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Automation and Management System for Bridges

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***Abstract*— India has a total road network over million kilometers. There are many types of major and minor bridges on these networks. Most of the bridges have been built several years ago and many of the bridges in the network have already crossed their design life. India is a developing country with limited resources, which calls for the careful management of the available bridge inventories as well as ensuring their full design capacity of serviceability. Bridge management system is a powerful tool for planning of inspection and maintenance activities and also forecasting the funding requirements to keep the bridge stock in appropriate serviceability level. A maintenance management framework has to be implemented. The framework consists of the following sequences namely creation of database, inspection practices and maintenance guidelines.**

INTRODUCTION

Structure types have been evolving throughout history. The evolution will continue into the future perhaps at an accelerated rate. Traditionally, the civilization has sprung up on the banks of the river and spread of civilization on the globe is essentially the interaction of such civilization founded on the banks of the river. When technology was not advanced, the communication between such civilizations was through land ways and ferryboats. Since the basic units of dwellings were on the banks, the land routes were longer and the routes through ferry boats were liable to vagaries of nature such as floods etc. therefore, essentially the interaction between such civilization was somewhat lessened. As the technique of bridge building advanced, this interaction of civilization also became more. There was more interchange of ideas. Clearly, the advent of man and the growth of civilization is clearly linked with the advances in the bridge building. Since bridges were essentially a link between towns and large dwellings, they also became more important from the point of view of military and capture of bridge by military was in fact the start of victorious military campaign. Winning the "bridge ahead" became very important from the point of view of military. The driving forces behind continued advances in bridge engineering are traffic congestion and costs in the future, just as now; the public will expect few traffic delays, if any. They will want transportation costs to be as low as possible. Computer technology will enhance traffic management so well that the public will become accustomed to flowing traffic and more aware of congestion locations. Disruptions from construction will be more obvious and even less tolerated.

HISTORY OF DEVELOPMENT OF BRIDGES

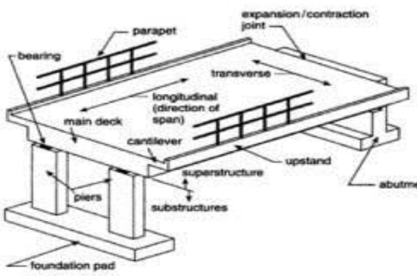
The history of development of bridges is closely associated with the history of human civilization. It may be well presumed that the idea of building a bridge across an obstacle such as a channel or water course occurred in human mind by observing natural phenomenon such as tree trunk fallen accidentally by a storm across a small water course or a piece of stone in the form of an arch over a small opening caused by erosion of soil below or a bunch of creepers from one tree to the other used by monkeys. It may be well imagined that in olden days man encouraged above mentioned natural phenomenon built bridges over a small water course by placing a piece of log or by tying a bunch of long creeper with the trees situated on either side of the water course. The former was the predecessor of girder type bridges and the latter that of suspension bridges. The earliest bridge on record was the bridge over the Nile built by Mener, the King of Egypt about 2650 BC. A number of arch bridges were also built by Mesopotamians, the Egyptians and the Chinese. The Chao-chow Bridge over Hsiaoho River was built by Chinese around 600 AD. It was actually built by the Romans who first took up bridge building on a systematic manner. They knew the use of pozzolona and made good use of this in making masonry bridges. The Romans built large arches and viaducts. The special features of Thames Bridge and Ponte Vecchio were in addition to the bridge decks were those bridges used to provide decorative and defensive towers, chapels, shops and dwellings.

The era of modern bridging activity started in the 18th century when use of iron was made by some bridge engineers. Cast iron and wrought iron were gradually replaced by steel. The first iron bridge of 30.5 span was built over the Severen in England by Abraham derby and john Wilkinson. The first steel bridge was the bridge at St Louis, Missouri. The world's first modern cantilever bridge is the Quebec Bridge in Canada. First cantilever bridge in India is the Howrah Bridge over river Hoogly in Calcutta. In the 19''' century due to manufacture of heavy load lifting equipment and high capacity compressor, pneumatic sinking of caissons in deep water became possible. As a result, construction of large spans in deep water could be taken up. Reinforced concrete bridges gained popularity in the 20th century because of their versatility in construction and economy in cost and maintenance. Also, reinforced concrete bridges can be cast in any convenient shapes and forms. It can be cast at site there by eliminating the carriage of heavy bridge components. One of the longest span reinforced concrete bridges is the Sando Bridge in Sweden with a span 264m. Manufacture of high strength concrete band prestressing the same by the use of high tensile steel wires improved the construction of concrete bridges. One of the early prestressed concrete bridges is the Marne Bridge in France. The first prestressed concrete bridge in India is the Palar Bridge, Tamil Nadu. Recent addition to the development of modern bridges is the cable stayed bridges. Many types of bridges have thus come into existence and therefore a need arose to classify the different types of bridges.

Infrastructure networks of roads and railways play a very important role in the everyday life of a country and its people. They provide mobility so that people can reach their destinations as quickly as safely as possible, and they have a major role in transportation of goods. To achieve this goal, regular maintenance, repair and rehabilitation operations must be carefully planned and executed at the proper time. Any network generally comprises of a number of bridges. The existing bridges are showing premature failure due to cumulative effect of inadequate maintenance and structural inadequacies to cater to needs of increased traffic volume and reduced availability of funds, the task of maintaining and preserving bridge stock assets. Generally bridge management system is applicable for A bridge may be defined as a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, railway, pedestrians, canal, a pipeline or a valley.

COMPONENTS OF A BRIDGE

The main body of bridge superstructure is known as the deck and can consist of a main part and cantilevers are illustrated. The deck spans longitudinally, which is the direction of span, and transversely, which is perpendicular to it. There may be up stands or down stands at the ends of cantilever for aesthetic purposes and to support the parapet which is built to retain the vehicles on the bridge.



Portion of bridge illustrating bridge engineering terms

PRESTRESSED BRIDGE

Reinforced concrete is the most widely used structural material of the 20th century. Because the tensile strength of concrete is low, steel bars are embedded in the concrete to carry all internal tensile forces. Imposed loads or deformations, or by load-independent effects such as temperature changes or shrinkage may cause tensile forces.. The external loads cause tension in the bottom fibers, which may lead to cracking, as shown. Practical reinforced concrete beams are usually cracked under the day-to-day service loads. On a cracked cross-section, the applied moment is resisted by compression in the concrete above the crack and tension in the bonded reinforcing steel. Although the steel reinforcement provides the cracked concrete beam with flexural strength, it does not prevent cracking and does not prevent the loss of stiffness caused by cracking. Crack widths are approximately proportional to the strain, and hence stress, in the reinforcement. Steel stresses must therefore be limited to some appropriately low value in order to avoid excessively wide cracks. Similarly, large steel strain is the result of large curvature, which in turn is associated with large deflection. There is little benefit to be gained therefore, by using higher strength steel or concrete, since in order to satisfy serviceability requirements, the increased strain capacity afforded by higher strength steel cannot be utilized. Pre stressed concrete is a particular form of reinforced concrete. Prestressing involves the application of an initial compressive load on a structure to reduce or eliminate the internal tensile forces and thereby control or eliminate cracking. The initial compressive load is imposed and sustained by highly tensioned steel reinforcement reacting on the concrete. With cracking reduced or eliminated, a pre stressed section is considerably stiffer than the equivalent (usually cracked) reinforced section. Prestressing may also impose internal forces, which are of opposite sign to the external loads and may therefore significantly reduce or even eliminate deflection. With service load behavior improved, the use of high-strength steel reinforcement and high strength concrete becomes both economical and structurally efficient. As will be seen subsequently, only steel, which can be tensioned with large initial elastic strains, is suitable for prestressing concrete. The use of high-strength steel is therefore not only an advantage to prestressed concrete, it is a necessity. Prestressing results in lighter members, longer spans, and an increase in the economical range of application of reinforced concrete.

Based on the method of construction, prestressed concrete bridges may be classified into four categories:

a) cast-in-situ bridges
b) bridges with precast girders
c) bridges with segmental cantilever construction, and
d) incrementally launched bridges.

The method of construction determines the design and computations for the superstructure. The cast- in-situ method of construction is applicable for short spans below 50m in locations where centering can be erected without difficulty. Bridges using precast girders placed in position by cranes are suitable for spans in the range of 30 to 40 m, particularly bridges in urban areas requiring least obstruction to traffic below. Segmental cantilever construction enables the elimination of centering and false work, and is therefore eminently suited for construction across wide and deep valleys involving very tall piers, and for structures requiring uninterrupted passage of traffic or navigation during construction. Incremental launching techniques used for bridges with a series of short spans in the range of 35 to 45 m.

NEED FOR THE STUDY

There are many types of major and minor bridges on the Indian road network. Most of the bridges have been built several years ago and neared or already crossed their design life. Many of them were designed for lesser traffic, smaller vehicles, slower speeds, and lighter roads than are presently encountered on the highways. In our country resources are limited; this calls for proper management of existing bridge inventories as well as ensuring their full design capacity of serviceability. Bridge Management System is a tool for management by planning for inspection and maintenance activities and also forecasting funding requirements to keep the bridge stock in appropriate serviceability level. In India the application of this management system is not popular and it's only in its preliminary stage of development.

OBJECTIVES

- To analyze the status of bridge management systems in India.
- To formulate a bridge management system for prestressed concrete bridge.
- To establish maintenance management framework for the existing bridge.
- To create an automated system for enhancing the conventional inspection and maintenance strategies.

SCOPE

- The study is limited to state highway departments.
- The maintenance management framework developed is applicable to prestressed as well as reinforced concrete bridges.
- The automation side is mainly focused on the upcoming new bridges and some of the existing bridges.

METHODOLOGY

A literature review was conducted to identify the Bridge Management systems being currently used and developed in the country. Survey has to be conducted to get an idea of the status of the management systems adopted in the country. Maintenance framework has to be developed for prestressed bridges.

Maintenance aid framework which includes a set of guidelines which is mainly split into the following:

- Creation of a database
- Inspection to be followed
- Maintenance practices

Main emphasis is given to the automation of the system with the help of latest developed monitoring equipments after the completion of evaluating the present status of Bridge Management Systems. It includes: Strain Gauges, WIM System and Vibrating Wire Based System.

A control room has to be setup to monitor the receiving signals. If wireless technology with high signal strength routers are implemented, simultaneous monitoring of more than one bridge at a time is possible.

Data sheet has to be made regarding the loading condition, strain deformations etc. Relevant information is updated to the database. Database serves as a basic tool for the maintenance framework created. The enhanced data related guidelines will improve the conventional form of maintenance and inspection strategies.

QUESTIONNAIRE DESIGN

The questionnaire survey is the apt way determining a picture of existing systems. The questions should be relevant to the current research study as applicable to India. The questionnaires are to be organized into various sections. A pilot survey has to be conducted prior to the actual survey. In this thesis mainly oral questions were asked, as the concerned Government department preferred this than the written or printed way questioning and giving feedback.

QUESTIONNAIRE ADMINISTRATION

The questionnaire had been administered to selected state/district highway bridge divisions in Kerala and other states of India. The following points are ensured prior to survey

- Identifying the apt person for information enquiry.
- Scheduling meetings as per convenience.
- Not disclosing obtained information to others.

Most of the respondents were trained and experienced in their fields.

Most of the departments use inspection manuals and almost more than half use maintenance and user's manual.

Only Indian railways have recently developed their own bridge manual guidelines for management of bridges. Specific railway zones adopt this system.

INSPECTIONS

Inspection practices are generally divided into two:

- Routine inspection
- Critical inspection

Critical inspection is again subdivided into two:

a) Principal inspection
b) Special inspection

Principal inspection is carried out with the purpose of:

- Monitoring the safety without any significant influence on traffic flow
- Detecting damages in due time
- Deciding the subsequent year for principal inspection
- Initiating special inspections in due time to determine the cause/extent of damages which needs to be rectified

PLANNING FOR INSPECTION

All the required activities are preplanned before the commencement. This is mainly aimed for careful management of the existing bridge inventories. Proper planning enables proper execution without delays and effectiveness. A thorough knowledge of the required aspects is very much essential, for this purpose mainly professionals are appointed termed as inspectors. A full picture of the inspection planning is represented by means of a flowchart as follows:

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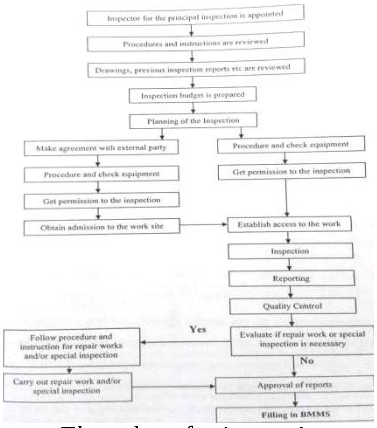


Flow chart for inspection

DATA ANALYSIS

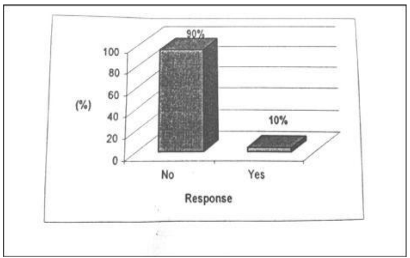
As mentioned earlier, questions to the concerned department were asked orally. Feedbacks provided by them are represented with the aid of bar charts mainly.

TYPES OF BRIDGES

Department	RCC	PSC	Steel	Composite
Road and Bridge corporation, Kochi, Kerala	13	7	3	10
Road and bridge , South circle Trivandrum, Kerala	85	18	9	11
PWD office 1 Chennai Tamilnadu	180	60	4	11
PWD office 2 Chennai Tamilnadu	123	80	0	8

Bridge types

RESPONSE



Bar chart for response

The responses for the queries are depicted in the above figure. About 90% of respondents were having NO as their answer for the question of usage of any particular management system for bridges ie: Bridge Management System. Only 10% of the respondents were having YES as their response.

EXISTING SYSTEM OF PRACTICE

As per the enquiry made on the existing system practiced, one thing which is very much evident is that, majority of department or the concerned authority is exercising the conventional methods of inspection and maintenance strategies.

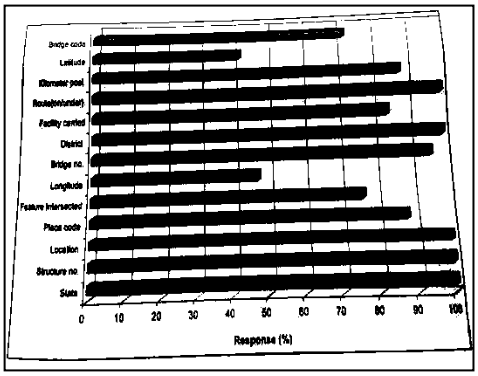
REQUIRED PARAMETERS

The existing method of management by means of inspection and maintenance are by analysis various parameters associated with bridges, they are as follows:

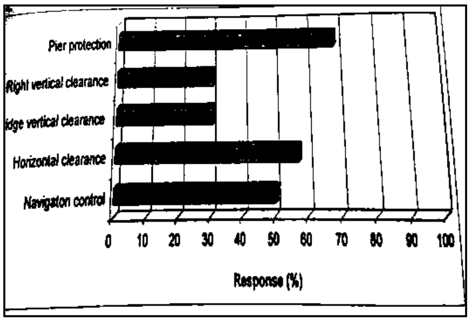
- Identification
- Geometrical Data
- Data classification
- Structural and Materials Data
- Navigational Data

REPRESENTATION OF PARAMETERS

Above mentioned parameters are depicted by means of bar chart as follows, by analysis the (data obtained from these charts, the decision related to the corresponding actions are prioritized and executed as per plan.



Bar chart for identification



Bar chart for navigational data

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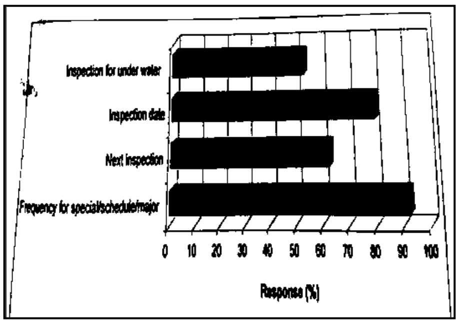

Bar chart for inspectional data

AUTOMATION SIDE

Looking into the history of bridge collapses and failures, one finding in common is the over exploitation of bridge serviceability levels. A premium luxury car costing lakhs are fully loaded with sensors to monitor its functioning and for prior warning of malfunctioning. It has become indispensable for the engineers to make use of latest scientific equipments into their creation so as to monitor and evaluate the performance to avoid failures.

FAILURE REASONS

The following are the predominant factors responsible for the failure conditions:

- Over estimation of the foundation capacity.
- Vulnerable components failure.
- Tension cracks due to increased traffic volume.
- Improper maintenance of the components prone to corrosion.

NEED FOR MONITORING

Monitoring of a structure means the continuous assessment of the state or condition. It is essential and indispensable so as to:

- Timely detect structural damages and take remedial actions.
- Evaluate the structure after retrofitting.
- Enhancing the conventional methods of inspection.
- Facilitate monitoring of external loads, stress distributions, deflections, design validation.

CAUSES OF DAMAGES IN STRUCTURES

The following are the major causes of damage in structures:

- Environmental degradation
- Fatigue
- Excessive loads
- Natural calamities
- Vehicle impacts
- Long endurance and intensive usage

TYPE OF SENSORS FOR STRUCTURE MONITORING

- Vibration (Acceleration, Velocity, Displacement)
- Environmental (Temperature, Pressure, Wind)
- Miscellaneous (Load, Strain, Tilt)

MANAGEMENT FRAMEWORK

- Management framework means the overall action starting from planning to realization of managing a bridge.
- An existing bridge or an upcoming bridge may be considered for this purpose.
- Strain gauges, load cells, WIM systems, fiber optic sensors and shape memory alloy bundles are mainly used for monitoring and relevant data retrieval.
- The effectiveness of the management system depends on how strongly the initial database is created.
- All the details from the starting without leaving anything is required for database creation.
- The data retrieved from the monitoring equipments are added at the end.

DATABASE

- Database contains the relevant information such as:
- Technical data
- Geometric data
- Drawings
- Current maintenance practices and data log sheet generated by monitoring equipments
-

CONCLUSION

Bridge management systems are decision support tools developed to assist agencies in determining how and when to make bridge investments that will improve safety and preserve existing infrastructure. In our country resources are limited; this calls for proper management of existing bridge inventories as well as ensuring their full design capacity of serviceability. A survey was conducted among selected highway departments in India. The feedback revealed the fact that in our country the management system for bridges are still in the preliminary level only. As per the survey about 90% of the concerned departments were not following any specific management systems. There were not aware of the existing Bridge Management software. Conventional methods of inspection and maintenance practices were mostly followed. Only 10% of the respondents were aware of this specific system of management for bridges. As per the current way of inspection and maintenance, data's were collected and depicted in the form of bar charts. It's high time that an effective new system of management should be incorporated into the field for carrying out the management process in a highly effective manner. This will ensure the full design capacity and serviceability of the existing as well as upcoming new structures. The first phase of this thesis dealt mainly with evaluation of the status of Bridge Management Systems in practice.

REFERENCES

[1] Kristen L. Sanford Et Al. (2000), 'Bridge Management And Inspection Data: Leveraging The Data And Identifying The Gaps.

[2] Paul D. Thompson Et Al. (1999), 'A New Bridge Management System For Ontario.

[3] H.E. Klatter Et Al. (2002), 'Bridge Management In The Netherlands; Prioritisation Based On Network Performance.

[4] Paul Jensen P.E. (2000), 'Determining Preservation Needs Using Inspection & Bridge Management System Data.

[5] Hisao Emoto1, Jun Takahashi2 And Ayaho Miyamoto1 (2009), 'Remaining Life Prediction And Verification Of An Aged Bridge Based On Field Inspections.

[6] Dr R J Woodward (1999), 'Review Of Current Practice For Assessment Of Structural Condition And Classification Of Defects.

[7] Fhwa Office Of Asset Management December, (2010), 'Aashto Guidelines For Bridge Management.

[8] Karen Smilowitz Samer Madanat(1994), 'Optimal Inspection And Maintenance Policies For Infrastructure Systems

[9] Paul D. Thompson (2001) 'User And Life-Cycle Cost Factors.

[10] Stephen Sahs (1994), 'Climbing Techniques For Bridge Inspection.

[11] George Hearn (1999), 'Segmental Inspection For Improved Condition Reporting In Bms.

[12] Sobanjo, Jo; Thompson, Pd; Lewis, M; Kerr, R (2002) , 'Estimating Agency Cost Of Maintenance, Repair, And Rehabilitation For Florida Bridges.

[13] Markow, Mj (1996), 'Collecting And Managing Cost Data For Bridge Management Systems.

[14] Steven J. Lorenc Brian E. Handlon B, Leonhard E. Bernold (1999), 'Development Of A Robotic Bridge Maintenance System.

[15] Choi, K. and Chang, F. K. (1996), "Identification of Impact Force and Location Using Distributed Sensors", AIAA Journal, Vol. 34, No. 1, pp. 136-142.

[16] Chudamani, B. (2011), "Development of Low-Cost SHM System for Defence Structures: Hardware Issues" M. Tech. Thesis, Department of Civil Engineering, IIT Delhi.

[17] Zhang, Z. and Aktan, A. E. (1995), "The Damage Indices for Constructed Facilities", Proceedings of 13th International Modal Analysis Conference, 13-16 Feb, Nashville, Vol. 2, pp 1520-1529.

[18] Zhou, S., Liang, C. and Rogers, C. A. (1995), "Integration and Design of Piezoceramic Elements in Intelligent Structures", Journal of Intelligent Material Systems and Structures, Vol. 6, No. 6, pp. 733-743.

[19] Zhou, S. W., Liang, C. and Rogers C. A. (1996), "An Impedance-Based System Modeling Approach for Induced Strain Actuator-Driven Structures", Journal of Vibrations and Acoustics, ASME, Vol. 118, No. 3, pp. 323-331.

[20] Zhu, W. (2003), Sensors and Actuators (E6614), Lecture Notes, Nanyang Technological University, Singapore.