

ABSTRACT

As of 2016, the Indian Railways system has 1.41 lakh bridges, 27% of which were more than 100 years old and 34% were more than 80 years old. It is necessary to analyse the condition of these bridges before proceeding with upgrading or replacing them. Three aspects of condition assessment are described in this study: fatigue-based remaining life assessment, deep learning-based crack identification, and fuzzy-based bridge rating. Each aspect has been implemented on existing bridges.

The overall study is divided into four sections: The first section describes various methods for determining the remaining life of steel railway bridges, as well as the use of the stress life method and the Linear elastic fracture mechanics (LEFM) method on an existing railway bridge case study. In the second section, an existing rail-roadway bridge is assessed for Per vehicle passage damage (PVPD) and remaining life using the stress-life approach. A stress band study is presented to demonstrate the variation in PVPD and remaining life for various stress bands. The third section describes deep learning algorithms for crack identification on masonry surfaces. And last part of this study presents fuzzy logic based rating of railway bridges. Each section presents case studies of real structures.

The railway bridge over the Bhakra River is an open web riveted steel girder bridge between the Bareilly-Rampur section that belongs to the Moradabad division of India's Northern Railway. Simulation-based fatigue life assessment of this railway bridge has been carried out for full-scale train loading given by Research Design and Standards Organization (RDSO). STAAD software has been used to analyze the bridge, identify critical members, and calculate residual life for "25T-2008" loading at various speeds with

a stress band of 5 MPa and 10 MPa for a stress life-based approach. Linear Elastic Fracture Mechanics (LEFM) based approach is also applied to assess the remaining life of the bridge. Analysis has evidenced that a smaller stress band should be used for a precise bridge life. This study will be useful in the conditional health assessment of steel railway bridges using an S-N curve based approach as well as a fracture-based approach.

The rail-cum-road bridge over the Ganga River is a riveted steel truss bridge near Kashi station in the Pt. DD Upadhyaya -Varanasi section belongs to the Lucknow division of the Northern Railway zone of Indian Railways. In this study, lab test results of steel, deflection at bridge site and corresponding deflection of STAAD model, and remaining life of calibrated FEM model for major and Minor span's identified critical members considering three future loading types, three different speed criteria and at four types of stress bands are presented. The main objectives of this study are to determine the remaining life of the bridge using various futuristic loadings running at different speeds and to represent statistics of variation in remaining lives and per vehicle passage damage (PVPD) using different stress bands with reference to stress band 'SB'. It has been found that the remaining life of the bridge's minor and major spans varies depending on the type of future loading and its running speed across the concerned bridge. For both minor and major span of the bridge, the remaining life's standard deviation of variation for wider stress band is more. The PVPD's standard deviation of variation for a wider stress band is greater for both the minor and major spans of the bridge. This study will be helpful in health assessment and timely maintenance of railway, highway, and rail-cum-roadway bridges.

As the concrete surface, i.e., the railway bridge substructure has a uniform texture, any cracks available on the concrete surface can easily be detected. Nevertheless, in the case of

masonry surface, i.e. masonry substructure of old railway bridges, the image surface has uneven texture, so crack detection over masonry surface is a complex task compared to a concrete surface or asphalt surface.

This research study focuses on the detection of surface cracks on masonry surfaces using deep learning techniques. This study compares the performance of various networks trained using deep learning techniques for semantic segmentation of cracks on masonry surfaces. For the semantic segmentation of cracks, the segmentation models U-Net, FPN, DeepLabV3+, and PSPNet are integrated with several CNNs acting as the network's backbone. Comparisons among networks using different metrics have been performed to find the most promising approaches. Over the training and validation masonry datasets, a total of 23 networks are examined. The results of this study show that three networks can also accurately detect finer surface cracks on masonry surfaces. As trained networks are performing well on existing masonry culverts. This part of study can significantly aid the detection of cracks in the masonry substructure of old railway bridges.

The safety and dependability of railway infrastructure are significantly impacted by the condition rating of railway bridge components. In India, qualified bridge inspectors carry out manual inspections to assess the condition of railway bridges. However, a lot of elements, like the inspector's technical proficiency, experience, perception, judgement, etc., affect the assessment's efficacy and dependability. Although inherent in the visual inspection process, these subjectivities may be addressed using a fuzzy approach. This technique can analyse a complex system with uncertainty by using approximative reasoning, which is neither precise nor inexact.

To address these limitations, this study proposes a novel approach for condition rating of railway bridge components using fuzzy logic. Main objectives of the present study are to

develop a fuzzy logic-based system for railway bridge condition assessment, test the developed system on a real-world dataset of railway bridges, evaluate the developed system's performance, and compare it to existing methods. The proposed approach aims to provide a more objective and systematic assessment by capturing the inherent uncertainties and imprecise nature of condition ratings. By employing fuzzy logic techniques, the proposed methodology enables the representation and handling of vague and uncertain information, leading to more accurate and comprehensive condition ratings.