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CONDITION ASSESSMENT OF A WROUGHT-IRON RAILWAY BRIDGE

H.Abeyruwan[1], U.I.Dissanayake[1,2], D.J.Gallage[2], K.R.B.Herath[1], S.R.Herath[1], M.P.Ranaweera[1], M.Raviprasad[1,3] and M.Vignarajah[1,4]

[1] *Department of Civil Engineering, University of Peradeniya,*
[2] *UDEC (Pvt) Ltd, Kandy, Sri Lanka.*
[3] *Department of Civil Engineering, North Dakota State University, USA.*
[4] *Department of Civil Engineering, Texas Tech University, USA.*

Introduction

In this paper, experimental and analytical procedures for the design checking and remaining life estimation of a truss type wrought iron railway bridge are presented. The bridge, having a single span of 32.5 m (Figure 1), has been in operation since 1880, initially with trains having steam engines. Presently it carries a single railway line with trains having diesel engines of axle loads up to 16.5 tons. It is anticipated that in order to meet the future demands the engine axle loads will be increased to 20.0 tons. The main objective of this study is to check the bridge under working conditions and determine its remaining life, under increased axle loads.

Figure 1. Railway bridge

Methodology and Results

To achieve the above mentioned objectives the overall testing and analysis procedures were divided into several stages. Firstly a condition survey of the bridge was carried out and bridge material was tested in the laboratory to determine its mechanical properties. This revealed that the bridge is in good condition except for some corrosion in a few members, and that bridge material has a density of 7600 kg/m^3, a Young's modulus of 195 GPa, an ultimate strength of 360 MPa, and a fatigue limit, at one million cycles, of 165 MPa.

Next a three dimensional finite element model (Figure 2) for the bridge was prepared using the general purpose finite element package SAP2000 (Computers and Structures Inc, 2008). Even though the bridge has riveted connections it was modelled as a rigidly jointed frame, as there is much rigidity at the joints (Spyrakos, 2004). A preliminary static analysis of the model was done with an M8 engine load to determine stresses and displacements in the bridge and identify its critical members. A modal analysis gave a fundamental frequency of 2.85 Hz in a sway mode.

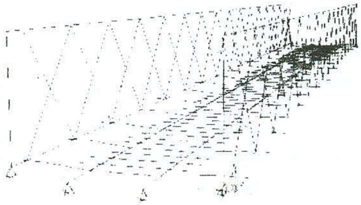

Figure 2. Finite element model of the bridge

Next, load testing of the bridge was done with an M8 engine under static as well as dynamic conditions, and displacements, strains and accelerations at selected locations were recorded. For the static load case the engine was placed at the centre and at the end of the bridge. In the dynamic loading the engine was passed over the bridge at different speeds ranging from 7 km/h to 48 km/h.

Using the results of static finite element analysis and load testing, the finite element model was validated, by comparing analytical and measured displacements and strains at known locations. As seen in Table 1, there is good agreement between the finite element results and those from load testing.

Table 1: Comparison of deflections and stresses at the centre of the bottom chord.

Engine Position	Deflection (mm)		Stress (MPa)	
	Test	FEA	Test	FEA
Centre	12	13	14	16
End	7	8	22	21

The dynamic load tests showed that the static deflections were enhanced by about 25% at the highest speed and that there is some significant lateral (sway) displacement at the centre of the bridge.

Next, the validated finite element model was analyzed with moving loads from the present schedule of trains and stress cycles for critical members were determined. The dead load stresses in critical members were combined with live load stresses to determine maximum and minimum stresses in members. In doing so the dynamic effect of moving trains were accommodated in the usual way by applying dynamic factors of 1.3 for diesel engines and 1.5 for steam engines.

Under present working conditions with engine axle load of 16.5 tons, the maximum tensile stress found was 54.9 MPa. This gave a factor of safety against fracture of 6.6 for bridge material. With the increase of axle load to 20.0 tons, the factor of safety reduced to 5.4. These values are well above the commonly accepted value of 4.0 for wrought iron (Hatfield, 2001).

Cyclic stresses obtained from finite element analyses were used to perform fatigue analyses to predict the remaining life of various components of the bridge. Miner's rule was used to compute cumulative damage in fatigue analysis (London Underground Limited, 1998). Previous load history of the bridge, as well as the present and anticipated future loadings were taken into consideration in this analysis.

A conservative calculation was first made by assuming that the maximum stress range is applicable to all stress cycles for the member under consideration. This gave a remaining life of more than 400 years for the bridge. As this is very large more detailed fatigue calculations, taking into account the actual cyclic variation of stress in the member, was not necessary.

Conclusions and Recommendations

From this investigation it may be concluded that all members of the bridge have adequate strength to carry normal working loads with anticipated increase in engine axle loads of 20.0 tons, provided corroded wrought iron members of the bridge are repaired. The bridge members also can last many years with engines having increased axle load of 20.0 tons, with the current schedule of operating trains.

The lateral deflections of the bridge can be excessive with trains having heavy engines operating at high speeds. These can be reduced by providing a suitable bracing system for the bridge. It should also be pointed out that, as Miner's fatigue life prediction theory is based on statistics, fatigue could still occur in the members in the bridge due to high stress concentrations, deterioration of members due to corrosion etc. Hence periodic inspection of the bridge is recommended.

References

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