridge but also for its advanced health monitoring system. It has a technology called MBM (Monitoring Based Maintenance) that enables the bridge maintenance engineers monitor the condition of the bridge in real time. The sensors installed on main cables, hangers, decks, towers, etc. detect the strain, acceleration, temperature and wind. The sensory inputs are process to represent the condition of the bridge against seismic loads and wind loads. Like Akashi Kaikyo Bridge, there are many bridges that have real time monitoring system in Korea. Akashi Kaikyo Bridge has the sensors placed on various parts of the bridge. It is as shown.

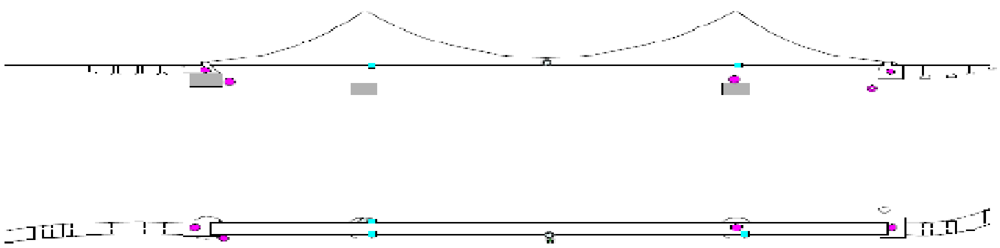

Figure 3 Akashi Kaikyo bridge design

On September 22, 1998, Typhoon No.7 occurred in the central area of the Kii Peninsula (east of Akashi Kaikyo Bridge). The wind direction and wind speed was measured by the anemometer near the middle of the center span and so did the transversal displacement of the related girder. By applying wind-tunnel test results and the wind resistant design guidelines for Akashi Kaikyo Bridge, a transversal displacement of 5.41m and vibration amplitude of 2.56m were calculated. The field-measured values showed a transversal displacement of 5.17m and vibration amplitude of 0.78m. It is confirmed that the field-measured values for transversal displacement have good agreement with the calculated results, but the vibration amplitude was about one-third of the calculated value.

- The Akashi Kaikyo bridge has a center length of 1991m , and it extremely flexible structure with low natural frequency which makes high wind resistance necessary
- Therefore the wind resistance design standards for the Akashi Kaikyo bridge were established (HSBA 1990).
- During construction the bridge was tested which showed its wind resistance to be 78m/s
- When the wind speed exceeds this value a warning is given by the monitoring system.
- The Akashi Kaikyo Bridge can handle accelerations due to earthquakes of magnitude of 8.5 Richter scale. During an event of earthquake the bridge is shut down automatically.

Figure 1 Akashi Kaikyo

Data control device was used for analysing recorded data, such as, time history data graphing, statistical and analytical processing. The data was formed into a database by a data processor located in a control station at Tarumi junction.

On September 12, 1998, Typhoon No.7 occurred in the central area of the Kii Peninsula (East of the Akashi Kaikyo Bridge). The Figure 5 shows the time history data for ten minutes before and after the peak wind speed and the maximum recorded transversal displacement. The wind direction and wind speed measured by the anemometer near the middle of the centre span are shown in Figures 5(a), (b), respectively. And the transversal displacement of the related girder is shown in Figure 5(c).

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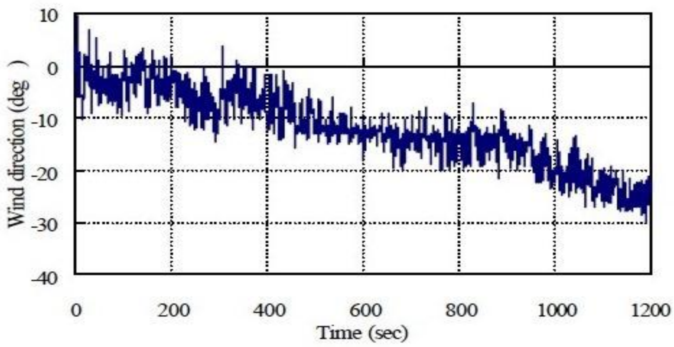


Figure 2(a) Wind direction (Perpendicular to bridge axis: W=0°)

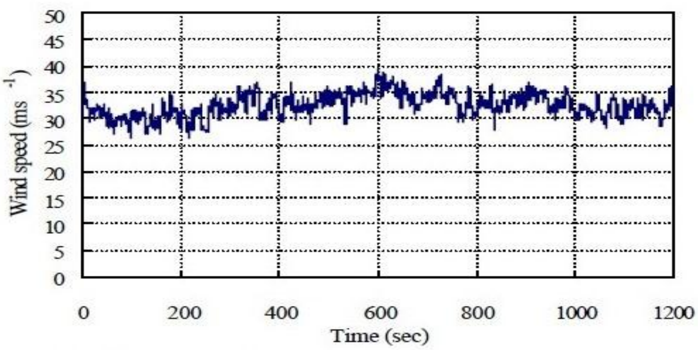


Figure 5(b) Wind Speed

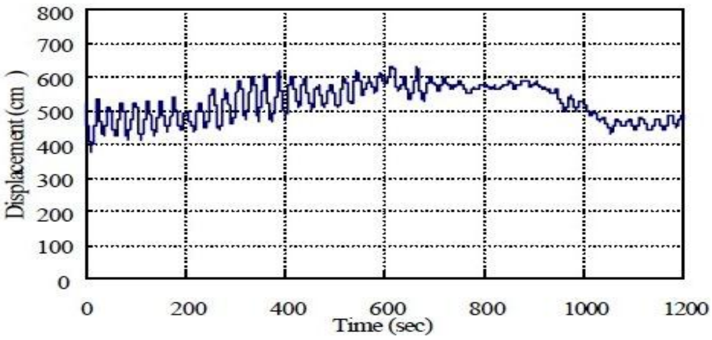


Figure 5(c) Lateral displacement of Girder at the centre of the bridge

III. System Design

3. Basic Overview

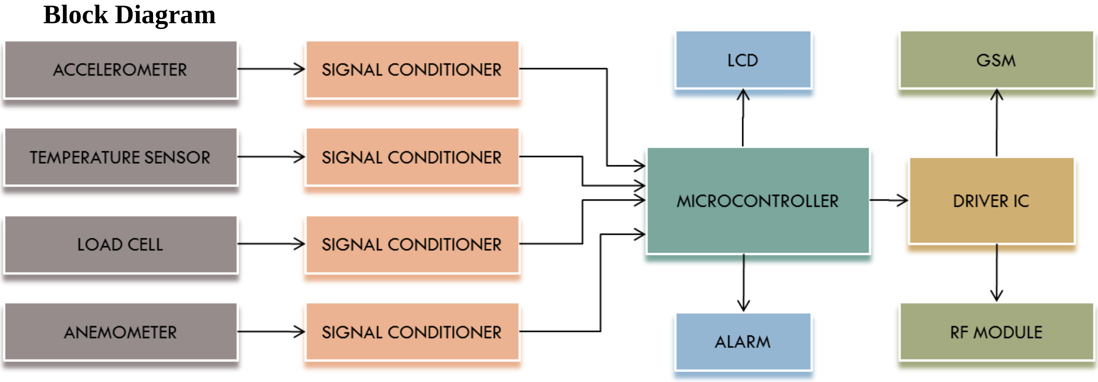
This project is based on 4 sensors:

- Accelerometer
- Load Cell
- Anemometer
- Temperature Sensor

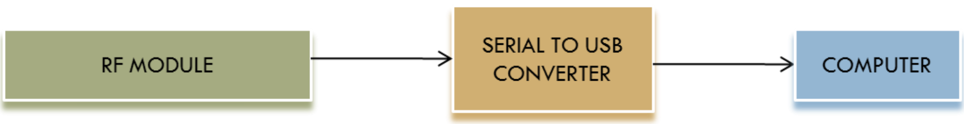
The micro-controller we have used is “PIC16F877A”.We’ve used LCD display to display the 4 parameters constantly. We have used a GSM SIM300 module for sending messages and RF module to constantly send the parameters to the control station.

We are going to use a computer as a Control Station where we have used Visual Basics 6.0 to display the parameters which are sending via the RF module.

4. Block Diagram



(a) Transmitter Side



(b) Receiver Side

5. Block Diagram Description

(a) Transmitter Side:

There 4 sensors used in the block diagram namely Temperature sensor Anemometer Accelerometer and strain gauge. The accelerometer is used to detect the bridge tilt. It senses the motion of the bridge in 3-axis.We are going to connect the accelerometer at the middle of the bridge. Then the temperature sensor can measure the temperature of the bridge components. The temperature sensor can be connected to any part of the bridge. There is a strain gauge which can measure the weight the bridge is carrying at the time. We have used a load cell for this purpose. The load cell is connected at the center of the Bridge. The anemometer is a sensor which measures the speed of wind.

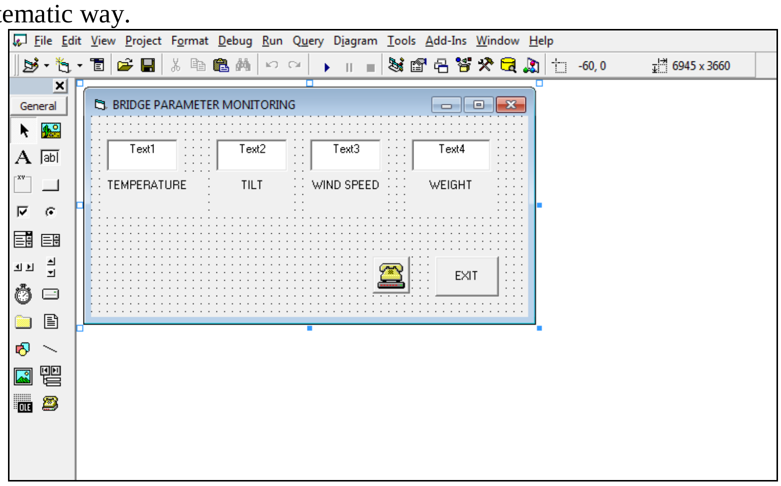
These 4 sensors are interfaced to the microcontroller through a signal conditioning circuit. The signal conditioning circuit is used to make the outputs of sensors compatible with microcontroller. As the temperature sensor is recalibrated we haven't connected a signal conditioning circuit for it. An alarm and a LCD are connected to the microcontroller. The alarm is triggered when the values of the sensors exceeds the threshold value. The LCD is used to display the parameters constantly. All the parameters are constantly transmitted through the RF Module to a remote PC. The RF Module is interfaced to the microcontroller through the driver IC. At the receiver the RF Module is connected to a PC through a driver.

There is a GSM module which is used if there is a need to warn any authorities which are responsible for the maintenance of the bridge. The GSM band used in INDIA is 850 MHz to 900 MHz. So we have used the SIM 900 GSM module which supports India's frequency band.

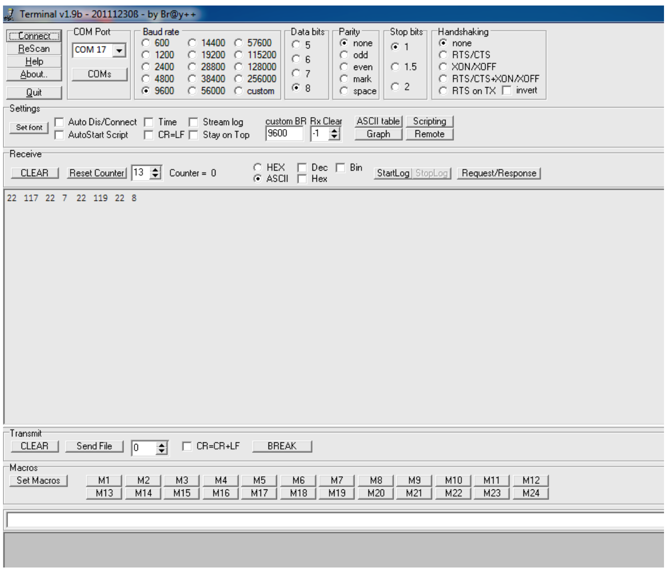
The PIC reads the output from sensors using "A to D" conversion, displays on LCD. The microcontroller sends this data to remote display unit in concerned office using RF Module. The remote display unit receives the data using RF Module and displays on the LCD.

(b) Receiver Side:

On the receiver side we are going to use a RF module for receiving the data from the transmitter side. We are using a serial to USB cable to connect the Receiver side RF module to the PC. The received data is given to the computer. The computer basically works as a Control Station which stores the data sent by the transmitter side from time to time. We are using Visual Basics for making a Module which displays all the parameters in a systematic way.



This is the module we have made in Visual Basics to display the parameters on the computer which works as control station.



We are using the software named TERMINAL, version 1.9b for connecting the RF module to the PC through the COM ports. The readings are continuously sent to the PC from the RF module through the serial to USB convertor cable we have used.

IV. Future Scope

Based on the potential combinations of different available sensors and systems, the range of applications is virtually endless. Application of structural health monitoring technologies to bridges has seen great increase in the past decade. Initial results from these applications have shown the capability of available SHM technologies in monitoring, analyzing and understanding the health of the monitored bridges. Since most of case studies and applications are just in past recent years, it is necessary to examine their performance and results over a long time by continuous monitoring to determine the durability and reliability of these systems.

In India hundreds of bridges are built every year in which the importance given to maintenance is very less. There are no Health Monitoring Systems used on any bridges of India. Around 70% of bridges in India are old and need repairs and 57% are over 80 years old. In such bridges the need for monitoring is very high, but they are neglected. According to a survey in 2003, around 23% of bridges in India need repairs and they should be monitored.

The cost of bridge health monitoring system is negligible as compared to the total cost of the bridge. So there is need for installing Bridge Health Monitoring Systems on all Bridges.

There are many bridges like the British-era Hancock bridge in Mazagaon which has been listed as a dangerous structure years ago where the need for such health monitoring system becomes obligatory.

Hence we have developed a new Bridge Health Monitoring System especially for the Indian Bridges which is especially very cheap as compared to optical fiber systems. This will certainly prevent the catastrophes occurring due to deficient bridges and also due to natural disasters.

As has been demonstrated through the information presented in the previous sections, SHM offers an enormous range of options to engineers who are interested in characterizing the short and long-term behavior of their structures. SHM is increasingly seen as an important tool in the maintenance of sustainable infrastructure systems, and it is reasonable to assume that ongoing advancements will continue well into the foreseeable future. In particular, two interesting emerging technologies are worthy of note: smart structures and live structures.

SMART Structures

(Choo 2009 thesis) The term “smart structure” has been increasingly used in the bridge SHM communication. Literature review has yielded various definitions of “smart structures”. Simply “smart structures” was defined as structures incorporated with sensors in some of the most advanced building materials (Tennyson 2000) or structures integrated sensing system (Measures 2001). A detailed definition by Phares et al. (2005) is given as:

A “Smart” technology is one in which the system systematically reports on the condition of the structure by automatically making engineering-based judgments, records a history of past patterns and intensities, and provides early warning for excessive conditions or for impending failure without requiring human intervention. These features make the system capable of providing and facilitating self-diagnostic, real-time continuous sensing, advanced remote sensing, self-organizing, self-identification, or self-adaptation (decision making and alarm triggering) functions. Further, the user is not burdened with demanding operational and maintenance tasks.

Phares et al. (2005) further elaborated that these features make the system capable of providing and facilitating self-diagnostic, real-time continuous sensing, advanced remote sensing, self-organizing, self-identification, or self-adaption (decision making and alarm triggering) functions. The user is also not burdened with demanding operational and maintenance tasks.

“Smart structures” can thus be simply summarized as structures that are instrumented with SHM system that proactively report the structural condition and warn the users upon the detected damage and deterioration within the structures.

Live Structures

Live structures represent the cutting edge of civil engineering design and analysis. These are, at present, largely theoretical types of structure that will be possible one day in the not-so-distant future. Live structures are not only able to sense loads, deformations, and/or damage (through sophisticated SHM and analysis systems), but they are also able to respond to the sensory input and take action to counter or correct the effects of loading. Recent developments in the area of self-actuating materials – materials which can change in shape and mechanical properties on command – are allowing civil engineers to consider the day when intelligent structures will both sense and respond to external loads and environmental influences.

2) Advantages:

- Improved understanding of in-situ structural behaviour
- 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

3) Disadvantages:

- The only disadvantage is that the sensors should not fail when there is an adverse condition.
- So there must be a system incorporated which will detect sensor failure

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