STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF

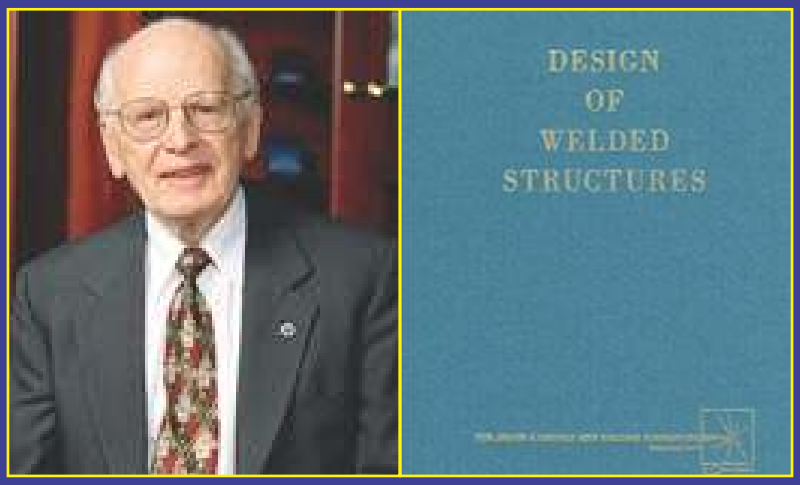
INDIAN SOCIETY

OF

STRUCTURAL ENGINEERS

ISSE

VOLUME 19-1 Jan.-Feb.-Mar. 2017



GEM 11: Dr. Omer W. Blodgett, Legend in Welded Steel Structures

(See Page 3)

Indian Bridge Management System

(See page 7)

Bridge Repairs And Rehabilitaion

(See page 15)

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INDIAN SOCIETY OF STRUCTURAL ENGINEERS

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VOLUME 19-1, Jan.-Feb.-Mar. 2017

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Contents

Editor : Hemant Vadalkar

Fraternity News

WELCOME TO NEW MEMBERS

(Oct. – Nov. – Dec. 2016)

M- 1523	Uday Lau Pawar	M- 1530	Rushabh Surendra Karnavat
M- 1524	Ajit Laxmanrao Dhadge	M- 1531	Balakrishnan C.
M- 1525	Musa Babulmahamad Faras	M- 1532	Kumar M. Muthu
M- 1526	Kaushik Ghosh	M- 1533	Divya Bhavana Tadepalli
M- 1527	Bhagvan Jagdish Jaybhaye	M- 1534	Amitkumar Nirmalkumar Kurne
M- 1528	Sanjay Ashok Naik	M- 1535	Jitendra Dhere
M- 1529	Ajinkya Suhas Joshi	M – 1536	Chetan Baliram Chhindam

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Members : 1536	Junior Members : 43	IM : 01

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- ❄ Environmental Engineering
- ❄ Non Destructive Testing
- ❄ Bridge Engineering & Other related branches

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries fo Responsibilities of Structural Engineer, commensurate with remuneration.
3. To get easy registration with Governments, Corporations and similar organizations all over India, for our members.
4. To reformulate Certification Policies adopted by various authorities, to remove anomalies.
5. To convince all Govt. & Semi Govt. Bodies for directly engaging Structural Engineer for his services.
6. To disseminate information in various fields of Structural Engineering, to all members.

GEM 11: Dr. Omer W. Blodgett, Legend in Welded Steel Structures

Dr. N. Subramanian
Er. Vivek G. Abhyankar

Dr. Omer W, Blodgett Sc.D., P.E., Dist. M.ASCE (27th Nov 1917-11th Jan. 2017)

If you've ever designed a structural weld, you would have definitely heard about Dr. Omer W. Blodgett and his monumental work on welding. He lived and breathed welding. His book, *Design of Welded Structures*, still remains as the standard reference for designers, even though it dates back to more than 50 years-which is a rare phenomenon in design books. Though you may know his name, it is interesting to know how Dr. Blodgett was involved in the area of welding.

Early Life

Omer was born in Duluth, Minnesota, in 1917, and grew up on the shores of Lake Superior. Blodgett's family had a fleet of lake vessels in the era of steam tugs and barges with sails. Like many of those who entered this profession at that time, he first learnt welding, through his family business at the age of 10, which he said began his life's journey of learning and teaching welding principles. In fact, his family actually lived on the boats during colder months, when they weren't in service. Thus welding was more than just a profession; it became a household chore! Repairs such as patching the boiler were an ongoing process. Interestingly, Omer's father purchased a welding machine, the year Omer was born, to save on labour costs! Through his high school years, he worked as a welder at his father's company and became certified as a welder for high pressure applications in 1938.

Association with Lincoln Electric Company

Omar Blodgett (left) with co-workers at the Globe Shipbuilding Co. shipyard in 1945

Omer W. Blodgett earned bachelor degrees in metallurgical engineering (1941) and mechanical engineering (1974) from the University of Minnesota. After graduating from college, he went on to work as welding superintendent with the Globe Shipbuilding Company in Superior, Wisconsin, where he refined his skills and learnt to resolve welding issues like distortion and cracking. There, during World War II, he supervised more than 400 welders, who fabricated twenty-nine all-welded oceangoing ships for the Federal Maritime Commission.

In 1945, he met James F. Lincoln, a man who not only become a life-long friend but also influenced him to work for his Lincoln Electric Company,

Cleveland. Blodgett joined Lincoln Electric in 1945 in a sales position, and later described it as highly educational. In 1954, he became a design consultant for the company and worked as a mechanical engineer. Though he knew welding from his own experience, this experience gave him insight on how others do welding. After spending more than six decades with the company, he retired in 2009 as a senior design consultant. Lincoln Electric is the world leader in the design and manufacture of arc welding products, robotic welding systems, plasma and oxyfuel cutting equipment. Headquartered in Cleveland, the Company has manufacturing operations in 16 countries and a worldwide network of distributors and sales offices covering more than 160 countries.

Dr. Blodgett conducting training sessions at Lincoln Foundation

Design Seminars

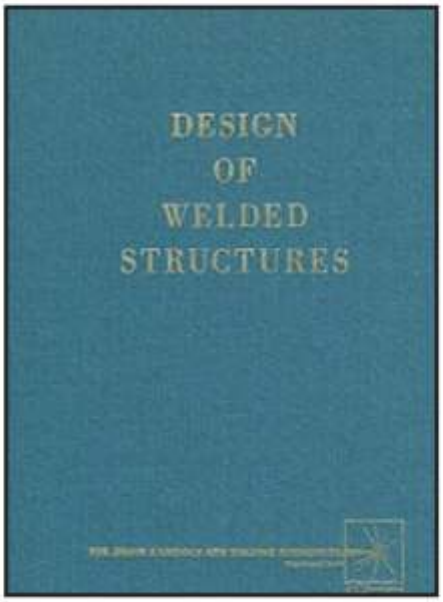
Since the mid-1950s, the Lincoln Electric's machine and structural Design Seminars, conducted by him, brought more than 15,000 engineers and designers from all over the world to the Lincoln headquarters in Cleveland. In these seminars, Dr. Omer taught them how to design safe, economical and dependable welded connections for a broad range of applications. These Seminars continue even now and are named in his honor. John M. Stropki, Chairman and CEO, The Lincoln Electric Company had once said "At Lincoln, we like to say 'we are welding the world together'. We ALL learn how to do that from the 'Dean of Welding', Omer Blodgett." He had been a lecturer at various welding seminars and had frequently spoken on welding design at

John M. Stropki, Chairman and CEO, The Lincoln Electric Company, presenting Omer with a plaque to mark his 60 years of distinguished service to the company

the American Welding Society's (AWS) sectional and national meetings. He has conducted his structural seminars all over the world, including Australia, South Africa, England and Brazil.

Papers and books

He is the author of several significant papers on sizing welds, control of distortion, brittle fracture, and fatigue. He is particularly well known for his two books *Design of Welded Structures* and *Design of Weldments*. Even though originally published over 50 years ago, they are considered to form the foundation for the entire field of design for welding.



His famous book on Welded Structures

His famous book on Welded Structures

He is recognized nationally and internationally as an expert in the design of welded connections and has been influential in the development of national standards such as the code of the American Welding Society. Omar Blodget is a legend in welded steel structures.

He was a licensed professional engineer in the State of Ohio, a fellow of the ASCE (American Society of Civil Engineers, ASME (American Society of Mechanical Engineers) and the AWS (American Welding Society). Other affiliations include Tau Beta Pi and Sigma Xi.

Awards and Encomiums

Mr. Blodgett was a long time member and contributor to a number of organizations including the AWS D1 Structural Welding Committee, the American Institute of Steel Construction (AISC) Committee on Specifications, and the Welding Research Council (WRC) Task Group on Beam to Column Connections. His contributions were recognized by AWS in 1962, 1973, 1980 and 1983, when he was awarded the A. F. Davis Silver Medal for his work in structural design. He earned a triple crown of AISC Awards: In 1983, Omer received the AISC T. R. Higgins lectureship award, one of the highest honors given by AISC to individuals that have contributed to the structural steel industry, The AISC Luminary Award (presented by Charlie J. Carter, the current President of AISC), in 1997(now called AISC Special Achievement Award), and the Lifetime Achievement Award in 1999. In 1995, the LeTourneau University in Longview, Texas, awarded him the Honorary Doctor of Science degree.

In 1998, LeTourneau University established a Chair of Welding and Materials Joining Engineering in Mr. Blodgett's name. In 1999, *Engineering News Record* identified him as one of the top 125 engineers in the past 125 years. American Welding Society in their 1991 Fellow citations lauded Omer W. Blodgett for his efforts in developing and promulgating efficient designs for welded structures.

In 1977, at the direction of Lincoln Electric, Omer started to look for an understudy and successor. During a visit to LeTourneau College, he discovered Duane Miller, now Lincoln Electric's manager of engineering services, who would become his protégé. Duane was asked to speak at Omer's funeral and summarized his mentor's attributes in three categories: an exceptional engineer, a tremendous teacher and a committed Christian. In an article about mentoring published in Welding Innovation, Duane Miller wrote about the remarkable advice Dr. Blodgett gave him over the years:

Provide a path for the load to be transferred to a member that lies parallel

- Don't over-weld
- Don't design with your heart
- Remember what you are designing for
- Listen to the welder.

"I have many fond memories of Omer, but I will mention one that illustrates his wide-ranging interest in others," said Ted Galambos, professor emeritus with the University of Minnesota's Department of Civil Environmental and Geo-Engineering. "One of his collaborators at Lincoln Electric was a man named Richard Sabo, who was of Hungarian ancestry, as am I. Omer learned a number of Hungarian phrases from Mr. Sabo, and each time I met Omer, he would use his Hungarian skills on me."

In the words of Dr. James M. Fisher, Ph.D., P.E. (former Chair, AISC Specification Committee

Vice President emeritus of, Computerized Structural Design), another great steel designer:

"Most structural engineers think of Omer as an icon in the field of structural engineering. The amazing fact is that most do not realize that Omer was not educated as a structural engineer. He studied mechanical engineering and metallurgy. He is, however, a truly gifted engineer, and his contributions to the *AISC Specifications* are invaluable. I was excited to be in the audience to see him accept the T.R. Higgins award in 1983 award, and to hear his lecture. The most memorable part of the event was his acceptance speech. I could not believe how such an icon could be so humble in his accomplishments. This is

something we should all emulate. I consider Omer's book Design of Welded Structures to be a classic text for structural engineers. I learned and solved many structural problems because of information in the text."

Leadership Award Winner Dr. Omer W. Blodgett and Wife Dorothy

Blodgett is known for his ability to distill complex concepts into simple summaries. He also has coined many memorable sayings that are easily transferred from one generation to another.Some of these are given below :

- Nothing beats hands-on experience.
- You'll never know it all, so become a life-long student.
- Sometimes, great gems of knowledge are ignored for decades; this does not diminish their sparkle!
- You've got to have the courage of your convictions.
- Learn from other industries.
- Codes are not always clear as to intent and purpose.
- Welding is not a fastener! It is a method of design.
- Don't hold back on accepting new ideas. You may be left behind.
- Codes always lag industry.
- A good picture is worth a thousand words.
- We're standing on the shoulders of giants.

Omer was preceded in death by his wife, Dorothy. He is the father of Robert (Linda), grandfather of Laura, Andrew and Mark.

You may get the wisdom of Dr Blodgett from the link: http://weldingdesign.com/blodgett/

We also suggest you to read: http://www.jflf.org/pdfs/papers/mentoring.pdf, where Dr Blodgett's mentoring skills are revealed!

ACKNOWLEGEMENTS:

The photos used in this article have been extracted from the Web.

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INDIAN BRIDGE MANAGEMENT SYSTEM

Sachin Joshi

Asset Management :

Asset management generally refers to a system that monitors and maintains things of value. This applies to tangible assets such as buildings, bridges, offices, factories, etc. Asset management is a systematic process of creating inventory and managing the assets in a cost effective manner.

Asset management in the engineering environment is a practice of managing public infrastructure assets to achieve the high returns by monitoring and maintaining the infrastructure with the objective of providing the best possible services to end users.

Concept :

Indian Bridge Management System (IBMS) is developed to create an inventory of all bridge assets on National Highways (NH) in India and apply a technical logic to manage the bridge asset during its life cycle. It generates detailed inventory data and condition ratings of assets to ensure that the dynamics of deterioration process are captured and this dynamism in the deterioration process guides the inspection and rehabilitation of bridges. The system allows the user to assign priority to maintenance activity based on the present condition of the bridge. The progressive improvement of all bridge assets is ensured over a period of time as worst bridges are first rehabilitated and then the less damaged bridges are rehabilitated.

Beneficiaries:

Major Stake holders in IBMS are the Government department which owns the bridge assets and general public who use the bridges. Each stake holder has benefit in short term and long term.

Government benefits by creation of database of all bridges in immediate present (6 Months for start of IBMS). This is the short term benefit and in the long term it optimizes the utility of funds available for rehabilitation/ maintenance of the bridges.

Over a period of time, the department will be able to monitor the bridges and ensure that all such bridges which are critical are rehabilitated first and then the focus of rehabilitation will shift to those bridges which show marginal distress. Once all such bridges are also repaired/ rehabilitated, then the overall efficiency of the bridges in our country will improve along with its longevity because of its timely and proper maintenance. IBMS uses the principle of "FRWD" ("First Repair the Worst Damaged") to ensure the entire bridge inventory is rendered safe. The fear of major sudden catastrophe can be reduced to large extent. This will assure prolonged utilization of assets.

General public is assured over time that all bridges are being maintained immaculately and are safe for usage. They are assured that proper protocol exists for inspection of any bridge that shows signs of distress. Dynamism of Distress is negated by timely and focused maintenance. Alternate routes can be identified in times of natural disaster or calamity to enable the public travel from point A to point B.

IBMS System:

IBMS is the largest platform in the world with a database that could exceed 1,50,000 bridge structures owned by a single owner. Development of the system posed its own challenge as the system to manage such a large number of asset in a manner where the field studies could be conducted with minimum effort and in which maximum details could be collected. The bridges had to given a unique identity number which was the first step of inventory creation. Then their precise location details in form of Latitude and Longitude had to be collected in an Auto mode using the Ground Positioning system. Once these details are collected, the engineering properties of the bridge design, material and other technical details of the bridge are being collected. These are essential components of inventory collection process. On completion of inventory data, the structural component rating is done using a 0 to 9 scale to define the status of various bridge components like Foundation, Piers, Super structure, Deck, Scour rating, waterway adequacy, structural status and also Socio- Economic parameter which decide the importance of the bridge in relation to its contribution to daily social and economic activity of the area in its immediate vicinity.

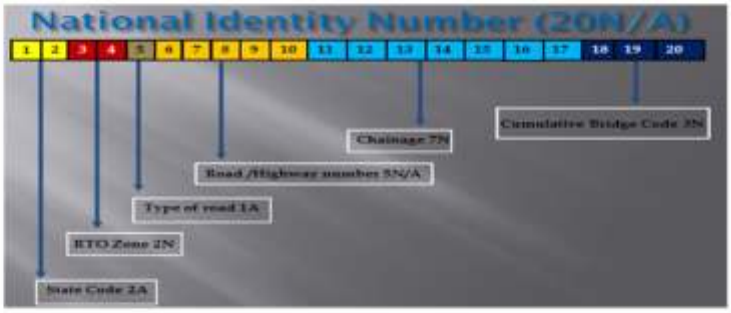
Inventory Data :

In order to ensure that all bridge inventory data captured is stored and retrieved properly, it was important to assign each bridge a unique identity number which was easy to understand and also accorded ease in data collection. Indian Highways numbers are undergoing changes and most general public is used to old highway numbering system. However IBMS is capable of converting inventory data collected as per old highway number to a Bridge Identity number which has the new highway number and also allocates the ascending chainage to bridges from starting point of the highway and a ascending number with the first bridge from start assigned number 001. The following bridge classification system was adopted in IBMS.

Bridge Classification

Classification of bridge is done by a series of alpha numeric number strings which is based on specific details of the bridge. There are 5 such strings used to classify the bridge. They being

National Identity number (20 A/N)
Bridge Location number (18N)
Bridge Classification number (22 A/N)
Bridge Structural Rating number (9N)
Bridge Socio- Economic rating number (6N)



National Identity Number : (20A/N)

National identity number is made of specific codes namely:

State code	(2A)
RTO zonal number	(2N)
Type of road	(1A)
Road Highway number (New)	(5 A/N)
Chainage	(7N)
Bridge Number	(3N)

Bridge Location Number (18N)

Bridge location number is made of specific codes namely:

Longitude	(9N)
Latitude	(9N)

Bridge Classification Number (22N/A)

Bridge classification Number is made of specific codes namely:

Structural form	(2N)
Material of construction	(1N)
Type of bridge	(2A)
Loading as per IRC	(2N,1A)
Age of bridge	(1N)
Traffic lane on bridge	(1N)
Bridge structure crossing features	(1N)
Length of bridge	(6N)
Width of Carriage way	(5N)

Bridge Structual Rating Number (9N)

Bridge Structural Rating Number is made of specific codes namely:

Rating for integral and non integral deck	(1N)
Rating for superstructure	(1N)
Rating for substructure	(1N)
Rating for bank and channel	(1N)
Rating for structural evaluation	(1N)
Rating for Deck geometry	(1N)
Rating for Vertical clearance	(1N)
Rating for Waterway adequacy	(1N)
Rating for Scour efficiency	(1N)

Socio- Economic Bridge Rating Number (6N)

Socio- Economic Bridge Rating Number is made of specific codes namely:

Rating for Connectivity between two cities	(1N)
Rating for Average daily traffic	(1N)
Rating for Social importance	(1N)
Rating for economy growth potential	(1N)
Rating for alternate route	(1N)
Rating for Environmental Impact	(1N)

PROCESS OF INSPECTION:

Based on this inventory and ratings codes, IBMS analyses the data and indicates the bridges which need further investigation which is in-depth or detailed study using various non destructive testing (NDT) procedure. The initial inventory and rating codes generates the deterioration process prognosis which is validated by the NDT procedures. A detail remedial plan is then defined for each bridge tested; which is based on the standard specifications for Repair, Rehabilitation and Strengthening of Bridges.

The objectives of this inspection and maintenance schedule are as follows:

(a) To improve operational availability of the structure.

(b) To prevent downtime and enhance the life of the structure.

(c) To avoid the accumulation of defects which manifest in the form of major defects at a later date rendering the asset unserviceable for prolonged duration.

(d) To prepare database to enable the user to detect the proper timing for carrying out maintenance.

(e) To consolidate requirements of periodical maintenance through suitable agencies/ offloading.

To achieve the above objectives, the maintenance schedule has been divided into two modules. These are: -

(a) Routine Inspection and Maintenance (RIM and RMM)

(b) Detailed Inspection and Maintenance (DIM and DMM)

The first step of inspection is the detailed visual inspection which is conducted as per various Routine Inspection Modules (RIM) . The results of the RIM decide which of the Detailed Inspection

Modules (DIM) needs to be implemented. IBMS has identified as per procedure and location of inspection over 125 RIM's and 90DIM's.

The factors attended to in RIM are as under:

Aesthetics of the Structure.

Cracks, crevices, spall on the surface of the structure. Appearance of structure as regards to painting and coatings.

Loosening and widening of gap / bond in rocks. Occurrence of Geometric deformation and deflections in any element of the bridge.

Functionality of Structure.

Seepages identification and water tightness for all water retaining structures.

Delamination and porosity in the structure.
Corrosion related symptoms.

Wearing surface and riding quality for roads, corridors, passageways etc.

Corrective Activity Post Inspection.

Grouting for control of seepage/ cracks/ porosity and patching up of carbonation coating post grouting.

Refilling the gaps for proper bonding in rocks.

Local repair for correction of spalls, crevices, corrosion and local delamination as evaluated in RIM.

Local replacement of wearing coat/ surface as required.

Routine Activity for Aesthetics
Painting of structure and crack filling.

Carbonation coating over coating.

Wearing coat and surface replacement/ overcoat.
Removal of vegetation growth.

Most of the RIM / RMM activities are pre-scheduled and should be completed within specified time frame as stipulated. The activity should be succeeded with corrective measures as required.

One of the factors that can affect the stability and cause distress is exposure of structure in different conditions i.e. area, which is above splashing of water, which shall be called as "DRY ZONE". Area below splashing zone shall be called "WET ZONE". Splashing zone is an area between HHTL +0.20m and LLTL –0.20m.

Detailed Inspection and Maintenance (DIM / DMM). Define the activities that are required for each structure irrespective of the type of usage and are to be adhered to at specific durations in the age of the structure and relate to its strengths, integrity and structural safety as defined in the maintenance schedules of that structure. DIM involve evaluation of specific parameters of the structure that define its safety and structural efficiency during its service life. These parameter include

Strength Parameters of the Structure.
Structural Integrity (overall and specific)
Grade of concrete
Corrosion potential in concrete/ steel matrix.
Adequacy of steel sectional area.
Vibration monitoring of structure and deflection evaluation under dynamic loading.

Balance Service Life Evaluation.
Evaluation of expected loss of service life due to corrosion.
Evaluation of expected service life based on strength parameters evaluated as per RIM.
Evaluation of balance service life based on results of all parameters evaluated in RIM.

Event Triggered Inspection.
Inspection for fire damaged structure.
Inspection for structure post flooding.
Inspection for sudden undersigned impact loading.
Inspection post-local failure of structure.

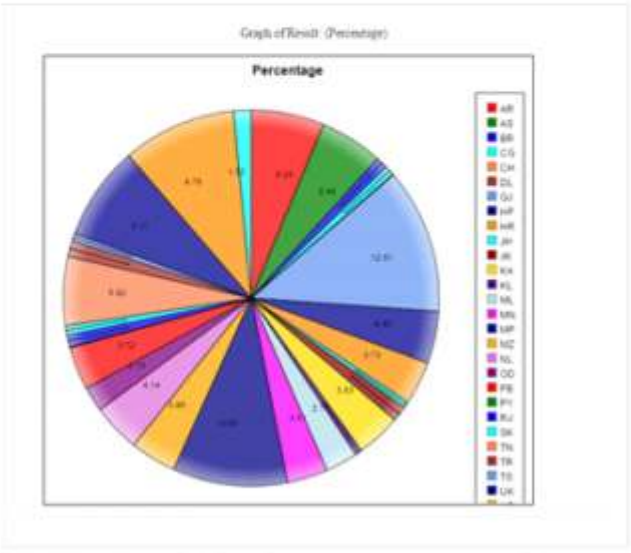
ANALYSIS OF DATA:

Asset Management depends hugely on the capability of the software to conduct analysis on the data to generate reports for various functional needs of the user department. IBMS being a system for National Highways is designed to provide tools to the Ministry officials to generate statistical analysis of the data to be able to answer Queries related to the same. Some of the filter

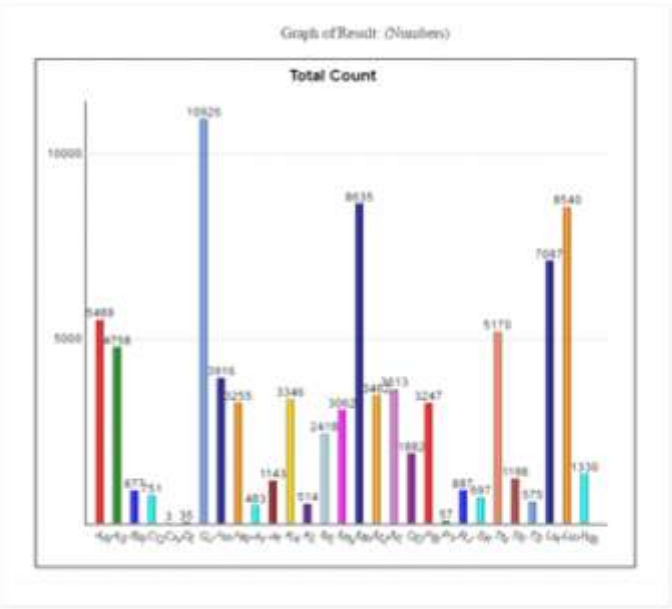
options are shown below:

Statistical Analysis that can be done using IBMS basically enables Division of database as per following parameters is possible in IBMS

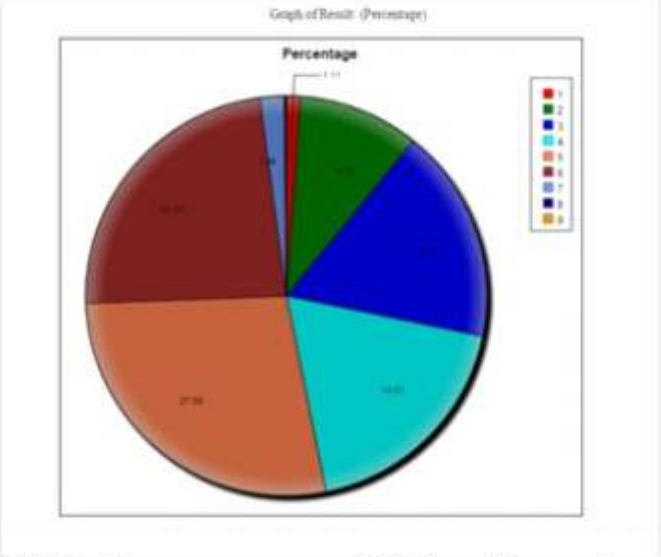
a) As per age of bridge
b) As per Daily Traffic count
c) As per type of Bridge
d) As per structural form of the bridge
e) As per material of construction
f) As per feature crossed by the bridge
g) As per present conditions by using Classification count method.
h) As per National Highway number
i) As per state, RTO district etc.



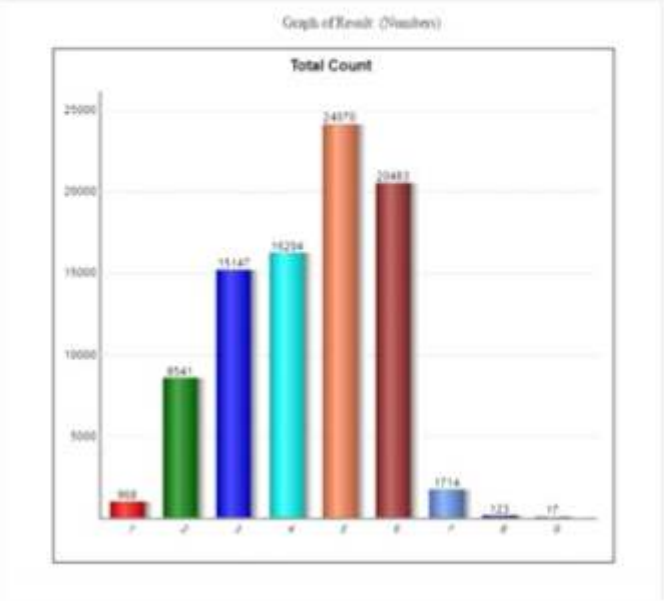
Distribution of Bridge as per states (Percent)



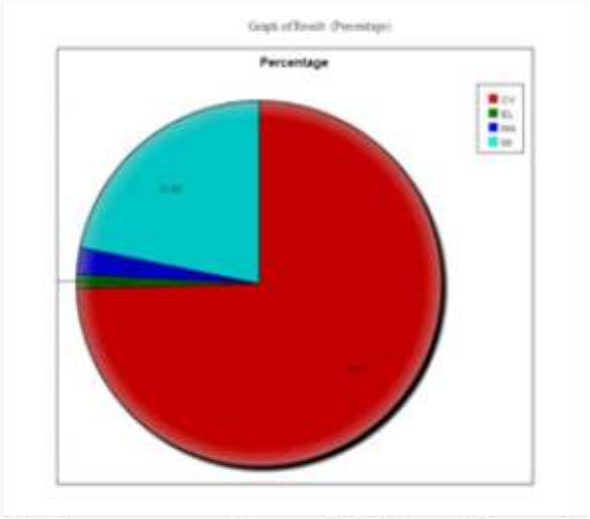
Distribution of Bridges as per states (Total count)



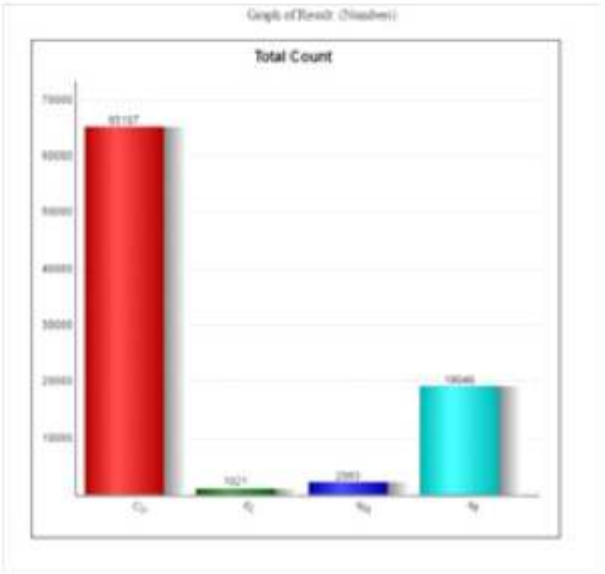
Distribution as per age of Bridge (Percentage)



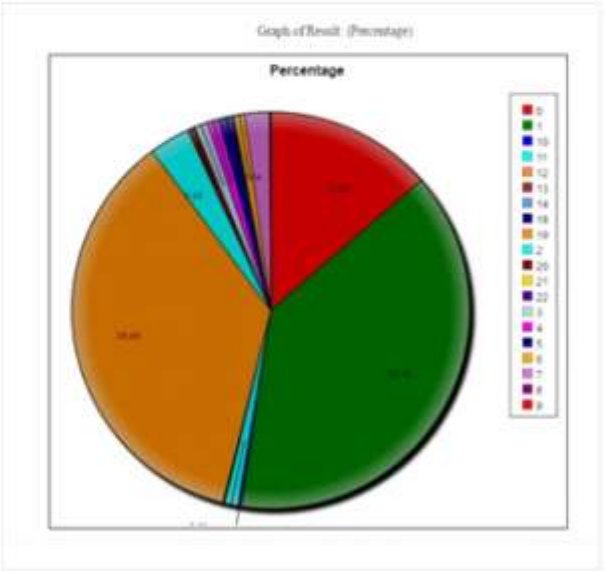
Distribution as per age of Bridge (Total count)



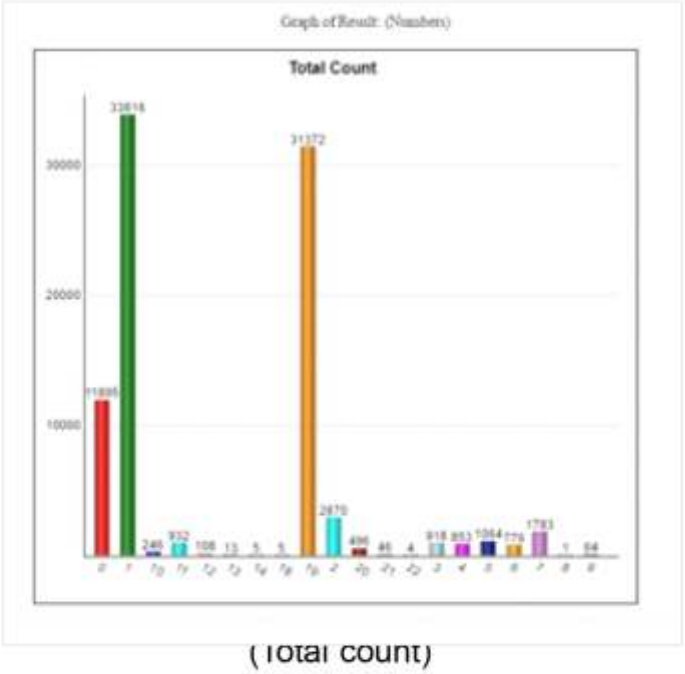
Distribution as per Type of Bridge (Percentage)



Distribution as per Structural form of Bridge (Percentage)



Distribution as per age of Bridge (Total count)



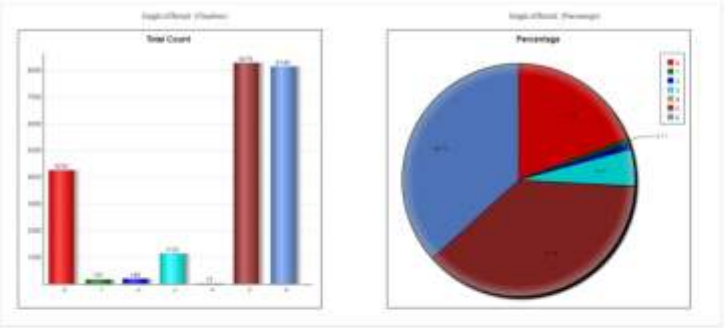
(Total count)

Technical Analysis of the data enables the user to define the level of deterioration in any bridge and to assign proper corrective action based on the analysis. Classification count is evaluated for each bridge post inventory and condition ratings to enable the user differentiate the bridges for further inspection, testing requirements. Based on the inspection and testing conducted, the designer is able to define and design the remedial measures that are required to be adopted to bring the bridge in safe zone. This cost of rehabilitation/ repairs/ retrofitting enables the user to then assign a priority to maintenance activity using the Priority and Ranking module of IBMS

Typical analysis of data could yield results like the one given below

S. No	Classification Category	Total Number
1	Immediate Inspection essential to decide if to reconstruct the bridge or rehabilitate	4250
2	Bridge to be closed for inspection and remedial action -	157
3	Closure of Bridge Short term for local repairs	189
4	Immediate Inspection Required to identify distress zones and rectify	1133
5	Inspection Required to make the bridge safer	15
6	Planned Inspection to be implemented as Bridge is safe	8276
7	Bridge safe.	8140

The graphical representation can be viewed as under:



PROCESS OF PRIORITY AND RANKING OF BRIDGES:

Ranking of bridges for repair is driven by a logical protocol which is based on the cost of repair, the importance of the bridge in Social and Economic scenario and the level of deterioration defined by the ratings as defined by Structural Rating number used in conjunction with the traffic on the bridge and age of bridge. The ranking module of IBMS defines a list of bridge that need to be repaired / retrofitted as per priority and can be taken up based on total fund available with the Ministry. This brings in technical and socio-economic logic to the sequence of bridges to be repaired.

Ranking and priority for bridge maintenance is based on rating evaluation done in classification stage. Priority is defined based on observations during classification stage. Priority is based on observation for the following rating numbers

a) Bridge Structural Rating Number
b) Socio- Economic Bridge Rating Number
c) Type of road
d) Loading as per IRC
e) Rating for average ADT

The Critical Weightage is termed as Cw is then used further in the ranking system. This Cw ensures that most needed bridges having severe distress are assigned highest weightage and Cw is accorded a value of 100. Similarly for non important bridges with least or no distress; Cw is accorded a least value of 10.

Once Cw is defined the second step in defining priority is to evaluate which of the bridge is most frequented and lies on important corridors with highest load rating. This factor is defined by Importance weightage Iw

Once Iw this is defined, we have then to evaluate if the bridge or its critical component should be repaired/ rehabilitated or replaced. This decision is based on two factors. One is Age of bridge and the second factor is the cost of rehabilitation as compared to cost of replacement. Both these costs are compared for the same type of bridges with cost index being the same for the comparison. Also the costs are compared for per square meter of deck area.

Age of bridge is compared to the cost of repair/ rehabilitation on a graph. This graph basically also determines if the bridge is to be repairs/ rehabilitated or replaced. Costs are taken as the average cost of construction of new bridge in today scenario on per square meter of bridge deck area. Similarly total cost of rehabilitation or repair is then converted to cost per square meter of deck area to be used for plotting on the graph.

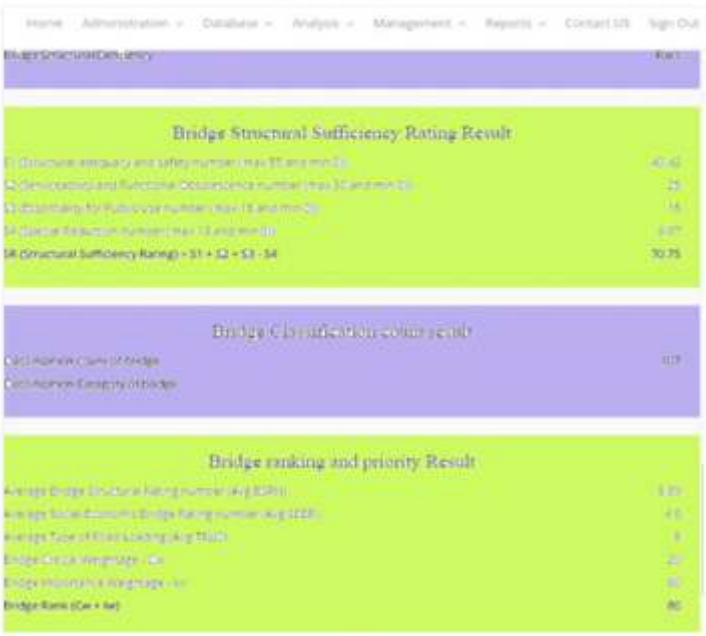
All bridges to be repaired or rehabilitated or replaced in a given period of time are taken together to form a set of bridge. Ranking of the bridge is always assigned from within this set of bridges being compared. Ranking of the bridge is given by RankBrig Where RankBrig is evaluated by arranging all bridges as per their Sum of Weightages WSUM in ascending order.

WSUM = Cw + Iw.

When WSUM is highest for a bridge that Bridge is assigned the RankBrig = 1 and for a bridge which has WSUM is lowest for a bridge that Bridge is assigned the RankBrig = Last

This type of ranking allows the various rating evaluation and bridge importance to be accounted for in the decision making process for deciding which bridge shall be repaired first. First Repair Worst Damage (FRWD) principle is hence used here in a modified form to account for importance of the bridge.

Various other modules like Deterioration rate, Prediction of balance life, Estimation of Life cycle cost, Optimization of funds are also part of the IBMS.



OBJECTIVES OF IBMS

a) Maintain Bridge inventory and network in an efficient manner
b) Guarantee safety of the users for specified risks.
c) Determine inspection and maintenance needs
d) Ensure level of service
e) Predict future needs of funds
f) Optimize fund utilization
g) Prioritize asset for maintenance needs
h) Predict balance service life and optimize its life cycle costs
i) Provide accurate and real time information of the asset to users and owners

Conclusions

Government of India constitutes various working groups to review the growth potential and scope of work that can be done in each 5 year plan. One such group is the Working Group on Central Road Sector. They submitted a report in 2011 for their recommendation for the 12th Five year plan (2012-2017). In that report the group makes a very strong case for implementation of Bridge Management system in a timely manner. Writing about Bridges they have stated that "A System of maintaining and updating database on bridge inventory needs to be set up for enabling timely decision making regarding formulating their maintenance strategies.

In the concluding part they have stated

Quote "Roads are valuable assets and justify preservation and regular maintenance. A modest erosion of 5% due to deficiency in maintenance, the loss is much more than the amount required for its preservation. THERE IS NO ECONOMIC SENCE IN LOSING OUR ASSETS." Unquote

Establishment of IBMS ensures that this concluding remark is upheld and implemented on National Highways network. NH network is about 2% of the road network in our country. The way forward is to implement IBMS on all state highways and also on all Major district roads so that at best 50% of road network can be brought under the gambit of IBMS which will ensure that IBMS is Protecting Indian Bridges.

Er. Sachin Joshi
Team Leader Indian Bridge Management System at IDDC Engineers Pvt Ltd
Mumbai Area, India
Civil Engineering

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BRIDGE REPAIRS AND REHABILITATION

S.S. Bhonge
Compiled by Vedang Vadalkar

Introduction:

The road network is a lifeline for any region as it provides the means for the people of the region to move large distances uninhibited. It also helps in connecting most remote of the places to the urban settlements which are the hotbed of activity in any region. The terrain is not always continuous and at certain places, there arises a need for the construction of bridges to overcome the topographical undulations. Bridges are built across rivers between hillocks and over the sea to facilitate fast and undisturbed movement of vehicles.

According to the World Bank statistics, almost 90% of passenger transport and 65% of freight transport in India is by roads. So the bridges on these roads are ingrained as a vital fabric in transportation. Thus, maintaining serviceability and reliability of this aging infrastructure deserves high priority.

Bridges in Maharashtra:

Bridges are an integral part of the road network. Therefore, construction of bridges has always been a priority of the State Government. Maharashtra, like all other states in the country, has a diverse geography and has constructed all types of bridges after independence. A Large number of bridges constructed pre-independence are also being maintained by State's PWD. Maharashtra has about 17000 bridges, 500 Flyovers / ROBs. The variety of forms and types of bridges in Maharashtra demonstrate the combination of art and technology. Maharashtra is also home to a number of ancient and historical bridges dating back to the British era and are still operational.

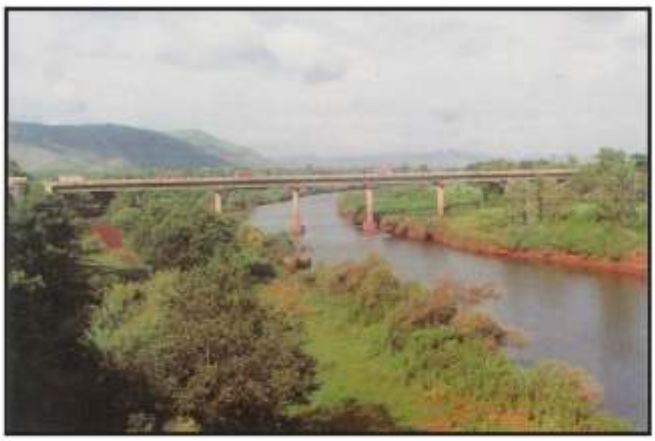
With the advent in the development of new and stronger materials and construction techniques, the state of Maharashtra has advanced from stone masonry arch bridges to long span pre-stressed concrete bridges. Consultants and the department, tasked with the building of these essential structures, will have to go hand in hand for this important duty of maintaining the assets of the society.

Various types of bridges presently in use in the state of Maharashtra are:

- Arch bridges
- RCC bridges
- PSC bridges
- Balanced Cantilever bridges
- Sky-walks
- Grade Separators
- Box cell bridges
- Viaducts
- Flyovers
- Steel bridges
- Foot over bridges
- Cable stay bridges

Landmark Bridges in Maharashtra:

Bridge across Tapi river, Jalgaon.



Bridge across Koyna river.

Bridge across Wainganga river, Pauni.

Bassein creek bridge.

Thane Creek Bridge

Need for inspection and maintenance:

Maharashtra has about 17000 bridges and 500 Flyovers / ROBs built over the years with the oldest one dating back to the British raj. It is now a need of the hour to assess our strategy of inspection, Maintenance, Repair and rehabilitation of Bridges. Regular inspection, Maintenance of bridges are necessary activities to avoid the unnecessary expenditure on major repairs/reconstruction.

The average life span of bridges is about 60 to 100 years. Currently, many bridges have crossed this design lifespan of 100 years and were built after 1960. The arch bridges are the most resilient and as a result, survive the longest as they are totally in compression instead of tension as in the case of modern bridges

Most parts of Maharashtra were subjected to very heavy rainfall in 2005 monsoon causing unprecedented damage due to the flooding of all the major rivers in the state. A similar situation arose in Kolhapur, Alibaug, Palghar and parts of Konkan in the monsoon of 2016. The flood levels in rivers exceeded the design levels creating concern in the minds of Engineers maintaining the bridges. The 1993 Latur earthquake underlined the importance of repairs & rehabilitation of bridges.

Technical Approach for Inspection/Rehabilitation:

1. Evaluation of the Structure from Documented Data Base & Inspections:

   The Guidelines for Inspection and Maintenance of Bridges are given in (IRC: SP-35).

2. Locating Damages /Defects/Distresses:

   a. Visual inspection

   b. Various testing methods to complement the results of the visual inspection.

3. Analysis of, Causes of Damages/Defects and Distresses:

   a. To determine the effect of damage to the structure's life and load carrying capacity.

   b. To determine its cause so as to determine an effective retrofit method.

4. Evaluation of Results of Structural Assessment: Data of investigation of a damaged structure including monitoring of its distress forms the basis for the decision regarding corrective action to be undertaken.

5. The design of Repairs for Rehabilitation/ Strengthening Works:

   To design an appropriate retrofitting/repair system which shall conform to the relevant IRC Codes.

6. Proposals and Estimation of Costs:

The proposal & the cost of the proposal will depend on whether:

a. only the cause of the damage has to be removed or

b. the structure must be restored to original condition or

c. the structure needs to be upgraded for its load carrying capacity.

Deterioration of concrete bridges:

The potential penalties for the ineffective inspection of bridges can be very severe. Instances of major bridge collapses are rare but the results are truly catastrophic. Current visual techniques prove to be inefficient. The life extension approach will require increased use of NDT, use of modern construction chemicals, nano-technology (CFRP – Carbon Fibre Reinforced Polymer) laminates, bridge instrumentation.

Corrosion of steel, cracking, Carbonation of concrete and other damages affect a bridge's load carrying capacity. Therefore, all of the elements that directly affect the performance of the bridge including the footing, substructure, deck, and superstructure must be periodically inspected or monitored. Fatigue cracking and corrosion will become increasingly important considerations as we go beyond the 50-year life expectancy. However, on an average significant distresses are noticed, before the bridge reaches mid-life i.e. 35 to 40 years.

Factors in deterioration of Concrete bridges:

- Aging:
- Construction deficiency
- Hydraulic problems
- River flow patterns and linear waterway
- Foundation settlement
- Failure of bearings
- Corrosion of rebar and pre-stressing steel
- Change in design flood level
- Loss of prestress
- Design deficiency
- Natural disasters like earthquakes and floods
- Accidental damage from collision or fire
- Overloading
- Clogging of expansion joints

Factors in deterioration of Concrete bridges:

Typical distress in bridges:

- Cracks
- Spalling of concrete
- Rebar Corrosion
- Cable Corrosion
- Excessive Deflection
- Shifting of Deck
- Settlement of Foundation
- Snapping of Cables
- Bearing Displacement
- Failure of expansion joints
- Railing/ crash barrier failure
- Damages to wearing coats
- Erosion and scouring in river beds

Bridges constructed in Masonry, which have crossed a life span of about 75 to 100 years. The actual safety level of these Bridges is uncertain due to the rise in traffic demand and the material deterioration that have occurred since they have been built.

Applicable IRC Codes for reference:

- IRC SP-18: Manual for highway bridge maintenance, inspection
- IRC SP-35: Guidelines for inspection and maintenance of bridges
- IRC SP 37: Guidelines for evaluation of load carrying capacity of bridges
- IRC SP 40: Guidelines on techniques for strengthening and rehabilitations of bridges
- IRC SP -51: Guidelines for load testing of bridges
- IRC SP 52: Bridge inspectors reference manual
- IRC SP 60: An approach document for assessment of remaining life of concrete bridges
- IRC SP 74: Guideline for repair and rehabilitations of steel bridges
- IRC SP 75: Retrofitting steel bridges by pre-stressing

Inspection:

The purpose of the inspection is to provide

assurance that the bridge is structurally safe and fit for designed use and identify potential sources of trouble. It records periodically and systematically the condition of the structure and provide feedback to designers and field engineers for effective performance.

- Routine Inspection: Carried out periodically by engineers in-charge of the bridge, twice a year, before and after the monsoon.
- Comprehensive or principal inspection: More intensive and detailed inspection mostly visual assessment supplemented by standard instrumentation aids.
- Special Inspection: Undertaken in the event of an unusual occurrence like earthquake, accident, unprecedented floods, major weakness noticed during the comprehensive inspection.
- Underwater inspection:

Method of the underwater inspection	Purpose of the underwater inspection	Detectable defects on the surface of the structure
Level I	General visual inspection to confirm condition and detect damage	Major spalling and cracking
Level II	Detect surface defects normally observed by marine growth	Surface cracking and crumbling, rust straining, exposed rebar
Level III	Detect hidden and damage which is about to begin	Location of rebar, beginning corrosion of rebar, change in material strength

Inspection of inaccessible portion of bridges

Structural audit: Structural audit is an evaluation of an overall health and performance check-up of structure, like a doctor examining a patient. It ensures that the bridge/flyover is safe and contain no risks. It analyses and suggest appropriate repairs and retrofitting measures required for the structures to perform better in its service life

The purpose of structural audit:

- To save human life and bridge (structure)
- To understand the condition of the bridge
- To find critical areas to repair immediately
- To enhance life cycle of the bridge by suggesting preventive and corrective measures like repairs and retrofitting.

Scope:

- Visual Inspection
- Distress Mapping
- Non-Destructive Testing
- Final Inspection Report
- Recommendations
- Structural Stability Certificate.

Distress Diagnosis:

Many times it is difficult to ascertain the actual cause of distress where many variables are involved for example poor quality of construction (faulty detailing, improper materials and workmanship), shrinkage, creep, reinforcement corrosion etc., The quantification of the level of distress is required to succeed the repair / strengthening strategy.

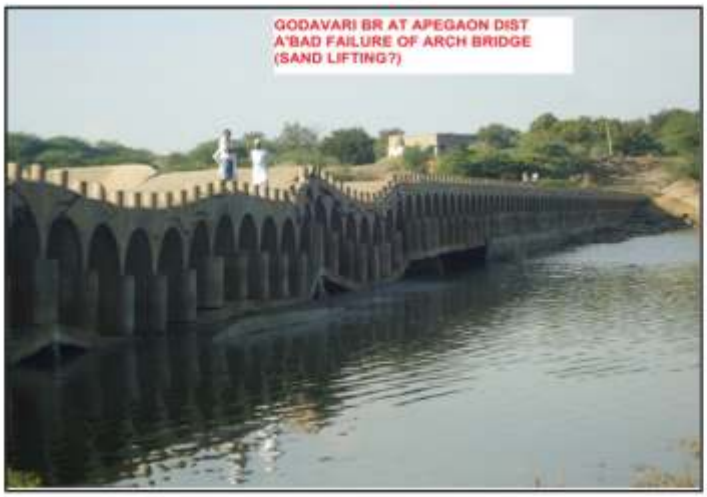
Following tests may be required to ascertain the cause and level of distress:

- Determination of Compressive Strength from NDT and concrete cores other NDT includes:

a. Ultrasonic pulse velocity test
b. Rebound hammer test
c. Half-cell potentiometer test & Resistivity Test
d. Vibration Measurement.
e. Pile integrity test/ Pulse eco method.
f. Span load test
g. Core cutting test
h. Core trepanning test
i. GPR – Ground Penetrating Radar
j. Rebar Locator

- Crack pattern evaluation
- Vibration Analysis
- Load tests to find out deflections
- Corrosion Studies (pH, carbonation depth, chloride)
- Deflections from Instrumented Bridge.

Savitri River Bridge, Mahad.



Vegetation growth

Erosion at the base

Erosion of soil below the abutment

Improvement of the longevity of structures:

Grouting technology: Grouting is one of the most important strengthening support system available for any structure if we want it to stand for longer durations. Grouting is a process of ground improvement /building strength/Filling voids by injecting fluid-like material into the subsurface soil or rock or concrete mass. Grouting is the injection of the specially formulated compound into cracks, pores, fissures or voids.

Applications:

- Bridges and roads
- strengthening and sealing of brick and stone masonry on bridges
- repair of cracks in the constructions
- improvement of subsoil parameters under pillars (also in rivers)
- anchoring and micro-piling of foundations

Properties:

- Fluidity
- Minimum bleeding and segregation
- Low shrinkage
- Adequate strength after hardening
- No detrimental compounds
- Durable

Methods of grouting:

- Chemical grouting
- Compaction grouting

Types of grouts:

- Cement grout
- Polymer injection grout
- Epoxy based injection grout
- Polyurethane grouts

Long-term monitoring of bridges:

Benefits of long-term monitoring

- Real-time monitoring and reporting.
- Reducing downtime.
- Improving safety and reliability, and
- Reducing maintenance costs.

Rating of bridges:

The rating of the bridge becomes essential when:

- The design live load is less than that of heaviest commercial vehicle plying on it.
- Design live load is not known.
- Records or design drawings not available.
- If during the inspection, bridge found to be in distress of serious nature.

Conclusion:

The durability of structures is one of the main parameters at the time of design and construction. Similarly, the durability of repair shall be given equal priority. Anti-carbonation paint and Corrosion inhibiting admixture in concrete play very important role in the durability of structure and its repairs. In Maharashtra, attention needs to be focussed on preservation and rational management of a number of bridges built in recent past by PWD, MSRDC etc. for the next 5 years. And to rehabilitate and strengthen the old bridges which have deteriorated due to inadequate maintenance.

"Technology in the hands of a skilled operator makes it possible to do more work of an even higher quality. But in the hands of one who has not mastered the skills of his or her profession, that technology merely enables one to do tremendous damage".

- Herbert T.

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Response From Reader

Mr. M.D.Tambekar

Gentlemen ,

At the outset I must congregate all of you for producing ISSE journal with relevant information so useful to profession.

Below are my thought regarding recent news on role of architect & structural Engineers. In fact we have derived this from British Era. Some 200 years ago, building were small and limited to 2-3 storeys Hence London county council adopted the term Architect for sharing all rights and planning to architects including stability.These were load – bearing walls with some sort of flooring (example – several old monumental Buildings in Mumbai – even in development of Ballard Estate about only 100years ago)!

But with scarcity of land, multistoried buildings have now come into vogue, which surely require structural Engineers. In short the roles of Architect and structural Engineers are complimentary and depend 100% on each other in the interest of final product.

In short, it is like this :

Architect :- Space planning as per local rules and bye laws

Structural Engineers :- design of foundation, building frame work with economy, knowledge of material available their use and testing under engineering supervision, inspection from time to time till the skeleton stand up. This is 70-80% of project.

Architect comes in to pictures for cosmetic, interior etc. to make it livable – and saleable !

Thus, both roles are complimentary and can not be separated. Unfortunately, we engineers. Were sleeping when Architects bill was passed in parliament to make it a law !

That is none can use title of " Architect " unless he is so qualified. This and the legacy of London bye laws crept in our rules. Time has come – in fact it is too late – to incorporate role of structural Engineer at all stages and to erect a stable, economic structure. BMC & Govt. of Maharashtra can make an ideal start as example for other states by involving knowledgeable expert and (perhaps institution from both side) only Architect can not do justice.

Warning :-

This is going to be resisted by Architect & arch intuitions vehemently but the fact remains that Architect are not qualified to certify durability and stability of foundation & superstructure.

Yours Sincerely,
Sr. Engg. Mr. M.D. Tambekar
(Age 90 Years)

Sir, when I said "IT people have come to see you", I meant computer professionals and not Income Tax officials

INDIAN SOCIETY OF STRUCTURAL ENGINEERS

ISSE

C/o. S. G. Dharmadhikari, 24, Pranit Niwas, S. K. Bole Marg, Dadar (W), Mumbai - 400 028
Tel.: [illegible] E-mail : [illegible] Website : www.isse.org.in

Ref : UD/ Defect liability/Objections/01
Date : 08 April 2017

To,
The Deputy Director (Town Planning),
ENSA Hutments, E-Block,
Azad Maidan,
Mahapalika Marg,
Mumbai – 400 001.

Sub: ISSE Suggestions / Objections to TPB/4317/1123/CR-32/2017/UD-11 dated 8th March 2017 regarding defect liability of Structural Engineers.

Respected Sir,

Indian Society of Structural Engineers is a body of about 1600+ Structural engineers connected with the building industry. We have been making earnest efforts to have healthier structures by frequent seminars, publication of books like "Seismic Design of R.C.C. structures", and also quarterly journal on structural engineering subjects.

With reference to above subject matter please find enclosed following objections.

1. Over all responsibility during defect liability period is of owner /developer only.

2. Liability of a structural engineer is limited to providing correct structural design based on parameters provided by the Owner / client / architects and in conformity with the prevailing code of practice at the time of design like National Building Code 2016 Part - 6 . Therefore, there is no question of any defect liability period for structural engineers. Hence, **the name of Structural engineer must be deleted** from this proposed provision of liability.

	Original Provision	Modification suggested
a)	Any or all of the following shall be held liable for any structural flaws or defects in the building with DLP, as per Sl. No. (a) and above for period of Two (02) years after the date of grant of occupation cum building completion certificate, except in case of natural calamities, damages, due to man made, i. Architect/Owner ii. Structural Engineer iii. Site Supervising Engineer iv. Construction Company including Contractor, sub-contractor v. Consultants appointed for various activities involved in the construction work.	Any or all of the following shall be held liable for any structural flaws or defects in the building with DLP, as per Sl. No. (a) above for period of Two (02) years after the date of grant of occupation cum building completion certificate or completion certificate issued by Authorities wherever is under practice except in case of i. Natural calamities damages, due to war, riots or if the damage in the building has occurred in the following circumstances: ii. Use of building for the purposes other than the which it has been designed iii. Any changes/ modifications to the original approved building plan / layout and which structural design is prepared by structural engineer carried out by the owner/its agencies without the consent or approval of the professional / structural engineer who has designed it. iv. Repairs/modifications/ changes/structural renovations / modifications carried out by the owner/its agencies. v. Any components with the safety norms by the owner/its agencies. vi. Structural due to damage from fumes, flood, water logging, ingress due to weakening effect, that would affect the structure. vii. Tampering with Strength / stability of the structure or carried by unlicensed designers appointed by occupants / owner without the knowledge of engineer/consultants. viii. Lack of periodical maintenance or inadequate maintenance by the owners/occupants. ix. Damages caused due to any reasons arising out of specialized consultancy/ advisory works with regard to design and supervision of

		the work entrusted to them, who were appointed / engaged in consultation with the Client or otherwise. • Damages caused to the building for the reasons beyond the control of the original Consultant. i. Architect/License Surveyor ii. ~~Structural Engineer~~ iii. Site Supervisor/Site Engineer iv. Construction Company including Contractor, sub-contractor v. Consultants appointed for various activities involved in the construction work.
b)	The above mentioned professional and the Construction Company including contractor and sub-contractor may take decennial professional liability insurance to cover such liability	Owner / developer must take care of all insurance policies pertaining to all professionals involved in the project. ***No any financial liability shall be there on the structural engineer.***

ISSE office bearers will be happy to have any meeting with the concerned official.

Thanking you.

Yours truly,
For and on behalf of members of Indian Society of Structural Engineers

Prof. O S Joshi
ISSE President

Edited and published by Hemant Vadalkar for ISSE, C/o S. G. Dharmadhikari, 24, Pandit Niwas, 3rd floor S. K. Bole Road, Dadar(W.), Mumbai 400 028. Tel. +91-22-24314423. e-mail issemubai@gmail.com Web : www.isse.org.in for private circulation and printed by Sudarshan Arts, 10 Wadala Udyog Bhavan, Naigaon Cross Road, Wadala, Mumbai - 400 031.

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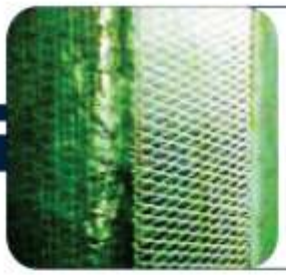

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