Structural Health Monitoring of Bridge Using WSN

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Abstract: **Bridges play an important role while considering a transport infrastructure. They represent a major investment for society and an important part of that investment goes to inspection and maintenance. Bridges often assign as bottlenecks in transport system with a few practical alternative routes. As such, closing them for repair, inspection or replacement entails large costs for users. Furthermore, safety levels in bridges are expected to be higher than other parts of the transport system. This comes naturally due to the fact that failure of a bridge could have severe consequences in material damage and human lives. Introducing monitoring techniques in its different forms i.e. damage detection, traffic monitoring, reliability assessment, etc. can save wealth by improving the understanding of a structure, thus reducing the need of overly safe assumptions and by granting the possibility to get early warnings of problems that develop. Now-a-days rapid development in the field of monitoring is going on. Advances in sensor technologies, different data communication devices and algorithms of data processing all explain the possibilities of SHM, damage detection, traffic monitoring along with other implementations of monitoring systems. Bridges form a crucial part in a country's infrastructure, as they require a huge amount to build and maintain. There is, therefore, much need to focus on bridges for monitoring which can enhance the life of a bridge. It can directly impact on avoiding or postponing any type of replacement, repair onto that bridge. Many bridges establish bottleneck in the transport network as they serve with few or no alternative routes. The amount of resources saved, by both the owner as well as the user due to reducing the amount of non-operational time can easily justify the extra investment in monitoring.**

Keywords — Bridge Monitoring, Global System For Mobile Communication, Structural Health Monitoring, Wireless Sensor Network.

I. INTRODUCTION

Transportation infrastructure is vital for society. Terrestrial transport links in the form of motorways and railways constitute an important part of this infrastructure. One of the critical points in every transport network is its bridges. They are expensive to build and maintain, and the consequences of their sudden failure are very severe. Therefore, bridges are expected to have a higher degree of reliability, which in practice means, among other things, thorough inspection and maintenance schemes. This fact has led to a great amount of interest in the possibilities of using Structural Health Monitoring (SHM) in bridge engineering.[1] Several projects supported by foreign governments have already addressed the challenges and opportunities of SHM of bridge structures with guidelines and recommendations The research within SHM is mainly directed towards the development of new sensors, and new algorithms to analyse the data gathered by them. Bridge monitoring has been used e.g. to follow the construction stages of complex structures to adjust cable pressures in post-tensioned structures and for load estimation purposes but damage detection techniques are generally confined to laboratory and numerical experiments. Thus, despite the advances in this area, SHM has not yet become a tool that bridge managers can use to optimize inspection and maintenance procedures.[1].

In the running year, the incident of a bridge collapse occurred at Satara, Maharashtra. As shown in Fig.1, this bridge was built over the Savitri river in 1928. Due to this disaster, many people died. The local authorities claimed that the structural audit had been inspected and directions were given for a complete investigation by the government. The National

Highway Authority of India advised the use of this bridge till May 2016 only and recommended necessary modifications in the structural work. However, all this work done by only visual inspection not by using any electronic equipment and it resulted in the loss of many lives.

Fig. 1. Bridge collapsed at Satara on the Savitri river

II. HISTORY OF SHM

The historical development of Structural Health Monitoring in bridges is a difficult issue to delimit. Firstly, theoretical advances in the field are most of the time developed as generic techniques can be applied to different types of structures. Admittedly, most techniques are developed with a specific structure type in sight, but this does not constrain their applicability to only such structures. Some techniques are developed for bridges specifically, but they are not confined to this type of structure. Therefore, a review of the theoretical advances in SHM techniques used in bridges will have very arbitrary limits. It becomes almost necessary to limit the comprehension to only field deployments in order to obtain a clear-cut delimitation. The purpose of this section is not to present the historical development of SHM in general and therefore only field deployments in bridges are listed[1].

Secondly, although some degree of automation is included in the term SHM, the exact boundary between normal inspection and what is considered SHM is not well defined and has changed through time. Although in theory, they could be automated, most of the first methods for SHM were not fully automated in practice, mostly due to hardware limitations. As the cost of computers decreases and its power increases, the hardware limitations are easily overcome. [1]

Today, Structural Health Monitoring is a large and very active research field even if only bridge structures are considered. It is worth naming that in later years, damage detection techniques not based in modal parameters have been developed. Also, Structural Health Monitoring is being recently used not only for damage detection but also for continuous reliability assessments. A common classification of SHM systems divides them into four classes of growing complexity; depending on the characterisation of the harm they are capable of achieving.[3] The first stage is the detection of damage. In this stage, the SHM system warns about a failure being detected, without further specification on the nature of this failure. This is of course the simplest form of SHM, and it is sufficient for many applications. The second stage consists of the spatial localisation of the detected damage. This usually requires more complex sensor networks and more advanced algorithms. In the third stage, a diagnosis of the type and extension or severity of the damage is automatically carried out by the SHM system. The fourth stage consists of a prognosis of the remaining service life of the structure.[4] Although this would be very useful, a few real implementations of this forth stage exist today. For a successful estimation of the remaining life, information on the healthy and actual (possibly damaged) state of the structure is not enough, since knowledge on the deterioration schemes and estimations of future loads are also required. These four stages are shown schematically in Fig. 2

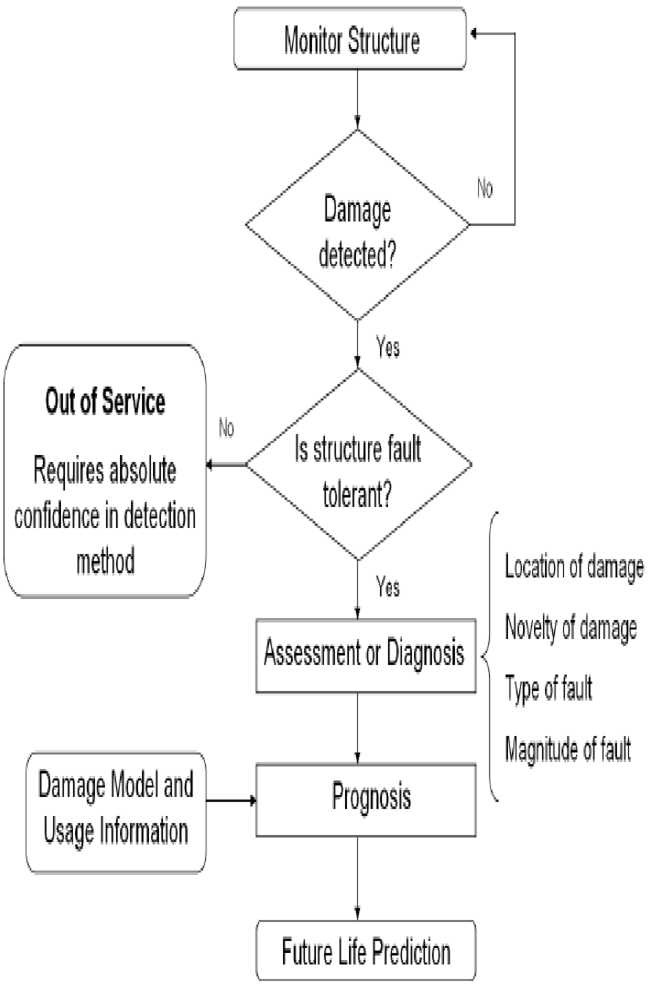

Fig. 2 A general flow chart of the given SHM system[1]

III. PROPOSED SYSTEM

The proposed system gets divided into 3 sub-categories as mentioned below-

1) Sensing sub-system
2) Processing sub-system
3) Communication sub-system

Sensing sub-system- The SHM process starts with the measurement of relevant physical quantities in the structure. This, since the advent of modern computers and data acquisition systems, is usually achieved by a sensor that transforms the quantity to be measured (e.g. acceleration, strain, cracks, temperature) into electrical signals that can be easily digitalized and stored.[6]

Sr.No.	Sensor	Physical Quantity to measure
1	Accelerometer	Vertical & Horizontal deflection of bridge
2	Load cell	Weight onto the bridge
3	Ultrasonic sensor	water level
4	flex sensor	Elongation into the bridge

Table 1. Sensors used in given system

Processing sub-system- In this sub-system, two stages working happens: the first is to take data from various sensors in a definite manner, process the data as per the given requirements and secondly send the data as per the communication protocols.

Communication sub-system- Data communication occurs in at least two stages for the most common SHM implementations: the first from the sensors to a central storage and analysis assembly, via a data acquisition system

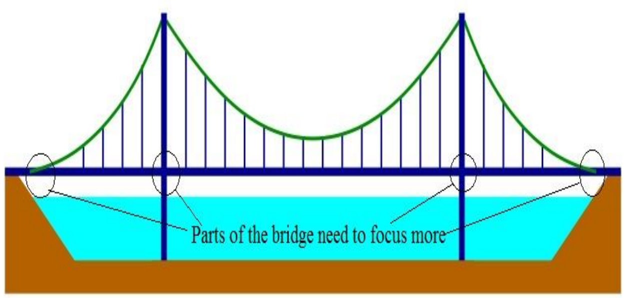

Fig 3: Area of the bridge for node deployment

and then from the central to the end user, usually the bridge owner. Technically the first of these stages represents more challenges, since data storage and analysis can be placed in a site that facilitates communication with the outside, while the placement of the sensors is constrained by the structure itself and by the variables chosen for monitoring.[8]

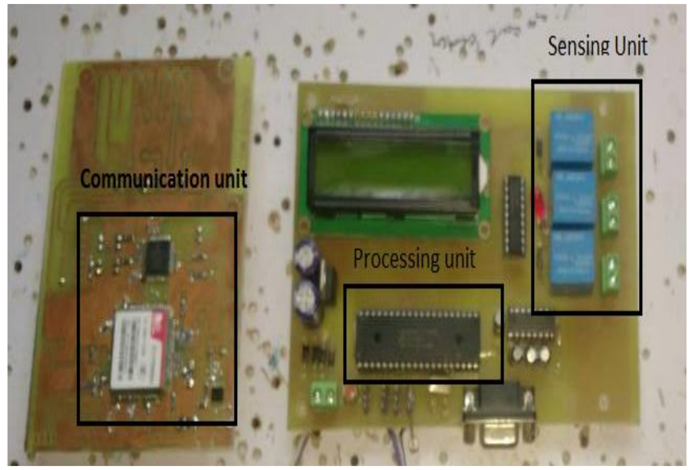

Fig. 3 Overview of sensor node

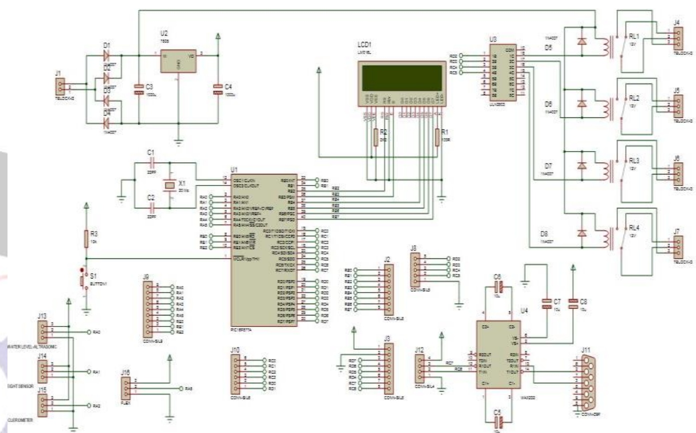

Fig. 4 Overview of sensor card

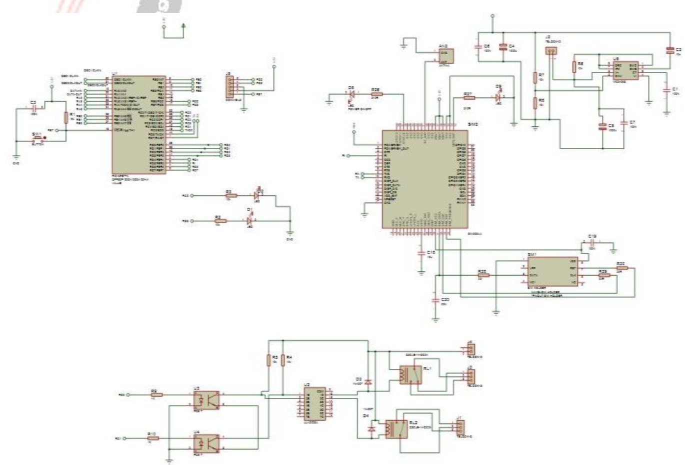

Fig. 5 Overview of GSM card

IV. RESULT & DISCUSSION

Firstly, when we open a website as shown in Fig. 4, it shows bridges onto that particular area from which we have to monitor one of bridge data. There is a need to select the bridge.

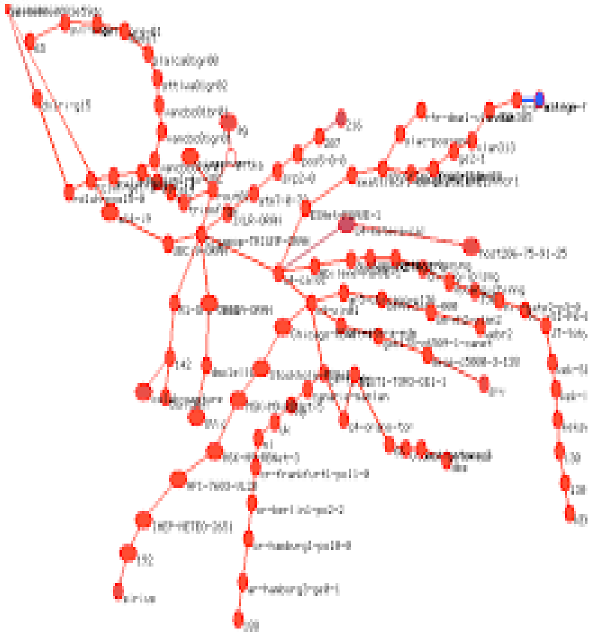

Fig. 7 Geographical area consisting Bridges

For the selection of a bridge in the given area, we need to provide a Bridge ID along with the name of the city. After submitting the information, it is logged into the particular bridge network for example, suppose we select area like Nashik city, then we need to choose the bridge number according to the location from where we have to monitor bridge like from Nashik. If we need to check the status of the bridge of ITI circle, then from the map, we need to choose its number and feed the information as Bridge no-12 and city name - Nashik as shown in Fig. 5. After a successful connection, we can observe the data in a graphical form like acceleration, water flow under bridge, water level, weight onto bridge etc. as shown in Fig.6

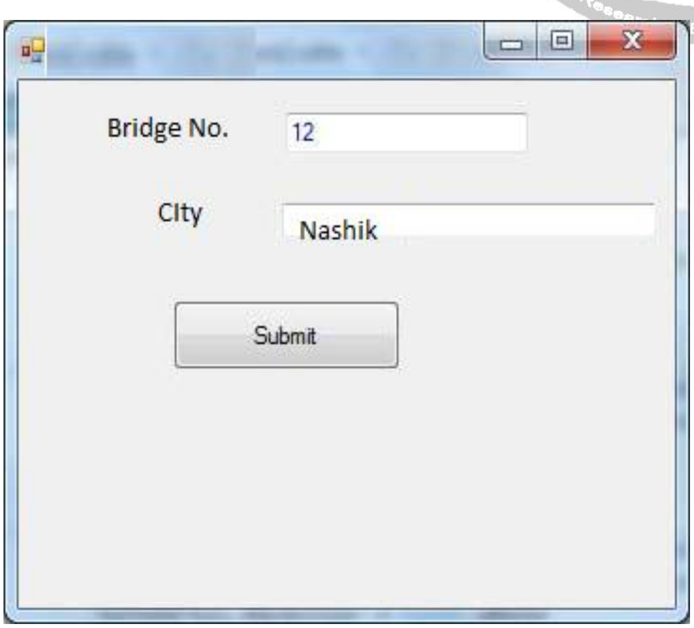

Fig. 8 Login page for a particular Bridge

Fig. 9. Information of a particular Bridge

V. Conclusion

The system is developed to process the status of a given bridge and alert the concerned operator/s regarding any abnormality. Furthermore, an interactive system is used to show the status of each bridge along with its exact location. A prototype was built to validate the proposed system. Operators can access the bridge real-time data through mobile phone. The system should cost effective and user friendly.

ACKNOWLEDGMENT

The work procedure in this paper would not have been completed without the encouragement and support of many people who gave their precious time and encouragement throughout this period. First & foremost I would like to express my deepest gratitude to my guide Prof. Y. R. Risodkar for his invaluable support, guidance, motivation & encouragement throughout the period this work was carried out. His readiness for consultation at all times, his concern & assistance even with partial things has been extremely helpful. It was a great pleasure to work under his guidance. I am very much thankful to Prof. P. A. Dhulekar (M. E. Co-coordinator) for giving me many useful inputs & guidance for improving work throughout the period. His suggestions with practical things have been extremely helpful. We are also grateful to Dr. G. M. Phade (Head of Department - E& TC) for her continuous motivation, support in all aspects and comments to improve my project. I'm most grateful to our honorable Principal Dr. S. T. Gandhe for giving me important comments to improve my project. I sincerely thank to the entire team of staff members, our college, our family, and those who knowingly & unknowingly have contributed in their own way in completion of this project.

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