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Structural Health Assessment and Remedial Measures of Old Age Bridges (Pune City)

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***Abstract*—India's sudden rise in population with urbanisation and modernization has led to increase in vehicular intensity. In the survey it was found that many cases of bridges have poor structural conditions such as cracks, corrosion of steel, etc. The preservation of these structures is very important. Installation of warning system can prevent the occurrence of any mishap to the bridges by giving warning in advance.**

Index Terms— LVDT, masonry arch bridges, monitoring

I. Introduction

In the field of civil engineering it is of great importance that the condition of aged structure need to be studied to detect damages that could possibly lead to failure of the structures. From this point of view, it becomes necessary to study the old age bridges and their failure causes. This paper also gives the information about the technique for prevention of failure and for the maintenance of the bridges.

Conservation of architectural heritage structures has become an increasingly important in the construction and engineering world. . The fact is that many of the structures are, whether damaged by natural deterioration or other causes, still needed to provide a particular service to the community in which it is located. Sometimes, a minimum intervention will not allow this service to continue. Two terms encompass conservation; preservation and restoration. Both preservation and restoration include methods by which a structure can be strengthened or repaired for the improvement of its designated purpose.

Recently we found many cases of bridges having poor structural conditions such as cracks in deck slab, scouring of piers, fatigue, decrease in compressive strength of concrete, corrosion of steel. Some of the bridges collapsed at the extreme situations .So, thorough structural health assessment is necessary for safety purposes.

II. Problem Statement

The construction of masonry arch bridges has long been abandoned but still some masonry bridges are still used for transportation in Pune city. The age of these bridges is more than 100 years and have almost completed their service life. The bridges were designed considering the past data but due to ever increasing traffic they are unable to carry the increasing load which is leading to deterioration and decrease in their strength. The poor structural conditions and presence of cracks in the structure makes it unsafe.

The increased water flow has caused scouring of piers and silting has resulted in increase in water level which is a big threat to the bridge. Due to rapidly changing conditions the masonry arch bridges are unable to stand firmly and are on the verge of failure.

A. Notable Bridge Failure

The collapse of the mahad bridge on savitri river in raigad district is one the latest of bridge failure in India. On 3 august 2016, mahad bridge collapsed taking life of nearly 50 people. Just before this incident the Gov. of Maharashtra had estimated the need of Rs. 2500 crore for the repairs and maintenance of bridges. Also a team of PWD engineers had inspected the bridge in the month of May and certified it as safe for use.

Soon after this incident a team of IIT experts was formed to carry out the investigation. In their report it was stated that that bridge collapse was due to flood. The excessive rainfall had caused the increase in the level of the water. Also the speed of the water was 10 times faster than usual.

Fig. 1. Collapsed Mahad bridge

Being a British era bridge it was more than 90 years old. As in the case of with all British era bridges the authorities were informed about the condition of bridge and how unfit they are. However the warnings were not paid attention to. These bridges were made of stone masonry and had arches. In these type of bridge whenever any joint collapses' the entire structure can fall down. In this bridge peepal trees had also started growing in the cracks between the stones, which weakened the bridge further.

III. Structural Audit

It is the health checkup of structure for safety. The quality of construction and quality of maintenance has effects on the health and performance of the building. With time the structure shows wear and tear, use, misuse, overuse, exposure to weathering all this factors affect the bridge significantly.

The structural audit is necessary for structures whose life is more than 30 years old. If, further use of such deteriorated structures is continued it may be harmful to human life and surrounding habitation. There is demand of appropriate actions and measures for all such building structures to improve its performance and restore the desired functions of structures which may leads to increase its functional life.

A. *Visual Inspection of the Structure*

- Verification of the accuracy of the original drawings or determination of basic building information, if no drawings are available.
- Identification of visible structural damage, such as concrete cracking or spa1ling, and observations on quality of construction.
- Identification of potential non-structural falling hazards, including ceilings, partitions, curtain Walls, parapets, fixtures, and other non-structural building elements.
- Observations on the condition of soil and the foundation.
- Documentation of existing conditions with photographs at key locations.
- Details about any deviations observed at the site from the original drawings have also to be recorded.

With its twin rivers, Pune is dotted with bridges that are vital links for the movement of people and vehicles from one side to another. The history of bridges in Pune dates back to the British era when they constructed many masonry arch bridges along the river which are still in use.

For our research we selected some masonry arch bridges in Pune city which are more than 100 years old. Detailed info of one the bridge is given below:

Fig. 2. Shivaji bridge

B. *Measurement of the bridge*

- No of spans : 10
- Total length of bridge : 201.27m
- Width : 19m
- Carriage way : 11m
- Footpath : 2m both side
- Parapet : 1m stone parapet
- Height of top slab from water level : 14.5m (approx.)

C. *Inspection*

- Approaches : Good conditionProtective works: Guide wall for the river near the bridge is damaged and need
- repairs.
- H.F.L. : RL 547.432m
- Waterway: The Bridge is not overtopped in floods. Thus, waterway below the bridge is adequate
- Erosion of banks : No erosion is observed
- Masonry arches: The stone masonry arches are in good condition. However, there is vegetation sprouting from the arches.
- Wearing coat : Condition of wearing coat is
- Good drainage : Drainage is good

D. *Recommended corrective measures*

- Retaining wall on the North side of the River requires repairs wherever damaged. Similarly, guide walls for the river channel are also to be repaired.
- Sprouting of trees to be removed. After removing the vegetation, the places should be filled by lime.
- Some levelling by earth is done in the river bed, it is better to pitch this area.
- The joints in the Arches at the end spans from where traffic is moving, should be repaired by 1:3 mortar with 10% polymer after removing existing damaged plaster.
- The thick plaster in the end span may not last long and this will have to be repaired.
- There is a longitudinal crack over parapet wall. It is better to provide 50mm thick stone coping over the wall by removing some of the old concrete.
- Where joints in Arch are loose, repointing of joints to be done.

After studying the masonry arch bridges in Pune city we came to the conclusion that the bridges are structurally stable and with the help of proper maintenance they can stand strong for more years with proper functioning. But we cannot ignore the fact that there are still many reasons that can be a threat to a structure.

Even though in the history of Pune there has been only single incident in 1961 which affected the bridge safety. After that there is no record about the floods reaching the level of arches and causing threat to the structure. But in case if any such situation arrives in future then there is a need to implement some safety measures which could prevent loss of life. So, knowing the severity of this we decided to use the sensors to check the stability of the bridge and to construct a barricade at the entrance of the bridge which will be closed as soon as the reading in sensors will exceed the limit.

The different type of sensors required for monitoring are:

- Crackmeter
- Displacement transducers
- Tilt meter

1. Crackmeter

The crack meter is used with a dial indicator to monitor movement at joints and cracks in concrete structure or rocks. They are used to monitor joints or cracks for unexpected movements to provide early warning of performance problem. The crack meter consists of a transducer and a mounting kit. Anchors are installed on opposite sides of the crack and the transducer is mounted across the anchors. A change in the distance across the crack causes a change in frequency signal produced by transducer.

This instrument can also be used in the masonry arch bridges to monitor the cracks in the structure. Anchors can be installed in the rocks on opposite side of the crack on which the transducer can be mounted.

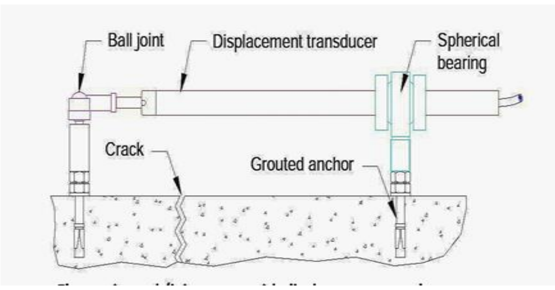

Fig. 3. Crack meter

2. Linear Variable Displacement Transducer

A displacement transducer is an electromechanical device used to convert mechanical motion or vibrations into a variable electrical signals. Linear Variable Differential Transformers (LVDT's) accurately measure the movement between the spring-loaded sliding armature and the exterior body of the transducer. These rugged and self-contained units are ideal for recording displacements on structural members due to live loads and temperature variations.

Fig. 4. LVDT

3. Tilt meter

The scour monitoring system is based on commercial off-the-shelf tilt sensors, also known as tilt meters or clinometers. Each sensor consists of two parallel curved metal plates with silicone fluid between them. A gas bubble floats in the fluid between the plates. As the bridge structure rotates, the sensor is tilted, and the bubble moves in the fluid, changing the capacitance between the parallel plates--essentially, the tilt sensor is an electronic spirit level, capable of resolving one one-thousandth of a degree of rotation. Unlike tilt sensors based on MEMS accelerometers, capacitive tilt sensors are not subject to long-term drift. The temperature response characteristics of the capacitive tilt sensors are well understood, and thermal drift is easily compensated for through a linear correction.

Rather than attempting to measure scour holes themselves, the approach is to measure the response of the bridge piers to scour. Using sensitive electronic tilt sensors mounted at the top of each pier, the system measures the movement of each pier cap. All bridge structures exhibit movement due to quasi-static loads such as temperature changes as well as much smaller movements due to dynamic loading from traffic, wind and other factors. Observation of the bridge's response to daily and seasonal temperature cycles indicates a pattern of normal quasi-static structural movement, which may be used to construct an envelope of typical safe operation.

For structures at scour prone locations, movement beyond expected norms is assumed to be the result of scour effects on the substructure. If pier movement during high water periods differs from the expected pattern, further action up to and including bridge closure may be required. However, if pier movement during high water is similar to the historic record, the engineer gains confidence that the bridge substructure is not affected by scour. This approach requires continuous monitoring with highly sensitive instruments, but provides a global perspective of bridge response, regardless of where or how scour holes develop around the substructure.

Fig. 5. Tilt meter

IV. Conclusion

The project should first begin with historical research, inspection and geometrical survey of the bridge. These are important steps in understanding the condition and behaviour of the bridge and the information collected will allow to assess the bridge and determine the best course of action. An accurate visual inspection will provide the means to perform and apply different measures as per defects. With the information from the investigation and analysis we will have an understanding of the bridge behaviour and the cause of damages or faults. It is important to ensure that the cause of the problem will be addressed and rather than only a symptom of the problem. It will now be possible to determine an appropriate intervention with a result that is compatible, is respectful to conservation principles, is performance improving, is durable, and is cost effective.

. Using sensors will help in continuous monitoring of the loads, deflection and cracks. By providing a proper connection between the sensors and the alarm system will alert the drivers and will allow the closure of the bridge on time preventing any loss of life.

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