Chapter 1

Introduction

1.1 General

In civil engineering field, all design codes enforce the use of safety factors and various analysis and design procedures to make sure that the structure is safe and serve satisfactorily during its design period but the built structures may experience extreme loading conditions, like earthquakes, strong winds etc during its design period. The structure may be able to withstand them, suffering minor damages or, in the worst case, collapse but even if a structure manages to withstand the loading it becomes crucial to examine its strength and load carrying capabilities to make sure no substantial damages have occurred. On the other hand, even if a structure is not exposed to extreme loads, it can weaken over the years due to deterioration, which if left unnoticed can grow into a major problem.

Civil infrastructure provides the means for a society to function and includes buildings, pedestrian and vehicular bridges, tunnels, factories, conventional and nuclear power plants, heritage structures, port facilities and geotechnical structures, such as foundations and excavations. Depending on the significance of structure, such structures have inspection, monitoring and maintenance programmes. The effectiveness of maintenance and inspection programmes is only as good when it has ability to reveal any deterioration to structure by continuous, online, real-time and automated systems. SHM has been used in some areas like oil industry, large dams etc where it has achieved great attention and research for installation.. Residential and commercial structures have received relatively little attention due to potential obligations and consequences of owners knowing about poor structural health.

The sustainability of civil infrastructures can be achieved by periodic and continuous assessment that necessitates easy and effective Structural Health Monitoring (SHM) tools and techniques. The conventional SHM procedures were laborious, time consuming and capital intensive specially in the case of large span bridges, heritage structures, monuments and elevated buildings of national importance. Traditional methods are not effective for rapid full-field monitoring and hence a radical monitoring approach is most needed. Since the last few decades, the focus has been raised in non-destructive testing in reinforced concrete as its application doesn't affect the structure. Currently, certain amounts of large-scale infrastructures have reached their design life. For damage detection in large-scale and distributed systems, employing large number of sensors is a popular trend as the thorough information can be obtained by densely implementing sensors in the structures. Thus structures, especially important structures, need continuous monitoring and evaluation on a regular basis and for that, use of an economical, flexible and accurate sensor is required.

1.2 Different structure damages and failures

The different civil structures such as buildings, dams, bridges and sewerage tunnels consists of an assembly of various members like columns, beams, slabs etc. Detection of structural damages in such member poses a great importance on the prevention of casualties caused by unforeseen structure collapse. Structural deficiencies causing collapses may occur because of earthquakes, dead loads, live loads, floods or ageing. These factors exert external forces on structural elements causing fracture generation. Two of the most influential external effects are bending moments and shear forces that provoke bending cracks and shear cracks, respectively . In a concrete building, bending cracks signal an on-going deficiency progression within the element. Therefore, monitoring the visible crack over time enables taking precautions. However, such process cannot be applied on shear cracks since they are formed abruptly . Shear cracks are capable of causing building collapse solely although they are usually formed besides bending cracks. To prevent casualties resulting from abrupt building collapse, utilization of systems that enable forecasting bending and shear cracks are vital .

Damage is defined as a change to the material and/ or geometric properties of the structural system, including changes to the boundary conditions and system connectivity, which adversely affect the system's performance (Farrar and Warden, 20 07). In most general term, 'failure' refers to any action leading to an inability on the part of a structure or machine to function in the intended manner (Ugural and Fenster, 1995). Structural failure refers to loss of the load-carrying capacity of a component or member within a structure or of the structure as a whole beyond a threshold. The ultimate failure strength of the material, component or system is its maximum load-bearing capacity. When this limit is reached, damage in the materials occurs, and its load-bearing capacity is reduced permanently, significantly and quickly. To avoid collapse/ accident, localized damage should be detected timely for taking appropriate measure. Any civil structure may fail when a structural component deforms excessively. Some of the failure of structural component such as beam, column, etc. are discussed below

Mainly two types of failure occur in beam

I. Flexural failure
II. Shear failure

Flexural strength is the property of material which is defined as the stress just before it starts yielding in flexural test. This type of failure is generally seen in the mid span of the beam due to larger deflection of the beam at mid span. Flexural failure can be brittle flexural failure when concrete yield before rebar and ductile failure can take place when rebars yield before concrete crushing. Shear failure can take place due to insufficient of shear resistance available between the materials.

Figure 1.1 Image showing flexural failure in beam

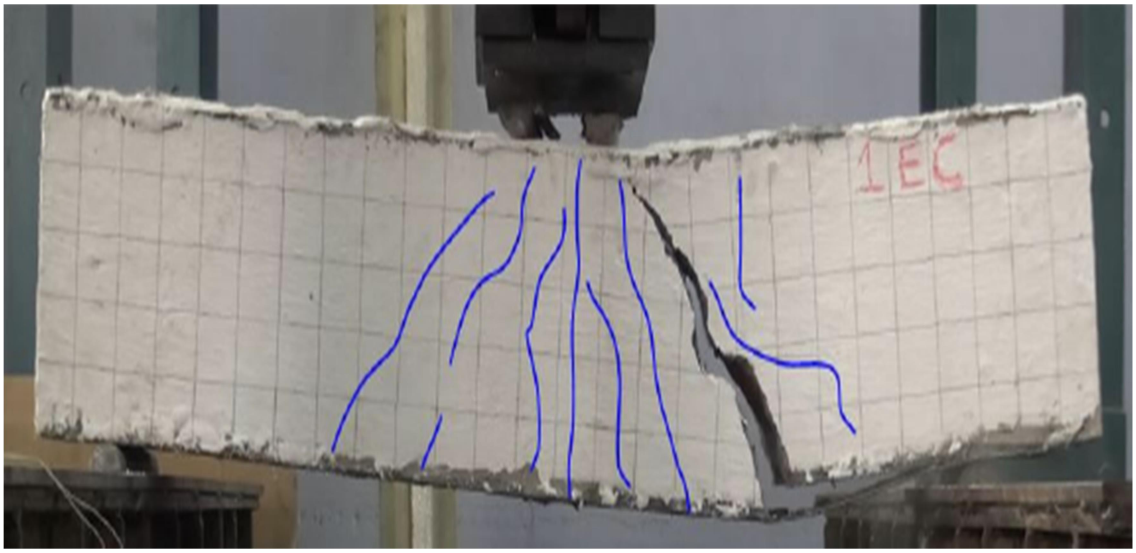

Figure 1.2 Image showing shear failure in beam

There are mainly two types of failure mechanism in column-

I. Buckling failure
II. Compression failure

Buckling failure can be seen in long column when slenderness ratio is more than 12. In such column for even small load, it becomes large enough to buckle the column in any side and more unstable structure. In compression failure, when applied load are high compared to cross sectional area of the column, the steel and concrete reach the yield stress and column is crushed without any lateral deformation.

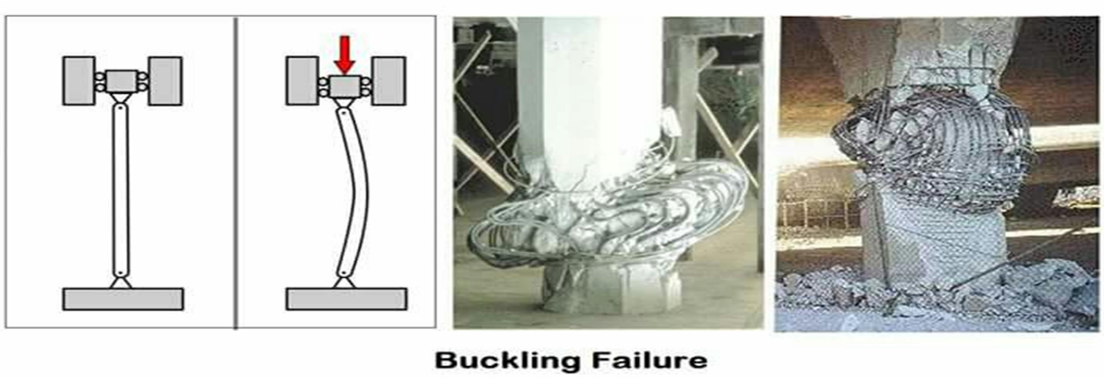

Figure 1.3 Image showing buckling failure in column

1.3 Recent structural damages and failure in India

1.3.1Kolkata-Majerhat-Bridge-collapse

A 50 year-old 66 foot deck bridge located adjacent to the Majherhat railway station in the Indian state of West Bengal collapsed on September 4, 2018 as shown in Figure no 1.4, resulting in the death of 3 people while injuring at least 25 others. Investigation committee found that the bridge lack regular monitoring, audit and maintenance.

Figure 1.4 Image showing Kolkata bridge collapse

1.3.2Bhagalpur-Flyover-collapse

A 150-year-old over bridge near the Bhagalpur railway station in the Indian state of Bihar was collapsed in December 2006 on the Howrah Jamalpur superfast express. The incident had led to the death of around 30 people. Investigation committee found that life of bridge was over and no monitoring was done about remaining strength and serviceability. It was also noted that the bridge was poorly maintained. Also as per "The Indian Express ",the Enterprises, which was awarded the contract to dismantle Ulta Pul and lay some roads near Bhagalpur railway station was responsible for it. One of the three span had been dismantled earlier, while another had collapsed on its own.

Figure 1.5 Image showing collapse of Bhagalpur flyover

1.3.3 Varanasi Bridge Collapsed

An under construction flyover bridge in Varanasi near cantonment railway station was collapsed in which 18 people were dead and several were injured. The investigating team said that the uninterrupted flow of traffic on the busy road was the main reason for vibrations that may have led to the collapse.

Figure 1.6 Image showing Varanasi flyover collapse

1.4 SHM-structural health monitoring

The process of implementing a damage detection and characterization strategy for engineering structures is called SHM.

SHM include following function:-

- ✓ Detection of Structural deficiencies using wireless sensor network.
- ✓ Send the data provided by the sensor mote to the data centre.
- ✓ Analyse the data collected and visualize the results.

SHM systems are used to monitor the physical status of critical structural elements, structure integrity and usually consist of multiple sensors placed on these locations, and microcontroller(s) responsible for environmental parameter measurement and data processing tasks. Statistical analysis of the measurement data gathered from sensors enables the assessment of current physical status of the structure. This way, structural problems can be detected earlier and thus, this provides better risk assessment. For monitoring tasks, the SHM systems may use various types of sensors depending on the parameters desired to be monitored. Moreover, the same kind of data may be measured using various types of sensors to increase reliability or availability. The performance within the target environment and the price of the sensor are the main criteria for sensor type evaluation.

Traditionally structural inspections, usually consisting of visual inspections, were carried out by trained or experienced individuals. In some special cases more advanced non-destructive methods such as eddy current, ultra sound, and other wave propagation based methods have also been used. The effectiveness of such inspections depends upon the accessibility of the structural location to be examined and to a large extent on the expertise of the individual conducting such inspections. Such approaches tend to be highly labour intensive and costly. The three key motivators to exploring an SHM strategy for a given infrastructure asset are to:

- increase user safety
- minimize cost (maintenance, replacement and/or downtime)
- maximize functionality (capacity, speed and service-life)

1.5 Structural health monitoring of railroad bridges

Railway is an important mode of transportation as it moves 8.26 billion passengers and transported 1.16 billion tons of freight daily. A key element of the rail network is bridges Extreme load events are a primary concern for bridges exposed to hazards. For example, bridges located in seismic regions are susceptible to ground motion which can lead to large lateral demands on bridges and residual displacements. This can be a serious issue for a number of reasons. Common damage mechanisms include vertical buckling, span displacements, and collapse of bridge piers. Undetected seismic induced damage can also render the bridge as unsafe for use by trains. The high live load-dead load ratio of rail bridges also leaves critical elements under an even greater risk of fatigue accumulation. The monitoring system is intended to be a permanent fixture on the bridge collecting data based on trigger events such as train loads and lateral motions. The monitoring system is interfaced to the Internet where data is pushed to an SQL data server for storage and data processing. An alert system is designed to alert bridge owners of extreme load events and excessive response of critical bridge components. In addition to notifying the bridge owner of potential safety issues, continuous monitoring of the bridge 68 response combined with traditional (visual) inspections will also assist in improving bridge 6 maintenance strategies.

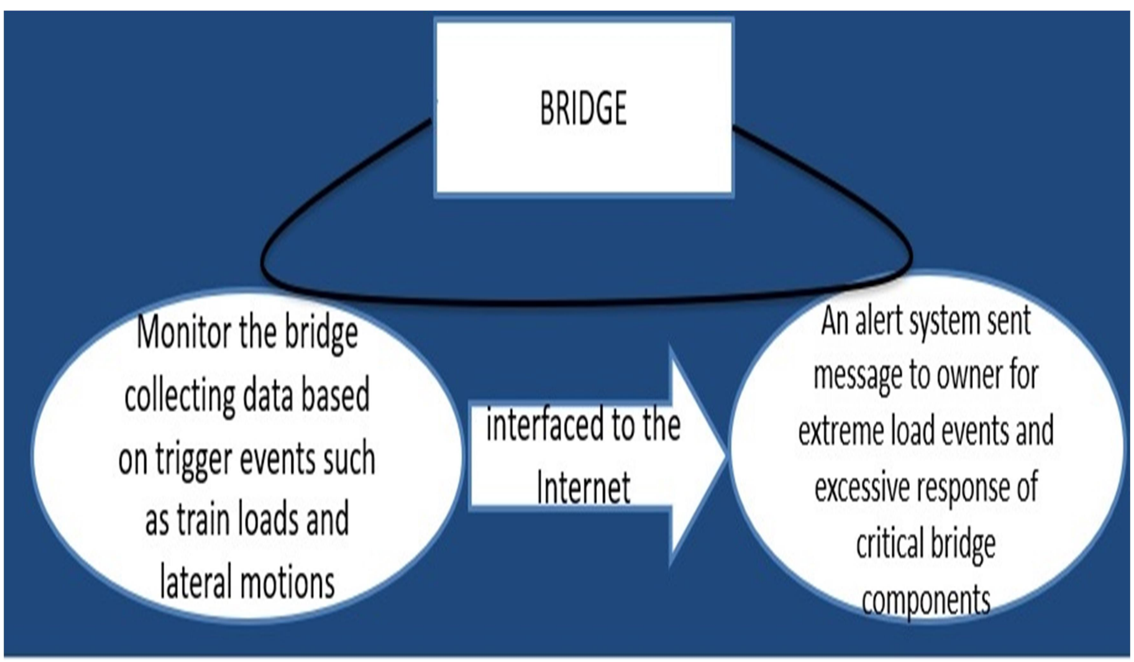

Figure 1.7 Block diagram for bridge monitoring

1.6 Need for SHM in India

Today India has been the developing country in terms of global market and more new structures are coming up in the field of civil engineering. Also India carries a burden of no of old structures which was built during British era and now which have been owned either by state or people. These old structures especially heritage building have known or unknown deficiencies which cannot be identified unless a disaster is experienced. However, it would be too late by then as the damage would have already happened. Apart from the old historic building like hospital, power, plant schools and commercial building may lead to loss of life of humans if the building suffers any damages due to calamity either natural or man-made.

Development of any nation largely depends on transportation facility. Huge amount is invested in transportation related infrastructure like construction of road, bridges, etc. The failure and damages of such structures which requires large investment may retard the development of any nation. Specially bridges can be monitored on regular basis to prevent damages.

1.7 Research gap

In this article, the various type of sensor used for health monitoring of different structural element have been discussed .Although, the above mentioned studies provide great effort to use SHM in civil engineering field but it has not provide any standard guidelines or data on the state of practice of SHM so that a structure can be classified as safe, unsafe or critical. Further it has not been discussed the optimum SHM methodology for rapid post –hazard assessment.

1.8 Objective

In view of above needs, this study aims to fulfill following objective:

- Optimize SHM methodologies for risk management, life-extension of aged structures and for rapid post-hazard assessment.
- Application of SHM
- To show the linear response of parameter used in beam using sensor system
- To measure the deflection of beam using sensor output and compares it with theoretical value.