

VIBRATION MEASUREMENT OF SCALED BRIDGE STRUCTURE IN LABORATORY THROUGH INTERNET OF THINGS

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ABSTRACT-Bridges are lifeline structure and must remain functional even after disasters. Henceforth its health monitoring and real time data is vital. Recent development of Internet of things (IOT) based SHM of structures have attracted many researchers to work in this direction. This paper is focused on attempting to get the real time data of ambient vibration of scaled model bridge structure connected through various sensors and circuits through IOT. IOT works in three steps, in first step data is collected from object or device, in second, data is sent to the cloud and in third step the software process the data and send it to user. The information sent to end-user via an alert to the user. This has advantage of securing serviceability and safety of bridge at the any desired place away from the bridge site itself. For this, the bridge at 150 ft. Kalawad road, Rajkot named as Chimanlal Sukla Bridge with 4 lane 1.3 km long with multiple spans of 25m prestressed concrete Box and I girder resting on 24 pillars is modeled with 1:100 horizontal and 1:10 vertical scale in laboratory. The model was fixed with sensors and IOT assembly at critical locations, found out by FEM based software. The bridge is given vibrations of varying frequency till its resonance. Further, the alarm is set to buzz at this resonant frequency which enables authority to take remedial actions like stopping traffic and advocating detailed physical inspection.

Keywords: Internet of things (IOT), SHM, Bridge, Sensor, Real-Time data, Vibration.

I. Introduction

A. Internet of Things (IOT):

Firstly, IOT phrase was coined by Kevin Ashton in 1999, dealing with the system associating objects in the physical trend to the Internet. Internet of things is an idea from computer science: interfacing conventional things to a computer network to prepare them "intelligent". IoT improve tracking of objects using sensors, which helps to get real-time insights. An embedded system or a computer connects each thing together in a network and to the internet. IOT permits individuals and things to be associated at any place and anywhere.

B. Structural Health Monitoring (SHM):

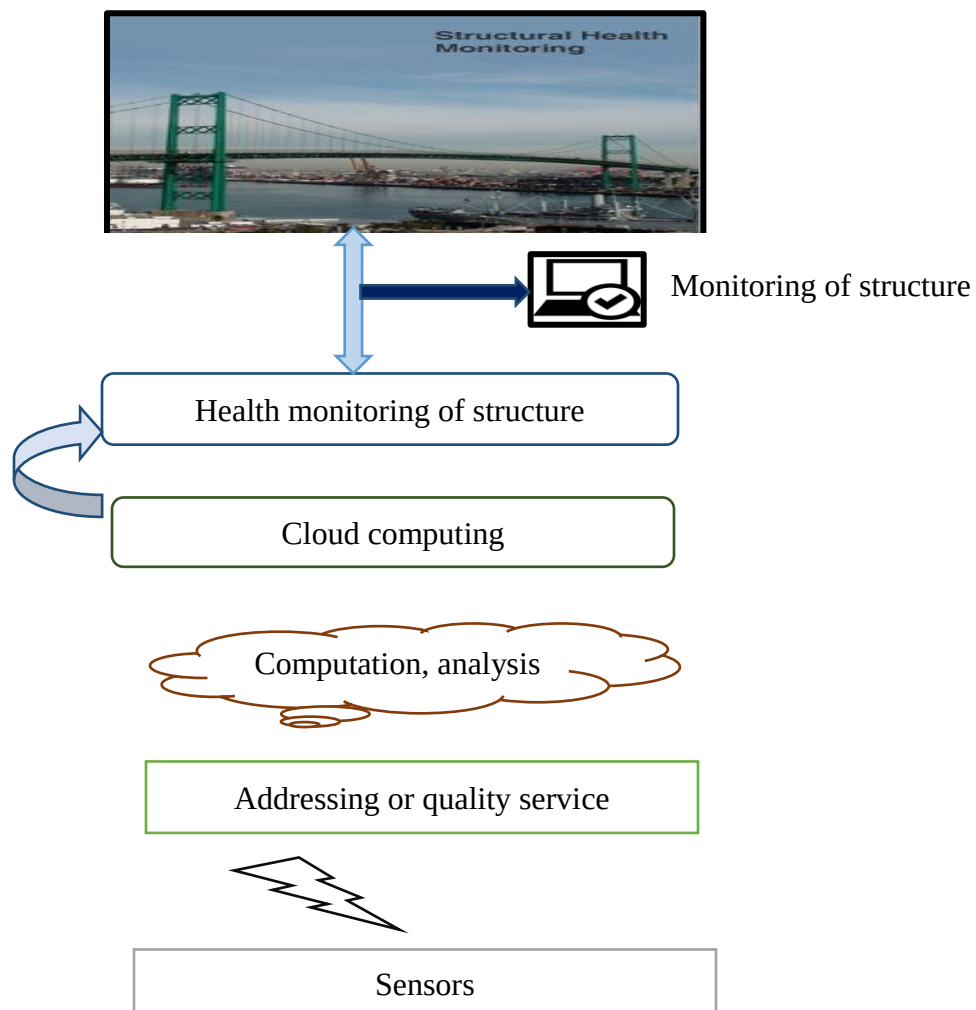
SHM is a system of monitoring distress through damage detection techniques as well as the condition of engineering structures from serviceability point of view. In this, we can define change in material properties, structural system and changes in boundary condition. SHM gives real-time information concerning the condition of structural health. It's a procedure of assessments to detect area and measure of damage, remaining life, and upcoming accidents will be predicted. Integrated system of Internet of Things with Structural Health Monitoring:

The IOT integrated with SHM will empower the authority to get the real time data. Structural health monitoring is more convenient at workplace rather in situ. For measuring vibration accelerometer or strain gauge sensor can be used. To screen a bridge progressively, it need to be checked for different quantities of parameters like vibration, redirection, and so forth. Whole system working on components like sensors, cloud, transmitter, receiver etc.

Ahmed Abdelgawad, K. Y. (2016) realize that IOT helps user to guide the real time data through following steps: in first step data collected from object or device, then data deliver to the cloud, as the data are uploaded to cloud, software starts its work. And the data is sent to the all users in a particular way. This could be via an alert to user. The damage location deliver to the Raspberry Pi using transceiver. The Raspberry Pi send information to the cloud utilizing a Wi-Fi. The put away information in the cloud and it tends to be checked from mobile phones or PC. Components of this system is Wi-Fi module and Raspberry Pi. **Ahmed Abdelgawad, K. Y. (2017)** again did research on diverse theories and implemented to meet requirements of structures mix of the assorted speculations has caused not exclusively to improve productivity and execution of SHM frameworks yet additionally to decrease the computational time. An entire SHM stage installed with IOT is proposed to determine size and area of harm in structures. Raspberry Pi was used for damage sensing from that detail send to Internet server. The data was stored on Internet server and monitored from mobile or any devices. **Alejandro Moreno-Gomez, C.-R.-G. M.-R.-A.-S. (2017)** derived Extensive variety of sensors to gauge natural properties of structure in three classes

like, kinematical (removals, speed, and increasing speed), mechanical (force, deformation, stress), and ambient (wind and temperature). Fiber-optic and piezo ceramic sensors can use as parts of the structure in arrange to develop self-sensing materials. **Andrea Zanella, L. V. (2014)** did comprehensive survey in urban IOT. Objects of day to day life will be connected with sensors for that will make them capable to interact with each other and with clients, that will be a piece of the Internet. They are basically focus on the Waste Management, traffic Congestion, quality of air, energy consumed by people or per house, smart parking and lighting etc. so they are using vibration and deformation sensor, temperature and humidity sensor and atmospheric sensor. **Arcadius C. Jr. Tokognon, B. G. (2017)** selected safe and reliable sensors. Short or long coverage (Zig Bee, Wi-Fi, or LPWAN technologies). **Dhivya, H. (2013)** Observes harm in any civil structures incorporates, consumption and break, vibration and strain estimation. Vibration examination is crucial rule of basic wellbeing checking framework is. A break in the solid structures characterized by novel detecting idea which utilizes the fiber optic sensor. To screen a working progressively, it need to be checked for various parameters like vibration, temperature, stack and so on. **George Lu, Y. Y. (2017)** shows that SHM has been done for most part of physically and intermittently. The interim between assessments fluctuates, contingent upon the working associations' practice. Modern SHM systems take favor of the low- power processors, sensors, and data storage for automatic inspection. **Liang, D.-L. Y.-D. (2010)** gave overall review of the internet of things and how IoT working and what are the devices which is connected in IoT. It is believed that in the near future the achievement of the vision of "from anytime, anyplace connectivity for anybody, we'll presently have network for anything. **Meonghun Lee, H. K. (2016)** gave idea about the monitoring system proposed a three-dimensional behavior analysis of bridge utilizing multiple GPS sensors and facilitates bridge safety management by transmitting horizontal & vertical strain data and warning signals in genuine time. Sensors such as optical fiber sensors, strain gauges, and inclinometers to increase its reliability. **Sreevallabhan, K. (2017)** measured Ambient vibrations by accelerometer and solid movement of structures utilizing Remote Sensor hence able to degree the data at any location. Wireless sensor network is configured into two major components transmitter and sensors are used.

C. Flowchart of whole system



I. Materials or equipment require during process

A. Sensors:

Different type of sensors are used for measurement of different properties of structure. Below table gives idea about the different properties and different type of sensor used.

Properties	Measurement	Sensors
Mechanical	Strain, displacement, rotation, distortion, curvature, forces	Strain gauge sensor, piezoelectric sensor
optical	Light, photon	Fiber optical sensor
Environmental effects	Temperature, Humidity, wind, velocity	Accelerometer, Temperature sensor, seismometer
Loads	Cable load	Load cell

B. Arduino:

Table 1. Different type of sensors and their uses

- The open-

source **Arduino** Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux.

This software can be used with any **Arduino** board.

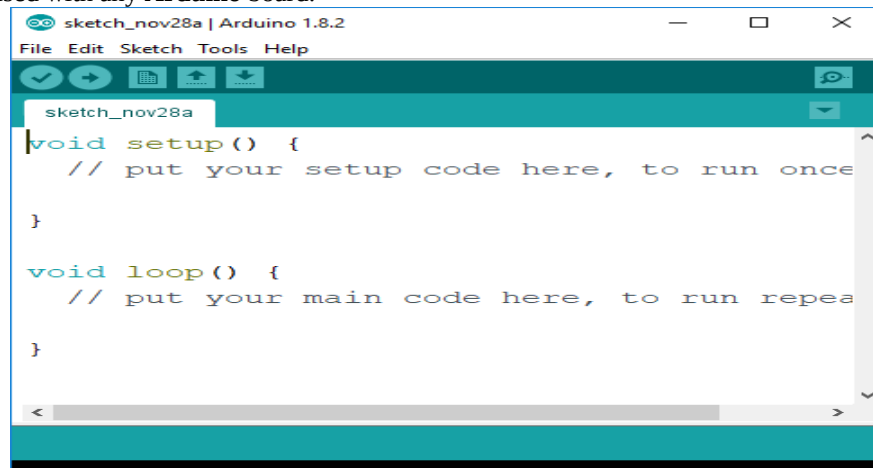


Figure 1 Screen of Arduino 1.8.2

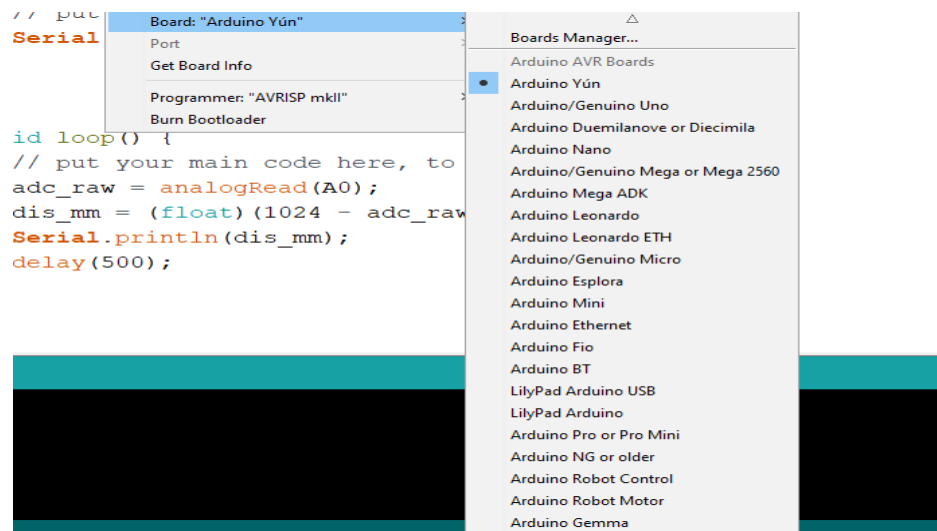


Figure 2 Different types of Arduino we can select from tools (path...tools – Board: Arduino yun – different types of arduino shown as screen)

II. Strain gauge sensor and its validation



Figure 3 a) Cracked specimen with strain gauge sensor b) TMR 7200 which shows strain gauge sensor data with data logger

Strain gauge sensor applied as shown above. With help of three point bending test cube is tested. To see the reaction of sensor whole assembly connect with laptop, so we can measure data. From the above practical we get graph time vs. strain.

III. Results of strain gauge

Strain vs. time graph shows how strain increasing continuously with load and this data further connected with other mechanism so get message at any location. This graph shows that how strain gauge working and how data collected. When load incising on specimen it shows graph as shown above and at one point it breaks and shows maximum value.

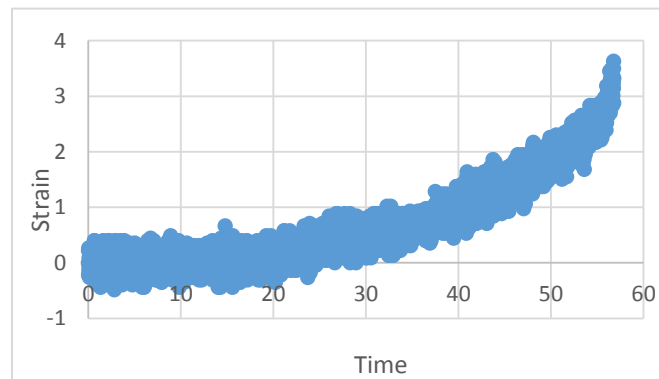


Figure 4 Time Vs. strain graph

IV. Bridge Structure critical locations

In bridge structure to find critical locations Finite element software using SAP2000. For this, the bridge at 150 ft. Kalawad road, Rajkot named as Chimanlal Sukla Bridge selected.



Figure 5 Flyover of 150ft. Ring road crossing kalawad road and university road Rajkot

V. Designing Bridge in SAP 2000

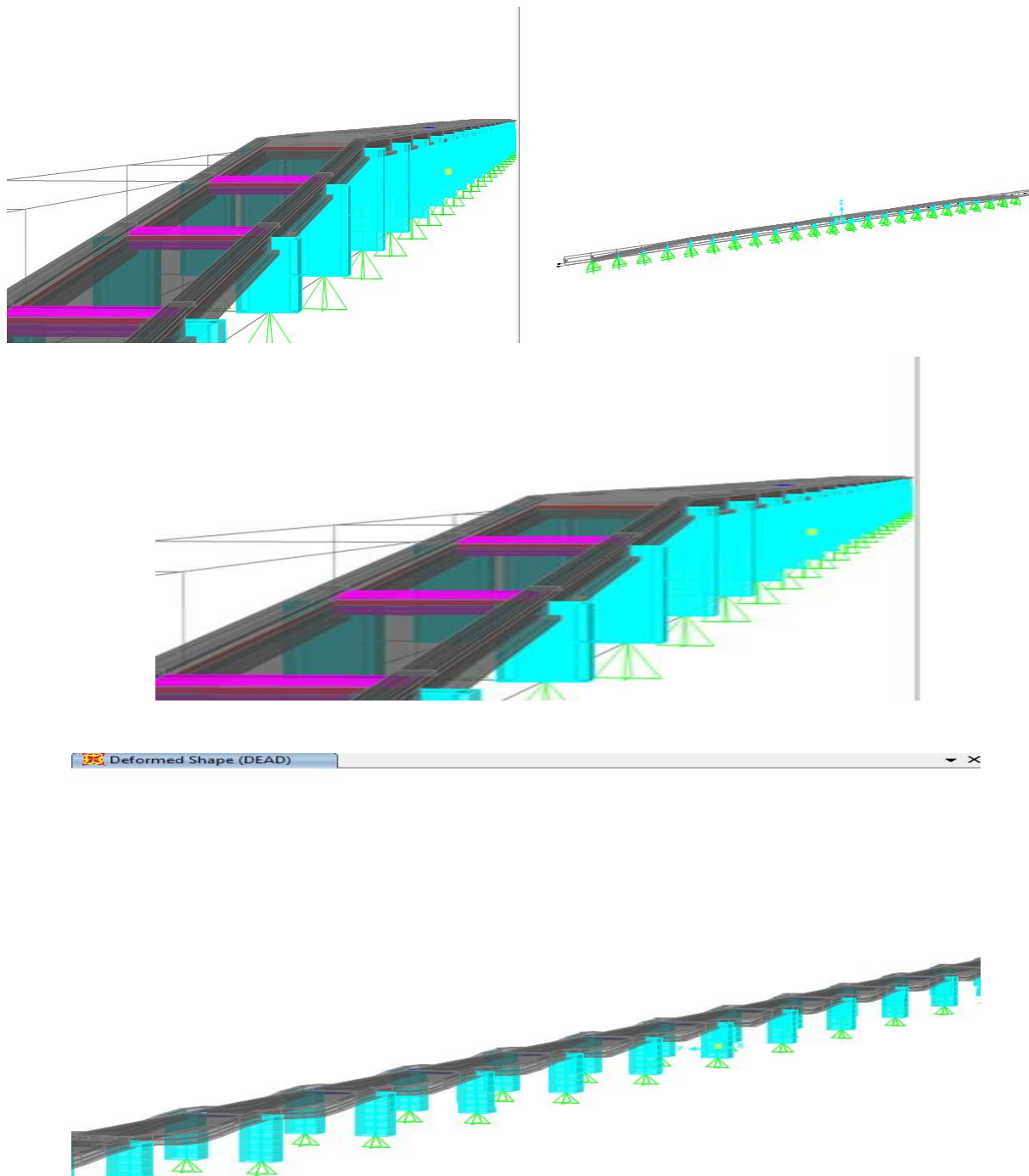


Figure 6 Bridge design in SAP2000

After analyze it critical points at different locations defined. Locations will be selected for sensor. After getting the critical locations further process will continue for experiments.

VI. Experimental model of bridge

To make model of this bridge structure scaling down actual structure. From the scaling data bridge model prepared. At defined critical locations sensor (accelerometer mpu-6050) applied, then sensor is connected to microcontroller unit Arduino UNO and it will directly connected with Wi-Fi.



Figure 7 bridge scaled model

Analysis of bridge model with free vibration by using accelerometer mpu6050 and Arduino UNO from that getting graph which shows, vibration in normal condition and if vibration will high due to any hazard it shows that vibration is increased and we need to prevent our structure.



Figure 8 Setup for analysis

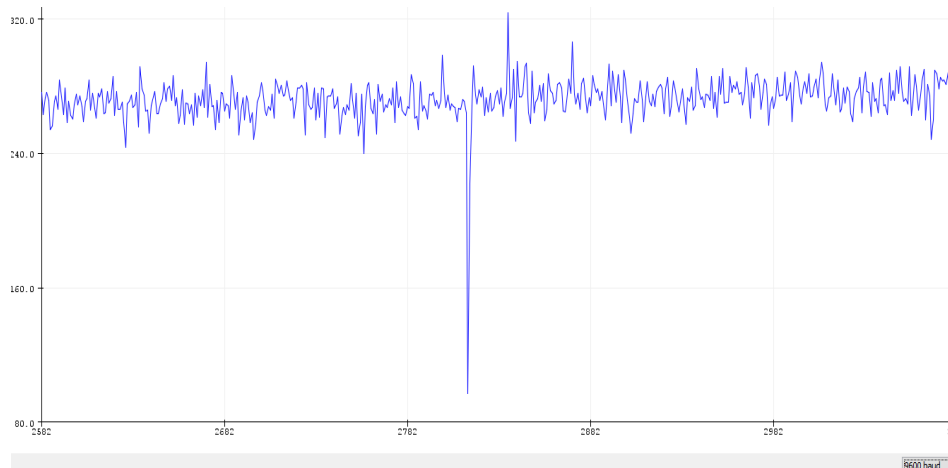


Figure 9 Time V/S displacement graph generated in Arduino

VII. Result - FFT Analysis

To convert time function into a frequency function fast furior transform analysis is used. From this graph of time vs. displacement is plotted from collected result from Arduino.

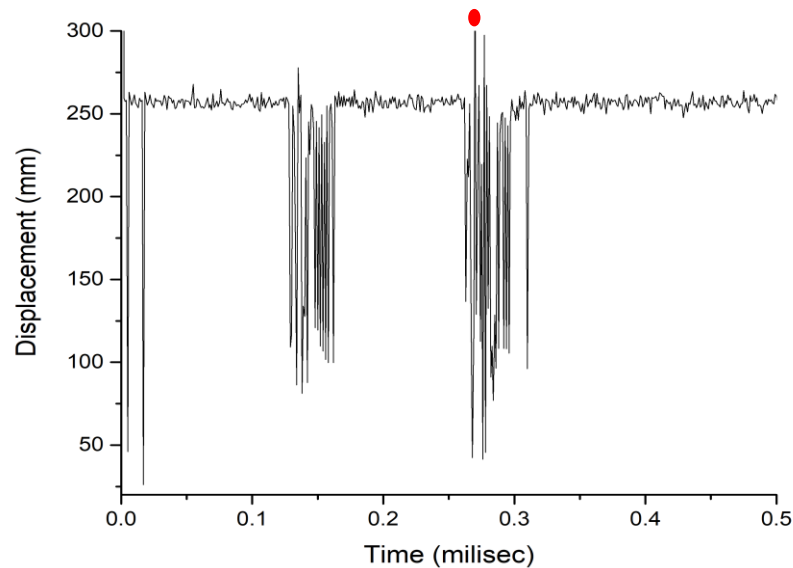


Figure 10 Time V/S Displacement graph

X= 132.54

Safe

X= 226.68

Safe

X= 49.81

Safe

X= 326.70

Not Safe

X= 57.72

Safe

Figure 11 Message shown structure is safe or not

VIII. Discussion

When structural model getting more vibration which exceed limit then it shows message that structure is safe or not. If structure is not safe at that time it will give message and with the help of it we can prevent our structure before its fail. When frequencies vary more than the actual frequency it shows that structure need to inspect and protect before its collapse.

IX. Conclusion

From this study IOT system apply on any structure. With help of this mechanism structural health monitoring can be done. At any location get information like damage and there is no necessity to check it at site. For proceed further with this bridge structure, sensor will apply and find some other factors with help of IOT which is affected more when it's going to damage. Next step of this paper will focus on remaining challenges and the development of an SHM application based on IOT by implementing sensors on bridge structure.

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