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Development of Rating System ofExisting Railway Steel Bridges

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Abstract: ***Railway bridges are designed to be serviceable for a long time. However, the structural conditions of railway bridges change over time due to environmental effects, fatigue and structurally unplanned modifications etc. which affect health of the structure significantly. Hence inspection and condition assessment of structure is required for their uninterrupted operation. Condition assessment is also required for maintenance and repairs of existing structures so as to avoid any mishaps and save valuable human life. Dealing with thousands of bridges and several factors that cause deterioration, makes the rating process extremely complicated. It is therefore necessary to develop a practical and accurate system, which will be capable of rating a network of railway bridges. Several bridge inspectionstandards and condition assessment practices have been developed around the globe. Some practices employ four linguistic expressions to rate bridge elements while other practices use five or six, or adopt numerical ratings such as 1 to 9. This research article introduces six colour codes in the proposed rating system for a network of railway bridges based on their current structural condition by means of visual inspection and different non-destructive evaluation techniques. The proposed rating system could provide bridge stakeholders with a rational appraising tool for condition assessment of railway bridges, allowing better allocation of budget and more precise maintenance decisions.***
Keywords: Railway bridges; inspection; condition assessment; maintenance; rating system.

I. INTRODUCTION

Bridges are complex structures that form critical links in the transport infrastructure and occupy strategic importance in movement of goods, passengers and defence materials all over the country. Their uninterrupted operation is vital for functioning of the economy and society.

In Indian Railways, the bridges are carrying day to day increasing axle load resulting in need ofcareful and maximum utilization of the assets. Railway bridges are expensive enormously and key elements of the network because of their crucial location and dangerous results when they fail or their capacity is reduced. Permanent loss of bridges or even their temporary closure, due to damage suffered during unusual events or for unplanned maintenance, result in significant costs in the form of network disruption and losses of the local businesses and also cause frustration to their daily users. Consequently, effective management of these assets is a major concern to the bridge owners and operators.

Research progress in bridge maintenance, safety, management and life extension has not been presented and discussed much more in Indian Universities. During execution stage, a bridge building is obviously properly supervised. But inspections, maintenance and structural management provide quality assurance for constructions and play either a very important role during entire and long-time exploitation. Regular Inspection and maintenance is important factor influencing durability of structure. Existing practices of maintenance inspection and rating system of existing railway steel bridges and concerned different standards in India and other countries has been studied. Based on findings from interaction with railway authorities and available documents, a rating system and maintenance-inspection plan for railway steel bridges has been developed. The developed system has been applied to an existing railway steel bridge in basin of the Ken River at city Banda in the state of Uttar Pradesh in India.

II. PROPOSED COLOUR RATING SYSTEM

In this rating system, condition assessment of a bridge is based on its current structural condition by means of visual inspection and different non-destructive evaluation techniques. Condition rating colour (CRC) approach used in the proposed rating system provides a suitable platform to develop a bridge condition assessment method due to its flexibility in incorporating any number of uncertain factors and ability to function with available limited data. Hence the approach does not impose any limitations on the number of condition assessment grades or number of bridge elements. In addition, the colour rating system is flexible to use different assessment grades for each element of the bridge if needed.

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A. Condition Rating Colour (CRC)

Each component of the bridge would be given a condition rating colour (CRC) based on its corresponding physical condition at the time of inspection using following colour code:

Table 1 : Colour Code and Indication

Sr. No.	Rating Colour	Colour Code	Indication
1	Green	G	Structure is in sound condition and requires routine maintenance only.
2	Yellow	Y	Bridge/bridge-component which may require minor/major repair/rehabilitation in near future but routine maintenance cannot beignored at any condition.
3	Orange	O	Bridge/bridge-component needs immediate major/special repair/ rehabilitation or rebuilding on a programmed basis.
4	Red	R	Serious and dangerous condition of the bridge/bridge-component, which warns that the bridge/bridge-component is not performing its intended function and immediate repair/rehabilitation or rebuilding is required.
5	Black	B	Not Applicable or Absence of the bridge-component
6	White	W	Not Inspected

After proper and complete inspection, each component of the bridge would be assigned a CRC and findings should be entered properly in the prescribed proforma for Bridge Inspection Register (Table 3) in the following sequence :

- Foundation and Flooring
- Protection and Training Works, if any
- Sub-Structure and Bed Blocks : Masonry/Concrete Work
- Bearings and Expansion Arrangements
- Super Structure : Girders/Steel Works and Track-Structure on the Bridge

1) Remark

a) CRC of a bridge-component shall be the worst rating colour applicable to the worst elementof that component. For example, if a bridge has 5 piers and 2 abutments which, requires rating Green (P1), Green (P2), Orange (P3), Yellow (P4), Green (P5) and Green (A1), Yellow (A2) respectively then, CRC for the foundation would be the worst of the 7 members i.e. Orange (P3).

b) If, in any bridge, one or more components say, Training and protection works do not exist, the CRC for such components shall be shown as Black.

B. Overall Rating Colour (ORC)

In addition to different CRC assigned to different components of a bridge in the proposed sequence, an overall rating colour (ORC) shall also be given to the bridge as a whole, where ORC would be the worst of the six CRCs except white, assigned to various components of the bridge. Physical condition of a minor bridge may be represented by ORC only.

1) Bridges with ORC-Red: Rating indicates that bridge requires immediate rehabilitation or rebuilding of the whole bridge or one/more of its components.

2) Bridges with ORC-Orange: Rating indicates that whole bridge or one/more of its components requires rehabilitation/rebuilding on programmed basis.

Engineer should recommend the required corrective actions, listing critical condition in the red bridges first followed by repairs to components in poor condition of the orange bridges and attention to the components in fair condition in the yellow bridges.

C. Unique Rating Colour (URC)

Physical condition of major and important bridges shall to be represented by URC consisting of the six colours, where the first colour will represent the ORC and would be written in a bracket and each of subsequent colour will represent the CRC given to five different components of thebridge in the proposed sequence.

URC = ORC followed by CRC of each of the five bridge components in proposed sequence
For example : URC of a bridge : (O) W, B, G, O, Y indicates the following :

1) (O): Bearing and Expansion Arrangements require immediate major or specialrehabilitation/rebuilding on a programmed basis.
2) W: Foundation and Flooring were not inspected.
3) B: Not applicable i.e. Bridge does not have any Training/Protection Work.
4) G: Sub-structure and Bed Blocks are in sound condition and need routinemaintenance only.
5) O: Bearing and Expansion Arrangements require immediate major or specialrehabilitation/rebuilding on a programmed basis.
6) Y: Super Structure and Track-Structure require minor or major repair/rehabilitationin near future but routine maintenance cannot be ignored at any condition.

D. Merits of Colour Rating System

The Colour Rating System envisages assigning a unique colour rating to represent condition of a bridge. It is a method of assessment which gives quick evaluation of physical condition of a bridge by means of a simple colour code. The system provides a way of recording progressive deterioration. It also provides a manner of assessing relative importance of factors which should be taken into account to establish priorities for undertaking repairs or rehabilitation. Thesystem further provides a common yardstick for technical examination not only in one division but on the whole railway system with the following merits :

1) Improves readability and maintainability of structure and it reduces complexity also.
2) It is flexible to use different assessment grades for each element of the bridge if needed.
3) Quick evaluation of physical condition of bridge by means of a simple colour code.
4) It is useful to create computerized data base for Railway Board Management.
5) It is a simple criterion for rating the component or the whole structure.
6) Representation of report is well organized and clearly informative.
7) Colour Rating System is useful for Bridge Management System.
8) Helpful to detect the physical condition of the structure easily.
9) Fixes priorities of bridge repair/rehabilitation/rebuilding.
10) The system is well organized and clearly informative.

III. APPLICATION OF THE COLOUR RATING SYSTEM

The developed rating system has been demonstrated by applying it on an Important Existing Railway Steel Bridge no. 1316/2 (Fig. 1: Ken Bridge), which is owned by the Indian Railways and managed by ADEN/BANDA Sub-Division of Jhansi Division, North Central Railway.

A. KEN Bridge

The Bridge was constructed in 1889, it exist between stations Khairar and Banda Jn. in Jhansi- Manikpur Section and located in basin of the Ken River at city Banda in the State of Uttar Pradesh in India. The Ken Bridge is Straight, Under Slung/Through Open Web Girder, Steel Bridge. Its superstructure carries Single Line of Broad Gauge Main Line (BGML). The track is fish plated and type of bearing used in the bridge is Sliding Motion. It consists of thirteen spansthat are supported by twelve interior piers across the Ken River and by two end abutments, founded on well foundation. The end abutments and interior piers are made of stone masonry in lime mortar. Bottom ends of each pier are fixed on bed rock. Its main span is 1x76.20 m long and other twelve spans including tail spans are each 30.48 m long, total span/water way is 441.96 m (i.e. 1x76.20 m+12x30.48 m = 441.96 m). The bridge is aligned along the East-West.

Table 2 : Data of the Ken River Bridge

Div.	Section	Bridge No.	LINE	Gauge	Track	Bearing	Type of Foundn	Const. Material	Water Way/Total Span	Strength ofSuper Str.	Year of Const.
JHS	JHS-MKP	1316/2	SL	BG	FP	Sliding	Well	SM-LM	441.96 m	100% BGML	1889



Fig. 1 : Existing Railway Steel Bridge (Ken Bridge) at City Banda

B. Detailed Examination of The KEN Bridge

Performance of a bridge depends on structural condition of various elements of the bridge. Therefore, all the required factors which are responsible for performance of different components of the Ken Bridge have been considered and physical condition of the bridge has been assessed by means of visual inspection and required non-destructive evaluation techniques. All the observations and CRC assigned to the bridge-components are concised in the proforma prescribed for Bridge Inspection Register as shown in the following Table 3 :

Table 3: Proforma for Bridge Inspection Register
{For entering Condition Rating Colour (CRC) to each component of bridge and to assign ORC/URC to the bridge}
Condition of Bridge at the Time of Inspection on Dated : 25.10.2023

Sr. No./ Bridge No.	Foud^{n} & Flooring : Extent of Scour/ Damage	Protection Works : Cond^{n} of Protective Works, Waterway/ Scour Slips/ Settlements	Sub-Structure		Bearing & Expansion Arrangements : Defects in Seating & Expansion Arrangements	Super-Structure				Initial of Inspecting Official and ORC/URC	Initial of Higher Officials with Remarks
			Masonry Work : Condition/ Cracks/ Defects in Piers/ Abutments	Bed Blocks : Cracks/ Defects/ Tendency to Move		Girder/Slab : Structural Condition/ Paint/Crack/ Defects in Girder or Slab	Sleeper : Year of laying/ Renewal required/ Condition	Track on Bridge : Line & Level/ Guard Rail/ Hook Bolts/ Trolley Refuges/ Footpath	Track on Approaches : Approach Slab/ Ballast Walls/ Rails		
	1	2	3		4	5				6	7
1) 1316/2	Yellow	Green	Green	Green	Green	Green	2011/No Green	Yellow	Yellow	(Y) Y,G,G,G,Y	
2)											
3)											
4)											
5)											

IV. RESULT

For Bridge No. 1316/2 ORC = Yellow and URC = (Y) Y, G, G, G, Y
Therefore, a yellow coloured signboard of standard size with red border would be erected at each end of the bridge.

V. CONCLUSION

A thorough review of bridge inspection manuals and practices shows that the inspection standards and guidelines vary from one country to another and may even vary in the different states within the same country, despite the fact most of the practices rely mostly on the same approach of visual inspection for data collection. There is no proper rating system for condition assessment of the bridges as per current loading standards. There is no parameter defined to judge the performance, serviceability and safety of the existing railway bridges. Although, inspection and maintenance plan of railway bridges are available and the activity is undertaken on need basis but these do not give any systematic idea for evaluation of physical condition of railway bridges. Whereas, Colour Rating System presents a well organized, simple and clearly informative technique to evaluate structural health of railway bridges.
It is also noticed that rating a bridge based solely on visual inspection can overestimate or underestimate its structural health, while integrating NDT techniques can provide a more reliable rating. The proposed system could provide bridge stakeholders with a rational appraising tool for condition assessment of railway bridges, allowing better allocation of budgets and more precise maintenance decisions. Nevertheless, the proposed method requires experts input in certain cases, especially if the experts decide to use different parameters other than the taken in this system.

A. Actions Resulting from Rating a Bridge

When a bridge is found to have inadequate capacity for legal vehicles, engineers need to look at several alternatives prior to closing the bridge to the public operation. Some of the possible remedial measures are imposing speed limits, reducing vehicular traffic, limiting for vehicle weight, recommending possible small repairs to improve the problem. In addition, when the evaluations show that the structure is marginally inadequate, frequent inspections to monitor the physical condition of the bridge and traffic flow may be recommended. When a more accurate answer is required, a more-detailed analysis, such as three-dimensional study or physical load testing should be performed.
All bridges requiring rehabilitation may not require speed restriction. It is not possible to lay down standardized guidelines for imposing speed restrictions. Based on the detailed inspection and evaluation, the inspecting official may impose a suitable speed restriction as considered appropriate. Each case has to be judged and assessed on its merits by the inspecting officer, keeping in view the nature and severity of deficiencies noticed.

VI. ACKNOWLEDGEMENT

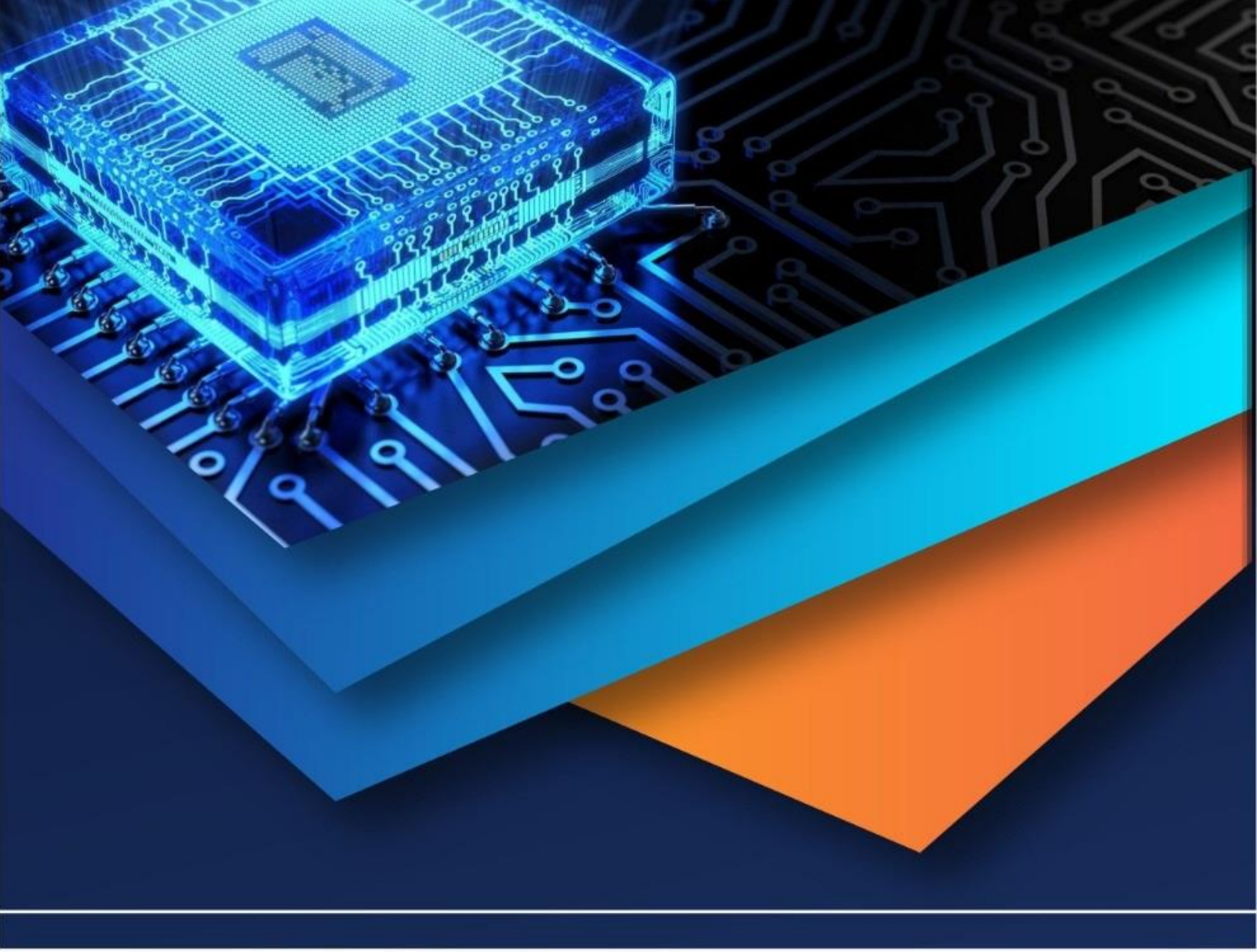
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