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A Study on the Applications of Structural Health Monitoring by Employing Wireless Sensor Networks in Bridge

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Abstract: ***The main idea of this research is to highlight the current technologies and developments in the domain of structural health surveillance (SHM) in applying wireless sensor networks (WSN) in civilian infrastructure bridges. The requirement for SHM has become important for the fields of Wireless engineering. The large sensor networks technology is emerging as the detection paradigms that the field of structural engineering has begun to consider as substitutes for conventional tethered monitoring systems, Capable of significantly improving the flexibility and versatility of SHM -WSN deploy as an essential tool for practical bridge applications and building advantages. The wireless structural health monitoring systems are easy to install, processing edge data and low cost detection. Hence, there is a tendency to apply WSN technology to replace traditional wired control systems. Although-have-been successful applications submitted SHM. In some large civil structures using the WSN technology in the laboratory and in the field; it is still too limited to be used for practical applications in structures. Consequently, Large-scale WSN applications running in the structures civilians remain a priority to be examined by the laboratory evaluation to eventually obtain the desired goal for SHM.***

Keywords: Wireless Sensor Networks, Structure Health Monitory (SHM); Cable-Stayed Bridge

1. Introduction

The desire to maintain control structures and framing conditions is a major challenge for engineers and researchers in the civil engineering sector. Structures such as bridges and buildings should be evaluated periodically for the maintenance of saving lives. Therefore, the economic benefits are obtained. To date, several methods have been proposed and SHM (Structure Health Monitory) systems, and some of them have been used to large-scale bridge structures; According to the research, the Bill Emerson Memorial Bridge in Missouri Are examples where the SHM has been applied. However, the cost of obtaining useful information for large SHM structures is higher.

Moreover, to having increased the safety and reliability of public works. It has access to identify mechanical, civil and SHM references. Thereby, SHM was considered a meaningful evaluation, with a number of buttons that can be applied in control applications, including ways to detect damage with appropriate algorithms, control system cables and recent wireless surveillance systems. Recently, the need for SHM has been increased in the field of civilian structures, its increasingly subjected to a load during its life, so the concern for public safety and maintenance of the main structures, but very high buildings and bridges have been expressed. Instead, with the integration of new technologies such as ABAQUS, software has the ability to simulate and model structures using a large FEA function. The integration of WSN with FEA software means it is playing an important role in the development of current WSN and SHM and [1].
According to the research, many researchers have used WSN to monitor bridge structures among them (Kim et al.2007; jang et al.2009,).

1.1 Descriptions for Cable Stayed

Cable-stayed Bridges may look similar to suspicion bridges, both have roadways that hang from cables. The structure is similar to an Elastic Beam supported by cables connected a tower or many towers. The Cable-Stayed Bridges system is one of the most modern systems. Below are figures (1) and (2) illustrating the two (2) examples of bridges with cables.

The Cable Stayed Bridges Structural system depends on three (3) main Structural sub-systems: cable, pylons and Rigidity of girder. The interrelation of these components makes the structural behavior of the suspended efficient and pleasing aesthetic solution for bridges for large span structures [2].

Figure 1: The largest cable stayed in Europe

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Figure 2: Rio Antirio bridge

1.2 A Cable arrangement

The Cable arrangement is an important subject regarding to the bridges cables. Its actions do not only depend on the structural performance of the bridge, but also the economics. The longitudinal dispositions are classified as follows:

Fan type: It is a modification of the harp system. The cables are connected at the same distance from the top of the tower. The fan system is attractive for a bridge where the longitudinal layout is a single-plane, because the cable slope is steeper, it needs and consequently the axial force in the girder is smaller. Illustration on figure (3).

Radial type: With the radial configuration, all cables are connected to the top of the tower. It is a convenient configuration cable because all cables have their maximum inclination; therefore, the amount of material required in the beam is reduced. This configuration may cause congestion and detail can be complex

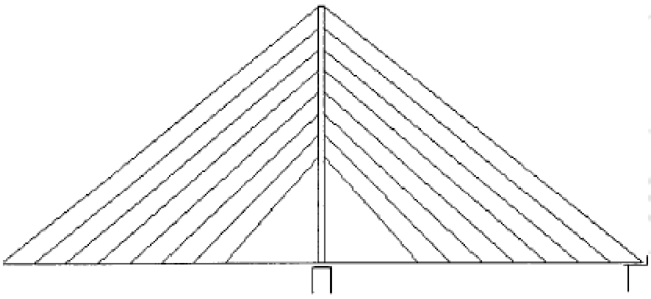

Figure 3: Fan system

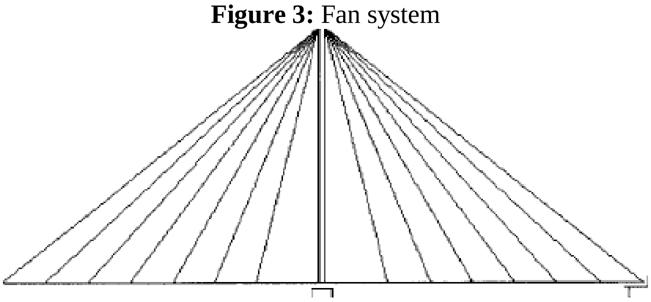

Figure 4: radial type

Harp type: cables are mutually parallel and are connected to the tower at different heights. The aesthetics of this type of configuration is good. However, in the beam compression it is superior to other models, and the tower is subjected to bending moments. The figure below gives an illustration [3].

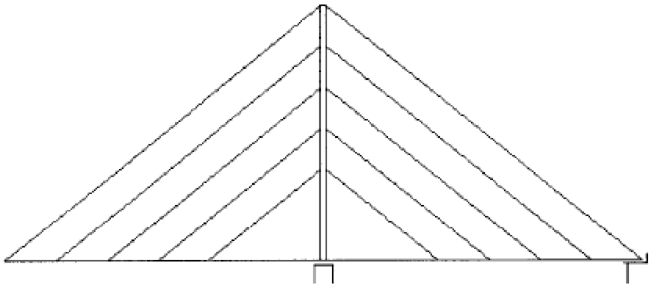

Figure 5: harp type

Transverse arrangement: The classification for the transverse arrangement is performed according to the positioning of the wires in different planes. Two basic classifications follow:

Single-plane type; this type is composed of a single cable arrangement along the longitudinal axis of the superstructure. This type of provision is governed by the torsional behavior. The forces are created by an unbalanced load on the bridge. The main beam must have sufficient torsional stiffness to resist the torque.

Two-plane type: If the tower is in the form of H-Tower, the arrangement is a two-storey plan vertical. If only a tower is provided in the middle Superstructure, then the design is a system of two inclined planes [4].

1.3 Pylons

The shape of the pylon is chosen primarily for aesthetic reasons and further refined based on proportions, materials and restrictions associated with the pylon design. There is a considerable variety of forms of tower. In general, the shape of the pylon is governed by the desired height and the environmental load conditions such as seismic zones and wind criteria. They may be made of steel or concrete or prestressed. Real pylons they are most common of steel pylons as they allow a greater Modeling, and are cheaper. pylons are classified according to the basic shapes shown in figure 6 below [5].

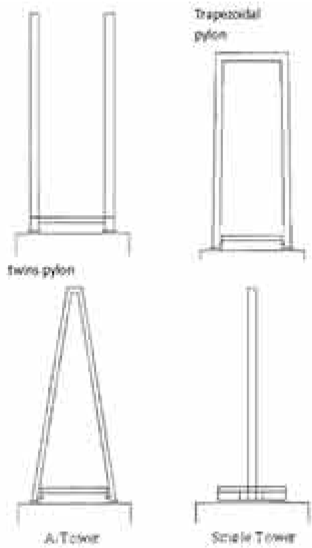

Figure 6: Pylons

1.4 Deck Types

The most common type of these bridges is orthotropic cover plate, consisting of longitudinal ribs resting on transverse beams. Deck systems are chosen according to the distribution cable, the span Sizes, material used and the special requirements of the bridge.

The most commonly used deck system is the lid of the box section which provides comfortable anchors, and has a couple of significant features. It is common to use diagonals and type of diaphragms frame to increase the rigidity of the box section. When selecting a deck, it is necessary to note the maintenance and deviation limits5.

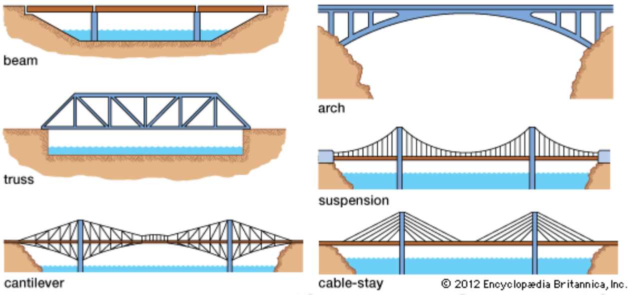

Figure 7: deck types

2. Literature Review

(a) A-A Structural Health Monitoring (SHM) Based on wireless sensor networks (WSN)

With the development of new technology in the twenty-first century, WSN are the most important technologies in the SMH structures like bridges are a challenge for engineers and researchers. Some years ago, the Department of Transportation of the United States announced that over 25% of bridges are functionally obsolete or fatigued. Therefore, the use of SHM in mechanical engineering, such as civil engineering, for example. For structures such as bridges, WSN are much more widely used. The discovery of the damage using WSN has a great enthusiasm for the challenge of data structure damage. In addition, the Alamosa Canyon Bridge in southern New Mexico was designated as a successful bridge WSN application of evidence. Many modal tests were performed in this facility to detect damage, says Lynch [6].

(b) The development of Wireless Sensor Network

Developments in wireless sensor networks have shown their ability to provide structural response data to assess the structural health, several issues, including stability of the network, reliability of the damage detection and power. Figure8

Figure 8: Wireless sensor unit

Wireless sensor network has the advantages of reducing the cost of implementation of structural health monitoring (SHN).

Strasser and Kiremidjian have proposed a wireless sensor device designed for applying in monitoring system called: wireless modular monitoring system, application use for civil structures (WiMMs). The purpose of this system was to reduce the cost of installation in civil structures on a large-scale. Otherwise, their studies has shown the liberty offered by wireless infrastructure system. Their work is seen as the biggest first step success in the field of structural engineering to the treatment of distributed data processing and WSN.Many researchers have explored the validation of wireless sensor network and application performance in real bridges. Kothapalli et al (2003) have proposed network architecture for wireless sensors at two levels involves the design of wireless sensing units and faculty of local sites. Sensing unit's role is simply collecting measurement data and transmits the data wirelessly to master the designated site. [7]

Basheer et al (2003) have suggested the design of a hardware whose design has been optimized to process data in collaboration such as damage detection between wireless sensors wireless sensors. The proposed wireless sensors are the building blocks of a network of self-organizing sensors called redundant network connection (RLN). Wang et al. They have proposed WSN design in order to account for and read the displacement and stress of thin film (PVDF). IEEE802.15.4 WSN was developed for SHM. This was a new wireless communication of standard. A constrained WSN energy power was designed and it was possible due to its peculiarity, such as extreme power expertise [8].

Allen [20] and Farrar [21] presented a new and different design strategy for WSN. The proposal focused on providing damage calculation panel algorithms of the SHM power wireless detection system. This has been an important development of WSN technology. Lynch et al. (2004) have extended their work to couple the computing power in the form of low-cost microcontrollers with wireless sensor nodes. The purpose intended to integrate the computing power directly with the sensors permeates the execution of localized analysis of embedded sensors engineering [9]

Heo et al. [8] have made a system of wireless MEMS accelerometer, which include a modular sensor, processing module and control, a wireless modem module, the adxl210 designed by analog devices is chosen to measure the acceleration that could be used directly with the microcontroller without A/D converters. That system called SWMAS.Figure (9)

Figure 9: Prototype of SWMAS

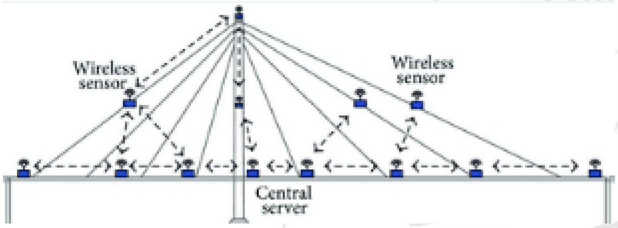

Figure 10: WSNs based bridge health monitoring system

3. Damage Detection

The maximum of the wireless sensors use of technology develops an amazing opening for the development of a low cost system for structural monitoring such as bridges, using wireless sensor networks, a large number of sensors can be used to detect damage. Researchers and engineers to study the parameters for the bridge monitoring have done many studies, but few have been used in the scenery of the real world.

The most important aspects of structural health monitoring is the ability to identify damage in structure and this ability detect damage could prevent failure or give insight into witch part of brig structure needs maintenance.Kirmser [1] and Thomson [2] were the first to attempt to quantify the vibrational response of a structure in the presence of a discontinuity due to a small groove.But the first attempts to analyze and calculate the local flexibility of a cracked region of a structural element are due to Irwin, Bueckner and Westmann [3], who have linked local flexibility to stress intensity factors .

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