SUPPLEMENT

SEMINAR ON BRIDGE INSPECTION & DIAGNOSIS HELD ON JUNE 03, 2023 AT MASHHADI HALL OF PAKISTAN ENGINEERING CONGRESS - SYNOPSIS

SEMINAR FOR *"BRIDGE INSPECTION AND DIAGNOSIS"* HELD ON SATURDAY 03RD JUNE 2023 AT MASHHADI HALL PAKISTAN ENGINEERING CONGRESS HQ (SYNOPSIS)

The seminar was held in collaboration with Communication & Works Department (C&W), Government of the Punjab to discuss various methodologies to assess the condition of the bridges, mechanism to define bridge rating and inspection procedures adopted in Japan, which are considered to be an integral part of effective Road Asset Management.

C&W Department, Government of the Punjab is developing Pavement Management System (PMS) and Bridge Management System (BMS) with technical assistance of Japan International Cooperation Agency (JICA). BMS comprises of compiling inventory data of bridges, inspection mechanism & manuals, diagnosis of bridges periodically and then prioritization of bridge maintenance works to formulate "Annual Maintenance Plan". The demand of budget is to be generated based on said prioritized plan to ensure timely Maintenance & Repair (M&R) of damaged structures. Unlike pavements, severe damage or collapse of bridge structures can not only prove to be fatal but it can also cause traffic disruption. This may lead to road network dis-connectivity, bringing the entire socio-economic activity to a halt. Therefore, it is need of the hour for Punjab province to compile a database and have a close inspection of bridges to diagnose damage at an early stage in order to repair it which may otherwise lead to complete or partial collapse of structure. The conditions of the structures on road network are generally inspected visually by evaluating the distress severity and extent of damage. Based on these parameters, an overall rating is assigned to each structure and accordingly, budget demand for M&R of structures is to be prepared for approval. Inspection of the bridges itself is a very difficult and cumbersome job and cannot be standardized as type of structure, construction material differs from structure to structure. Therefore, each bridge needs to be considered separately for inspection and diagnosis.

There are many complexities associated with bridge inspection &diagnosis and to discuss some of them, experts from academia, bridge designers of C&W Department and Japanese expert (from Pacific Consultants Pvt. Ltd. hired by JICA) were invited to the seminar. The topics of papers presented in seminar are given below;

1. Condition Assessment of Bridge (History, Overview and Case Study)
2. To index the Bridge Performance by the Vehicle Induced Vibration
3. Common Defects Found in Various Bridges and their Rectification Techniques
4. Detailed Inspection of Bridges and Rehabilitation
5. Corrosion Damage in Steel Girder Bridge and its Evaluation
6. Introduction to Master Bridge Damage Catalogue

After the research papers were presented, an interactive Question & Answer session took place between the Speakers and the audience. The Chairman and Co-Chairman for the technical session were Engr. ZubairImranKhawaja and Engr. Ch. Muhammad Arif, AZ Engineering Consultants. The concluding remarks were delivered by Engr. ZubairImranKhawaja. Shields were conferred on the speakers by Pakistan Engineering Congress. It was a highly attended event.

SEMINAR ON BRIDGE INSPECTION & DIAGNOSIS HELD ON JUNE 03, 2023 AT MASHHADI HALL OF PAKISTAN ENGINEERING CONGRESS (WRITE-UP).

Communication and Works Department, Government of Punjab

A seminar was held on 3rd June 2023 (Saturday) in Pakistan Engineering Congress regarding "Bridge Inspection & Diagnosis." The speakers from academia, bridge designers and Japanese expert from Pacific Consultants Pvt. Ltd. hired by Japan International Cooperation Agency (JICA) were invited. The topics of papers presented in seminar were given as under.

Condition Assessment of Bridge (History, Overview and Case Study) by Dr. Azhar Saleem

To index the Bridge Performance by the Vehicle Induced Vibration by Dr. Tauqir Ahmed

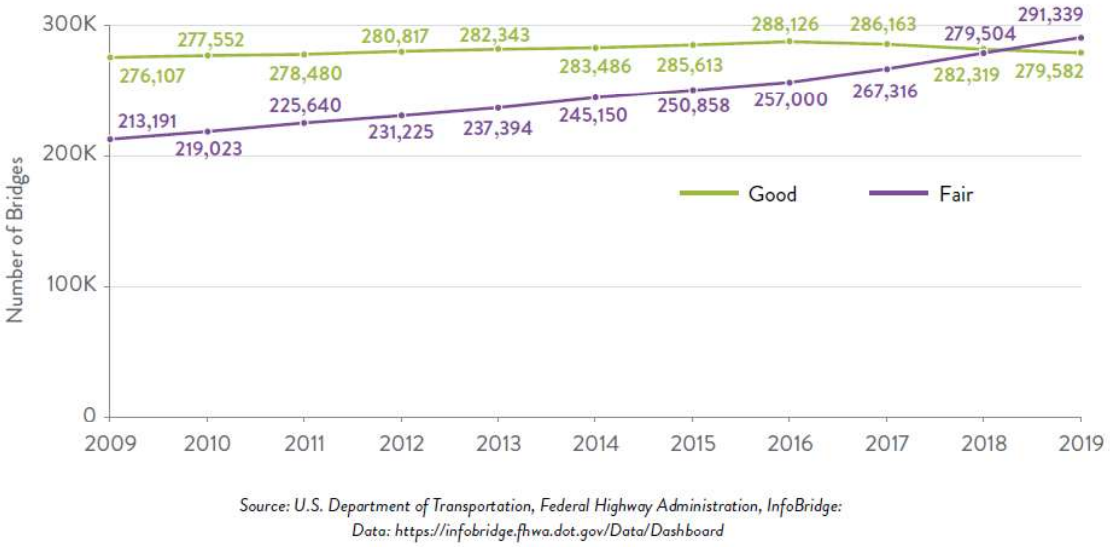
Common Defects Found in Various Bridges and their Rectification Techniques by Engr. Hafiz Shoaib.

Detailed Inspection of Bridges and Rehabilitation by Engr. M. Afzal

Corrosion Damage in Steel Girder Bridge and its Evaluation by Dr. Nauman Khurram

Introduction to Master Bridge Damage Catalogue by Eiichi Tsuji MUTO

The First Paper was presented by Dr. Azhar Saleem, Associate Professor, Civil Engineering Department of UET Lahore. In the introduction, the history of bridge inspection in USA and formulation of National Bridge Inspection Standards (NBIS), 1971 were discussed. The USA had started bridge condition evaluation and rating system in 1967, when Silver Bridge on Ohio River failed and collapsed in West Virginia resulting in a loss of 46 lives. After this incident, the NBIS were launched as first nationally coordinated bridge inspection program which were updated over the years and latest version was issued in 2022. These standards help the government / authorities in Informed budgetary decisions as part of Asset Management Program. As per these standards each State should maintain a bridge inspection organization and after every two years, bridges are inspected, and National Bridge Inventory (NBI) is updated. In this regard, Specifications for the National Bridge Inventory and Bridge Inspector's Reference Manual (BIRM) were formulated and shared with each State. As a result, it was determined that there are more than 617,000 highway bridges across the United States, 42% are at least 50 years old, 7.5% are structurally deficient, meaning they are in "poor" condition and structurally deficient bridges specifically are nearly 69 years old on average (Infrastructure Report Card, 2021). As per the Federal Highway Administration (FHWA) definition of structurally deficient bridges with one of the key structural elements — the deck, superstructure, substructure, or culverts — are rated in "poor" or worse condition.



Source: U.S. Department of Transportation, Federal Highway Administration, InfoBridge: Data: https://infobridge.fhwa.dot.gov/Data/Dashboard

Figure-1: Bridge Condition by Year in USA

In USA, federal government mandates national bridge inspections for all bridges on a periodic basis. Inspection interval can range from 12 to 48 months and is based on the bridge condition, type of bridge, traffic, location, and age of the structure. If the bridge inspector finds any deficiency in the structural capacity, that bridge could be posted for weight, or speed restrictions, temporarily repaired; and/ or closed (Infrastructure Report Card, 2021).



Figure-2: I-35W bridge, Minneapolis, 2007

After the collapse of I-35W Bridge in August 2007, a joint ASCE/SEI-AASHTO ad-hoc group was formed to review the in-place bridge maintenance and inspection policies. The findings of inspection group included that (1) risk-based approach should be adopted to determine the inspection interval for bridges, instead of a pre-defined 2-year cycle. (2) Good condition bridge would be inspected after a period longer than 2 years. In Europe, longer inspection periods are normal, as much as 6 years in some cases (ASCE/SEI-AASHTO Ad-Hoc Group, 2009).

The limitation in bridge management system in USA is that National Bridge Inventory no longer tracks functionally obsolete bridges, there are still over 94,000 bridges nationwide with inadequate vertical or horizontal clearances or inadequate approach roadway geometry. Such bridges do not serve current traffic demand or meet current standards, and many of these bridges act as bottlenecks, increasing congestion and crash vulnerability due to inadequate widths, lanes, or shoulders, substandard vertical clearance, or insufficient lanes for traffic demand (Infrastructure Report Card, 2021).

Now, America's emphasis has slowly evolved from building new bridges to maintaining existing ones. New technologies, materials, evaluation techniques, and construction methods have advanced in recent years to meet this challenge. AASHTO now requires new bridges to be designed with a 75-year service life, compared to the customary 50 years, meaning bridges are now being built to last longer. Bridge engineers are now using materials such as ultra-high-performance concrete, corrosion-resistant reinforcement, high performance steel, composites, and improved coatings. All this increases resilience and adds durability, higher strengths, and longer life to bridges. New technologies are being deployed to assess bridge conditions such as infrared thermography, ground-penetrating radar, and remotely operated surveillance devices like flying and submersible drones (Infrastructure Report Card, 2021).

To have real time inspection process, engineers are designing "living bridges" where sensors are being embedded into new and existing structures to provide continuous feedback on structural conditions. Prefabricated bridge elements and Accelerated Bridge Construction are being used with more frequency to reduce the amount of time traffic needs to be disrupted while a bridge is repaired or replaced. All of these innovations, technologies, and evaluation methods are effectively allowing engineers to identify problems earlier, increase the lifespan of the bridges, stretch limited resources, and prioritize public safety (Infrastructure Report Card, 2021).

Contrary to USA, Reactive Approach of agencies in Pakistan is more common with no mandated requirement for periodic inspection and national bridge inspection standard/manual. As an initiative, a study was carried out by speaker with his MSc student as research project with scope of (1) visual condition rating of two highway bridges in the city of Lahore (2) propose an index which would represent the condition of concrete highway bridges in Pakistan and (3) emphasize on the need to adopt proactive approach for bridge maintenance and to develop a BMS in the country. Fortress Bridge constructed in 1974 and Sherpao Bridge constructed in 1974 were inspected in research project. Methodology covered the preliminary inspection, Development of as-built drawings, Coding of all members, condition rating of all members and development of Bridge Performance Index (BPI). BPI is an index from 0 – 10, designed to indicate the

overall condition and performance of the bridges based on structural elements and non-structural elements.

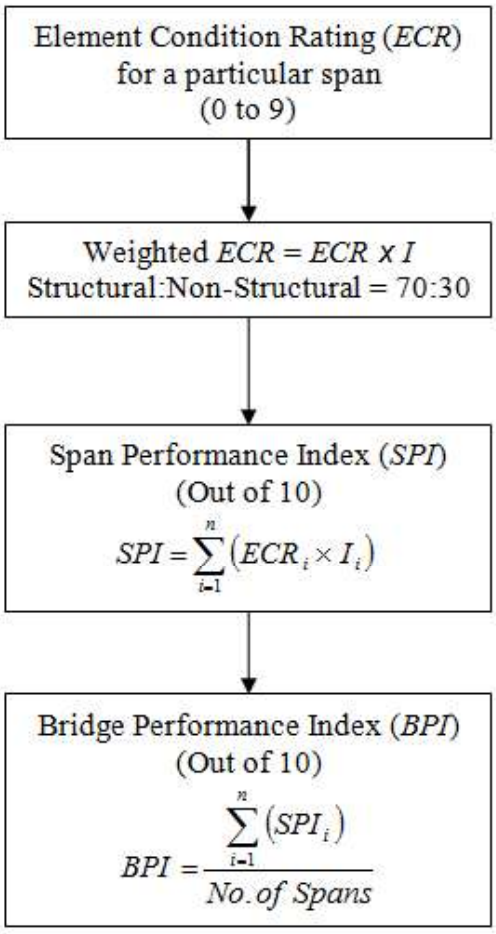


Figure-3: Bridge Performance Index (BPI)

The study concluded that there is a need to prepare bridge inventory and database of BPIs for entire bridge stock of Pakistan, which can be used to develop bridge management system (BMS). Structural elements of both bridges were in good condition however, non-structural elements like expansion joints, bearings, and drainpipe were in poor condition. Given the circumstances in the country, the frequency of Inspection should be decided based on the condition of the bridge and environmental/geographical conditions but not exceeding a fixed cycle of 2 years. This limiting time of 2 years may be changed based on the observation of several inspection cycles/BPI (M. A. Saleem, 2020).

References:

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ASCE/SEI-AASHTO Ad-Hoc Group 2009.

https://doi.org/10.1061/(ASCE)1084-0702(2009)14:1(1)

M. Azhar Saleem, Salman Bin Rafiq (2020, Oct 25). Condition Rating of Two Highway Bridges in Lahore and Proposal for Bridge Performance Index (BPI). Pakistan Journal of Engineering VOL1_1_Oct2020. http://journal.pec.org.pk/PJE_Archives/PJE_VOL1_1_Oct2020.pdf

The Second Paper was presented how to index the Bridge Performance by Using Traffic Induced Vibrations by Dr, Tauqir Ahmed, Assistant Professor, Civil Engineering Department, FAST NUCES Lahore. The paper emphasized the use of innovative techniques in bridge inspection rather than time consuming and expensive manual / visual inspection techniques. The research project was under progress by the speaker with his one of the MSc students with the objectives to develop a method for the detection of anomalous bridge span for the purpose of detailed structural health monitoring, considering the traffic flow should not be interrupted and the procedure must be efficient in time, resources, and space. The methodology of research includes recording the traffic induced vibrations, processing the data for Frequency Estimation and evaluation for selection of analogous span/bridge. The research work was mainly carried out on Saggian Bridge over River Ravi in Lahore which is a pre-cast I shaped girder dual carriageway bridge with 2 traffic lanes in each direction. Vehicle induced vibrations were recorded using smartphone accelerometer. The natural frequency from these vibration data was calculated as an indicator of structural integrity. Any decrease in natural frequency ultimately indicated decrease in stiffness of the structure due to various reasons.

Traffic induced vibration are affected by the mass and speed, surface condition, number of vehicles present at a time, different suspension system and condition of expansion joints etc. Due to these variables, it is not easy to get a single value of frequency and there will be a specific range of frequencies while processing the data. The frequency range with the most peaks was assumed to have the most valuable information. So, a valid technique was used to get a single value of frequency that will be the natural frequency i.e., Windowed Fourier Transform, Monte Carlo Simulation. Out of 16 spans, only two spans were found to have different spectrum curves which were further proposed for detailed investigations. Limitation of this study was it could only access the super-structure while deficiency in sub-structure are very hard to estimate.

The Third Paper was presented on topic of common defects in bridges and its rectifications by Hafiz Muhmmad Shoaib, Deputy Director, Directorate of Bridges, Communication and Works Department. Common defects in bridges can be broadly categorized into three main types: (1) Initial Defects which occur during construction e.g., Honeycomb, Cold joint etc. (2) Damages- due to the action of external forces e.g., flood, vehicle load, vehicle collision, earth pressure etc. (3) Deteriorations because of aging and cause changes in condition e.g., carbonation, alkali-silica reaction etc.

Some of the common defects in bridges includes siltation, corrosion of steel reinforcement, cracks, spalling, scaling, honeycombing, efflorescence, neoprene bearing

pad, deflection / settlement, scouring, crack on brick masonry, failure of column cap, problems in expansion joint, potholes in deck slab, settlement in approach slab etc. To avoid these defects, regular inspection, maintenance, and rehabilitation are vital for ensuring the long-term performance and safety of bridges.

Properly implementing rectification measures enhance bridge functionality and durability. Cleaning and removal of siltation is equally important for maintenance of bridges. Common rectification techniques include short-creting over exposed reinforcement, carbon sheeting over cracked element or crack injection with suitable sealant, protective coating against scaling, replacement of damaged bearing pads, repair / replacement of expansion joints, partial or complete replacement of slabs, replacement of piers and transoms and reconstruction of severely damaged bridge. It is also important to ensure collaboration between engineers, construction professionals, academic institution and maintenance teams for effective defect rectification and bridge damages preservation.

The Fourth Paper was presented on "Detailed Inspection of Bridges and Rehabilitation Works" by Engr. Muhammad Afzal, Ex-Director, Directorate of Bridges Communication & Works Department. The purpose of bridge inspection includes confirmation of the results of bridge condition inspection, as built drawings and design documents, investigations necessary for evaluation of defects including physical testing and / or structural analysis, and documentation of the observed defects with sufficient information for future design of required major maintenance works. A specially designed mobile inspection gantry is required to carry out detailed inspection of super structure / underside of the bridge. Detailed inspection normally covers preliminary appraisal of concrete strength, study of the nature and variety of structural crack patterns, signs of internal corrosion in reinforcement and post-tensioning steel, indirect evidence of state of grout in pc pre-stressed beams / RCC beams, determination of failure mechanism, identification of critical spans for detailed investigation and acquisition of photographic evidence of distresses.

General recommendations for rehabilitation of super structure includes re-grouting of the prestressing ducts in the primary structural components for improved durability, crack injection and epoxy repair of cracks, re-formation of damaged expansion joints, replacement of deformed bearings by raising the deck with help of jacks and improvement of the asphaltic riding surface. External prestressing of distressed deck and a system of high tensile multistrand post-tensioning encased and protected in PVC ducts be applied. This system can be installed on the existing structure using specially designed brackets.

Bridge rehabilitation after detailed inspection was carried out for bridge over Harrow River on Haripur Taxila Road in District Rawalpindi by the Communication & Works Department in 2014-16. It was a 13-span bridge with span length of 52.5 feet. The bridge was designed with I-shaped 4 girders along with RCC slab in one span. The foundation of bridge was composed of 4 No piles of 30 inches diameter. The bed of Harrow River at structure location was severely scoured due to narrowing of waterway by dumping of stone dust on upstream bank of river by crushers.



Figure-4: Excessive Scouring in Bridge over Harrow River



Figure-5: Bed of Kansi Nullah Degraded by Excessive Scour due to Dumping of Waste Material on the Banks

Additional piles along with pile cap was proposed along with stonework flooring in effective spans. Guide banks were also proposed and constructed at site to guide water in specific waterway.

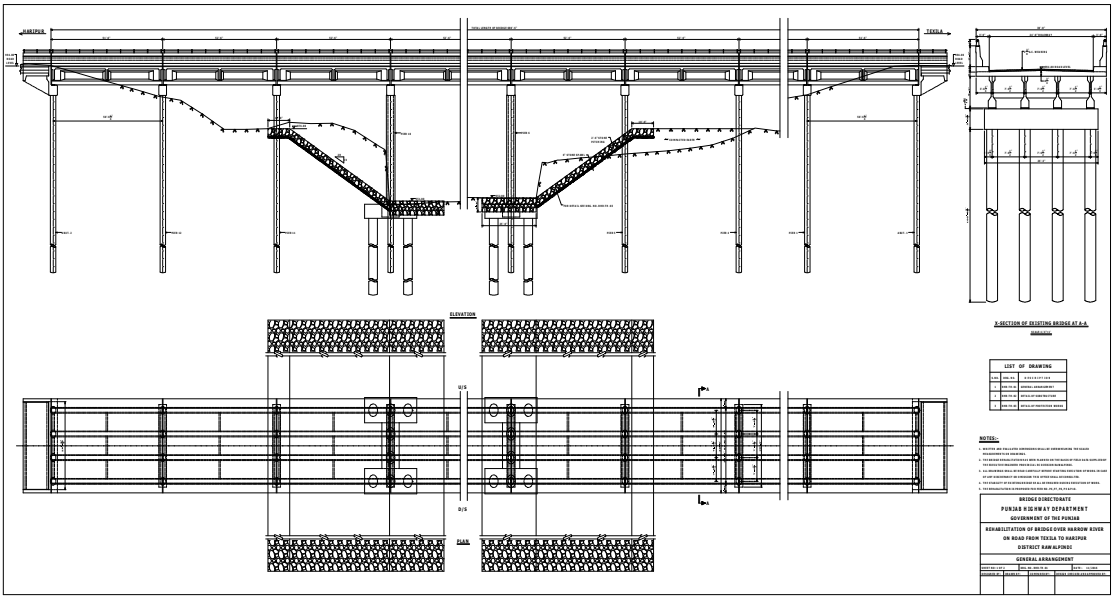


Figure-6: Rehabilitation Work Proposed for Bridge over Harrow River to protect unsafe pile foundations.

The Fifth Paper was presented on corrosion damages in steel girders bridge and their evaluation by Dr. Nauman Khurram, Associate Professor, Department of Civil Engineering, UET Lahore. Majorly, steel bridges in Pakistan are possessed by Pakistan Railway which are mostly constructed in British era. About 48% of total railway bridges (14895 Nos.) are made of steel and currently, 936 Nos. of bridges are abandoned. Many of steel bridges are above 100 years old and affected by wear and tear due to corrosion. Lack of regular maintenance is the main cause of degradation in these steel bridges.

Steel bridges are basically integrated due to fatigue and corrosion. Fatigue depends on traffic volume & intensity, No. of loading cycles while corrosion depends on environment, exposure conditions and preventive measures adopted. Corrosion is complicated to control due to its different patterns and variability in climatic conditions. On the other hands, fatigue can be controlled by restricting the heavy load on steel bridges.

To deal with corroded plate girders, detailed bridge inspection would be the first thing to do. It is also observed that about 50% of corrosion in steel bridges is due to water leakages from joints and cracks. From previous experience, it is observed that general corrosion patterns are highest at end of girders and subsequently thickness reduction in steel cross-section is also highest at end of span Tamakoshi (2005). Flange corrosion reduces the capacity against bending, corrosion in web and stiffeners reduce the bearing capacity and shear capacity of steel girders Real et al. (2007).

Corrosion factors in Pakistan includes high temp in summer ≈ 45 ^{0}C, high humidity in rainy season, low maintenance, most of the bridges are on canal and rivers. Therefore, it is recommended that any section with thickness loss of more than 50% should be monitored to avoid any accidental failures, proper maintenance work should be carried out by providing protective coat and critical locations such as flanges on mid-span should be checked more often.

References

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The Last Paper was presented on introduction to master bridge damage catalogue by Eiichi TSUJIMOTO, JICA Expert on bridge maintenance and management. The bridge damage catalogue helps the bridge inspectors in identification of damage severity and overall rating of structure. Federal highway Administration (FHWA) has classified the overall condition of bridge into 9 conditions with score from 1-9. The highest score shows the good condition while the lowest score indicates the severe condition. Poor and severe conditions structures are critical and require some remedial measure to avoid any untoward situation. On the other hands, Japan is using four soundness classification with general raking such as good, fair, poor, and severe.

The overall condition of structure is based on individual raking of each component such as deck, girders, piers etc. It also accounts for non-structural components comprising of expansion joints, railings, surface course, drainage pipes etc. Individual ranking of each component (structure / non-structural) is again classified into four categories (good, fair, poor & severe). The good condition covers no problem in element or some minor problems. Fair condition covers minor deterioration in structural elements, or all primary structural elements are sound but may have minor section loss, cracking, spalling, or scouring. Poor conditions cover the advanced section loss, deterioration, spalling / scouring or serious condition due to affected primary component or localized failure. Server condition covers the critical or imminent failure condition in which bridge must be closely monitored or closed for traffic.

The damage catalogue mainly covered the type of damage, description to its severity level along with photographs. The type of damages mainly included in catalogue are scouring of foundation, delamination / spall / patched area, exposed rebar, efflorescence / rust staining, cracking, abrasion/ wear, distortion, settlement, scour and damage. The elements to be inspected are covered in catalogue which includes prestressed concrete, concrete protective coating, masonry, concrete reinforcing steel protective systems, joints, steel, steel protective coating, timber, wearing surface and bearings.