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Structural Health Monitoring
Case Study Review

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ABSTRACT

Today the development of a country is decided on the basis of its infrastructure, therefore a major part of country's revenue is invested in this sector as our lives rely on them. For the proper management of infrastructure, their condition and serviceability should be regularly monitored. Structural health monitoring is a technique used to determine strain, stress, displacement etc, at critical members and some of the dynamic parameters like natural frequency, damping and modal shapes with their time variations. It detects the damage to increase the performance or life of a structure. The objective of this paper is to give a review on case studies of Structural health monitoring in different countries all over the world and the reason this techniques shall be used in our country.

Keywords: structural health monitoring, damping, modal shapes

INTRODUCTION

Until and unless something huge happens in our country it doesn't concern us or draws our attention towards it. The Nepal earthquake shook everyone around the world no matter they are developed or developing nations. Structures have a certain age and after that their strength starts dwindling, but everyone is so busy with the new that they abandons the old.

The countries around the world are using different methods of seismic designing such as base isolation, damping, active vibration control techniques etc. India is also evolving and adopting these new techniques. But the main question arises that after applying these methods or techniques, is the structure performing as per designed. For this monitoring of structures is needed. The future can never be predictable in case of disasters and we must be ready for any situation. People are still living in prehistoric houses and buildings which are more dangerous than modern structures when they come under the influence of seismic activities. These structures need inspection, investigation, proper monitoring for the detection of damages, drawbacks or any kind of issues so that they can be repaired, refitted and restored.

Structure health monitoring is a technique which provides information on the current status of building by measuring structural vibration response and detecting the damages in different sections of structure.

REVIEW OF CASE STUDIES

RUSSIA-monitoring of vintage bridge - The bridge was constructed in 1936-37 over Moskova river in Moscow next to Kremlin. It is a Reinforced Concrete arched box girder bridge. It was declared a heritage building as it is more than 70 years old. Total length of bridge is 250m with 3 spans (43+92+43), 3 parallel arches. The SHM was started in 2003. Types of sensors used were 16 standard SOFO sensors in central arch plus 6 thermo couples. Numbers of sensors used were 22. Instrumentation was designed by SMARTEC SA, Switzerland and ZAO Triada holdings, Russia.

Purpose- To continuously monitor temperature and average strain along horizontal and vertical directions.

Results- Settlement of an abutment producing cracking of the stone lining and structural element. Another was chloride penetration into the structure leading to reinforcement corrosion.

DUBAI- monitoring of world's tallest building BURJ KHALIFA TOWER

It is 828m tall with more than 160 stories.

Construction period - 2004-2010

Temporary real time monitoring - After earthquake in Iran on 9th sept,2008. Permanent full scale real time monitoring - After earthquake in Iran on 20th July, 2010.

There are many sensors installed at different stories with their own significance such as:-

- 3 pairs of accelerometers at foundation to record base acceleration,
- 6 pairs of accelerometers at level 73, 123, 155 on the top of concrete and 10M3, Tier 23A on the top of pinnacle to record the tower acceleration simultaneously at all levels,

- There is a GPS system installed at level 160 M3 to capture the building displacement,
- 23 sonimeters at all terrace and setback levels to measure wind speed and directions,
- A weather station at level 160M3 to measure wind speed and direction, relative humidity and temperature,
- There are sensors to capture building frequencies, damping ratio at low amplitude due to both wind and seismic events,
- Time history are also recorded at the base of the tower due to seismic events.

CHINA- MONITORING OF TALL TOWER

SHANGHAI TOWER (632m) :- The construction period was from 2008 to 2015 and the monitoring was done in 2011 to 2012. There are 400 sensors of 11 types at 11 substations in 9 different zones that are 1m, 33.45m, 49m, 173.7m, 239.4m, 314.1m, 393.3m, 465.4m and 542m. Strain sensors were installed inside the RC shear walls of inner tube and on embedded steel columns.

RESULTS

- Vertical deformation at representative location on external frame and core tube.
- Stress at fifth floor of a super column with and without temperature compensation.

SINGAPORE REPUBLIC PLAZA

It was completed in 1995 and the dynamic response monitoring was done from 1996 to 2005. It is a 280 m office tower with 65 storey in Singapore. Stress call and SGs were installed in a concrete shear core and in the concrete within the steel columns.

- SGs were installed on the main beams of the horizontal framing system of two floors and on the steel tubes of the external ring of vertical load bearing columns.
- SGs were read manually at intervals during the construction and brief period following completion.

RESULTS

- Fundamental translational frequencies were tracked by free vibration measurements during the latter part of the construction and beyond.
- Revealed distribution of structural dead load and how the load distribution changed over time.

JAPAN - MONITORING OF SUSPENSION BRIDGE

Hakucho bridge which is situated in Muroran, Hokkaido, Japan was opened on April 17, 1998. The main span of the bridge is 720m installed with sensors placed at locations z1 to z19.

Objective:- To determine the relationship between the aerodynamics and the bearing friction forces.

JAPAN - MONITORING OF TALL BUILDING ON RECLAIMED LAND

It is a 147m 33floors tall building in Toyosu, Tokyo, Japan. Toyosu area is a land reclaimed from sea. Long gage length fiber optic sensor system (SOFO) was adopted. The construction period was 2004-2006 and the monitoring started from May 2005 to October 2010. SOFO sensors were installed on the second floor which had 33 steel columns. From that 5 columns were inspected and each columns was monitored by 1 sensor at centre. Length of sensor was 1 m. Axial load was the dominant load.

PURPOSE:**-** Evaluate the post earthquake, strong wind and ground sinking.

INDIA-MONITORING OF HERITAGE TEMPLE

Bhand Deval Temple in Arang tahsil Raipur district, Chhattisgarh. It is a heritage temple which was built in 9th century AD under the ruler of Haihaya dynasty. The monitoring technique adopted is Rapid visual screening in which damageability grading system is used.

PURPOSE

- Identity the primary structural lateral load resisting system.
- Identity building attribute that modify the seismic performance expected for this lateral load resisting system along with non structural component.

RESULTS

- Ensure adequate maintenance at regular interval throughout the year various NDT techniques.
- Retrofitting should be done for severe vertical irregularities observed in the structure.

INDIA- SHM OF NAINI BRIDGE (2001-2004)

CHALLENGE- Building a high channel count SHM system to continuously scan the response of a large cable stayed bridge due to various changes in climate and operations.

SOLUTIONS- To design and implement a distributed data acquisition network to continuously acquire and process more than 400 parameters using NI Field Point hardware and the NI LabVIEW Real Time Module.

RESULT- The data acquisition system based on NI hardware and LabVIEW and DIAdem software, they were able to economically deploy on advanced and scalable structural health monitoring system that can be remotely operated and managed. The system can process and communicate critical events and alarms in real time and some as a valuable tool for maintenance.

DISCUSSION

- These case studies around the world had shown some strong reasons that SHM should be an essential part of a structure.
- India is a developing nation and it is very important for the country to be enlightened and well informed about its infrastructure.
- Earthquakes are uncertain so structures which comes under high seismic zones shall be monitored to avoid the irreversible losses.
- India is adopting certain SHM techniques but they are very basic and their results are not very effective and can be better with new technologies like sensors based SHM, Wireless SHM, SHM software which are already being used in the above case studies.
- SHM techniques differs for different infrastructure as the soil and environment conditions are not same for two structures.
- Economically SHM is not that expensive, it is 2% to 5% for monitoring structure over 10 years.
- Universities in India are working on machines which can predetermine the possibilities of earthquake which definitely is a very important topic but rather than waiting for future, organizations shall work on taking measures to conserve the structures.
- On 6th February, 2017 an earthquake of magnitude 5.8 hit the northern Himalayas, Uttarakhand to be exact and fortunately no causalities were there but a low intensity earthquake can't be taken lightly. It can create minor cracks inside the structural members which are not visible at the instant. These minor cracks grow with time and as Uttarakhand lies under seismic zone 5, on the next seismic activity consequences will be much severe.
- Therefore Structural Health Monitoring has become a vital need of a structure so that the damages can be detected and later be retrofitted.
- Retrofitting is a technique by which resistance can be provided to the structures against the seismic actions for which they were not originally designed.
- India shall have an **Indian Standard Code** on Structural Health Monitoring and it has to be mandatory for all the upcoming and previous structures.

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