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Performance Studies on a Model Under-Slung Railway Bridge

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ABSTRACT

It is observed that Indian Railway network has several hundreds of bridges which are more than 100 years old and needs to be repaired or rehabilitated for normal services of Rails. The Railways bridges have been subjected to higher loads and speed which is concerning factors to the Designers of Railway Bridges. Hence, an attempt has been made through this study to assess the health of a bridge under normal and defect condition of bridge member. Through successful health monitoring, the performance of bridge can be monitored and catastrophic failure events can be prevented. This paper presents the damage assessment through Structural Health Monitoring (SHM) of an under-slung railway bridge model, fabricated using aluminum material.The performance of bridge model has beenevaluated under centric and eccentric loading experimentally under normal and defective members and compared with theoretical performance of bridge model under same loadingcondition. Experimental and analytical results have been compared to evaluate the damage assessment which helps in understanding the performance of bridge structure.

Keywords

Structuralhealth monitoring ,deflection**.**

1. INTRODUCTION

Structural Health Monitoring (SHM) has gained a lot of interest in the past couple of years for safety and smooth functionality; thus, becoming a priority for the structural engineers.SHM helps in keeping a check over the performance of the structure while in operation as well as throughout the life and hence, monitoring its serviceability.SHM not only increases reliability, but also significantly reduces maintenance cost. Moreover, all these positive points, could be achieved without actually interfering with structure itself.

2. REVIEW OF LITERATURE

There have been many research works carried out by the various researchers, therefore, dealing with the health monitoring of structure. Some of the prominent literature available on condition assessment of bridge structuresinvolving analytical and experimental work is reviewed briefly in the subsequent paragraphs.

Jun Zhao [1] presented the application of the modal flexibility approach, to a field study of a bridge in which the bearings were partially restrained in colder weather. Casas [2]provided an overview of the intensity modulated and spectrometric fiber optic sensors and techniques to assess the condition of existing structures in order to enhance the durability of the new bridges, increasing lifetime and reliability and decreasing maintenance activities.Rafiquzzama [3] proposed health monitoring approach via the static local damage detection algorithm using operating vehicle load. Xiaozhai and Zi [4] addressedthe methods of local measurement. Hsieh and Halling [5]illustrated three applications of structural health monitoring that had been performedby the researchers at Utah State University and suggested that forced-vibration testing can be used as a structural condition assessment tool. Altunok and Reda Taha [6] focused on the application of the theory of possibility to the damage detection problem. Olund and DeWolf [7]reported the monitoring of the threebridges and further, demonstrated the benefits of using long-term monitoring systems to provide information on the structural performance that is useful both to those responsible for the bridge infrastructure and to researchers interested in bridge monitoring.Liu and Frangopol [8] presented an efficient approach for assessing the performance of a bridge system through a series-parallel system model consisting of bridge component reliabilities.Yun and Min [9] presented recent research and application activities on smart sensing, monitoring, and damage detection for civil infrastructures are briefly introduced. Orcesiand Frangopol [10] presented a methodology for lifetime serviceability analysis of existing steel girder bridges including crawl tests and long-term monitoring information.Enckell and Glisic [11] reported a large-scale structural health monitoring project based on stimulated Brillouin scattering in optical fibers for an old bridge. Catbas and Gokce [12] discussed a novel methodology for structural health monitoring of a bridge with implementations for bridge load rating using sensor and video image data from operating traffic. Xinqun and Hao[13] reported on the development of an integrated structural health monitoring system for bridge structures in operational conditions. ElSafty and Gamal [14] developed a new alarming system as part of a structural health monitoring system and installed in a scaled-down structure models. Modares and Waksmanski [15] revealed that early indication of defect by SHM systems can prevent high repair costs and catastrophic failures from occurring. It can also extend the expected life of a deteriorating bridge. Srinivas and Sasmal [16] presented details of full-scale field testing and performance-evaluation studies carried out on a typical steel plate girder railway bridge under increased axle loads are presented.

3. PROBLEM DEFINITION

Based on therefore mentioned review of literature. An effort is made in the present investigation to assess the performance of an under-slung railwaytruss bridge model in the presence normaland damaged truss members, when subjected to centric and eccentric load, through experimental and analytical study. Further, the study is carried out with respect to normal condition and damaged condition of few members.

4. EXPERIMENTAL SET UP AND PROCEDURE

A typical under-slung truss bridge model was chosen for the study. The bridge consists of two trusses interconnected laterally. The bridge has dimension 1200mm (length) x 300mm (width) x 300mm (depth). The top deck has two rail lines. The superstructure is supported on two piers through rocker and roller bearings at each end respectively. Various Aluminium sections like Flat, Angle, Channel, T, etc. were used for fabrication of bridge model. All the joints were connected with 6mm diameter Aluminium bolts and nuts. Material properties are shown in Table1whereasFig.1 shows the under-slung bridge model.

Table.1: Material properties of sections

Properties	Value
Ultimate Tensile Strength (MPa)	111
Proof Stress (MPa)	87
Percentage Elongation (%)	22.8
Modulus of Elasticity (GPa)	62
Poisson’s Ratio	0.34

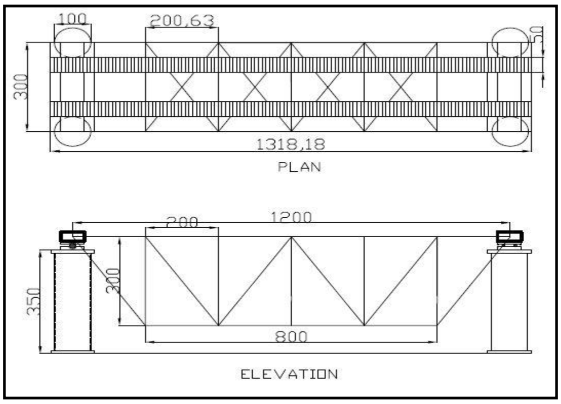

Fig.1:Drawing of the under-slung bridge model

4.1 Procedure

The under-slung bridge model was placed on the floor. Vertical and horizontal alignment was checked to confirm the stability of both substructure and superstructure. All the bolts were checked for proper tightening of bolts. One deflection sensor each was installed at the bottom chord of each truss. A base plate with wheels was placed at the centre of the span. Initial reading of both the deflection sensor was noted down. Dead weights were added on the base plate in sequence and at each dead weight the deflection readings were noted down. Maximum dead weight of 70 Kg (inclusive of base plate) was applied centrally. The dead weights were removed and the deflection was noted down for no load condition.

The experiment was repeated with base plate displaced from centre to a distance of 200mm (offset loading). At this point the bridge was loaded in same sequence as above and the deflection at the centrewas noted down at each steps of loading. The dead weights were removed and deflection was noted down for no load again. The experiment was further repeated with base plate shifted from 200mm to a distance of 400mm (offset loading). At this point the bridge was loaded in same sequence as above and the deflection at the centre was noted down at each steps of loading. The dead weights were removed and deflection was noted down for no load again. Fig.2shows the arrangement of loading at the centre of span, 200mm offset, and 400mm offset.

Further, the test procedure was repeated for the damaged condition.Three members (i.e., diagonal member on left side, vertical member and diagonal member on right side), each of both the trusses, were damaged by reducing the cross section. The load tests (central loading, 200mm offset, 400mm offset) were carried out as done in the normal condition studies. Fig.3 shows a close view of defect members. Further, Fig.4 shows a view of loading at center, 200mm offset and 400mm offset in damaged condition.

Fig.2: View of loading of bridge at the centre, 200mm offset and 400mm offset under normal condition

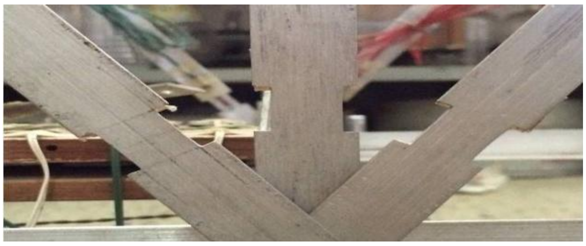

Fig.3: A close view of the defect members

Fig.4: A close view of bridge loaded at center, 200mm offset and 400mm offset in damaged condition

5. PARTICULARS OF THE ANALYTICAL STUDY

For the purpose of analytical study, a finite element based software STAAD isused. It provides a user friendly interface that helps the user to achieve the results easier, faster and accurately. It automates the charting, analysis and reporting functions that support technical analysts in their review and prediction of the required results.

The bridge structure is modeled as a space frame structure. Nodes are created and they areconnected by the assigned members. The material properties are assigned to the members. Once the material properties are assigned, load is added to the bridge according to the actual loading as done in the experimental studies. A maximum of 70 kg is added on the bridge distributed on 8 points as in the experimental case. Various loading cases are studied and deflection data is recorded. Each load caseisapplied at various locationson the rails (centre,200mm offset and 400mm offset from the centre) as done in experimental studies.

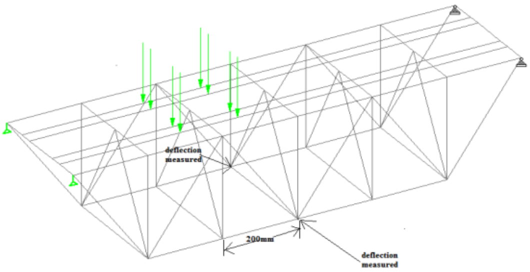

Fig.5: Mathematical model of a bridge in STAAD

The data (nodal deflection) output is obtained in the post processing mode of analysis. Fig.5shows modeled bridge structure in STAAD program. Fig.6 shows the sectional properties defined in the STAAD program. Fig.7 shows location of load applied at center, 200mm offset and 400mm offset simultaneously on both the lanes.

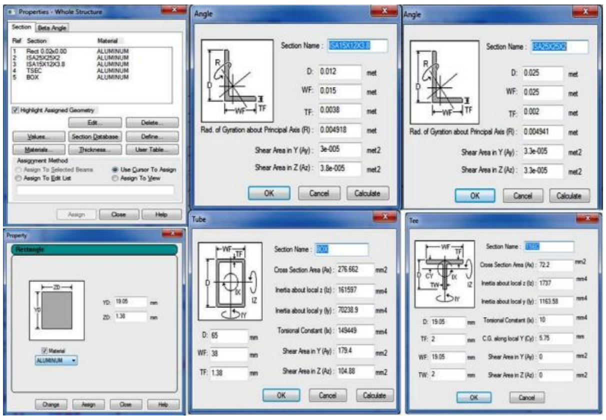

Fig.6: Sectional properties defined in the STAAD program

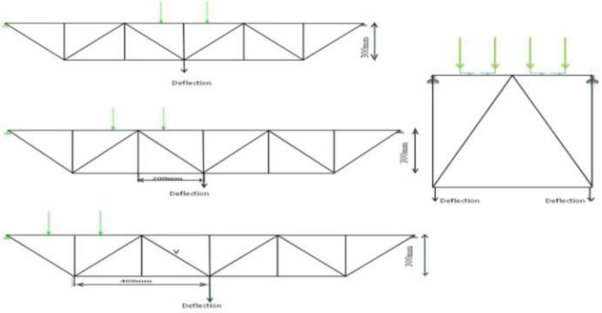

Fig.7: Load applied on both the lanes at center, 200mm offset and 400mm offset

Further the procedure is repeated for the damaged condition. Three members each of both the trusses (viz. diagonal member on left side, vertical member and diagonal member on right side) are damaged by reducing the cross section. The reductions of section of relevant members are configured in the program. The loads (central loading, 200mm offset and 400mm offset from the centre) are simulated as done in the normal condition studies.

6. RESULT AND DISCUSSION

The deflection for various amount of loads placed at the three locations mentioned in one of the preceding sections obtained experimentally and analytically by resorting to the numerical procedure using STAAD for the members with normal condition and the defect condition is shown in Fig. 8-11.

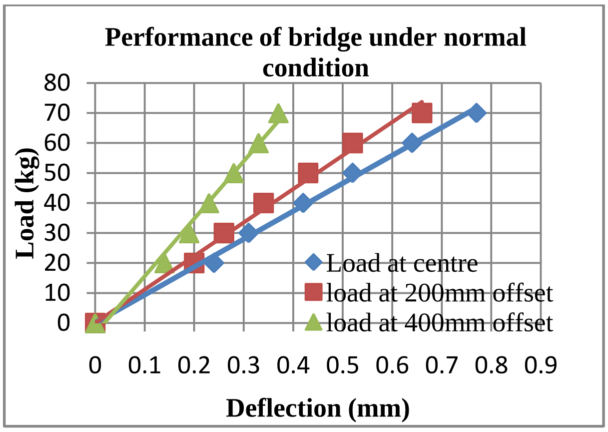

Fig. 8: Variation of deflection (experimental) under normal condition

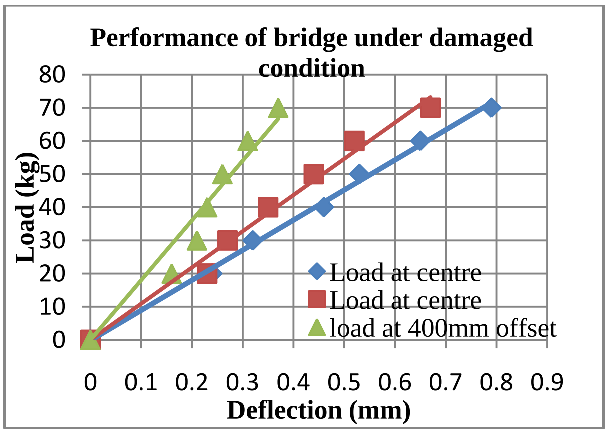

Fig. 9: Variation of deflection (experimental) under damaged condition

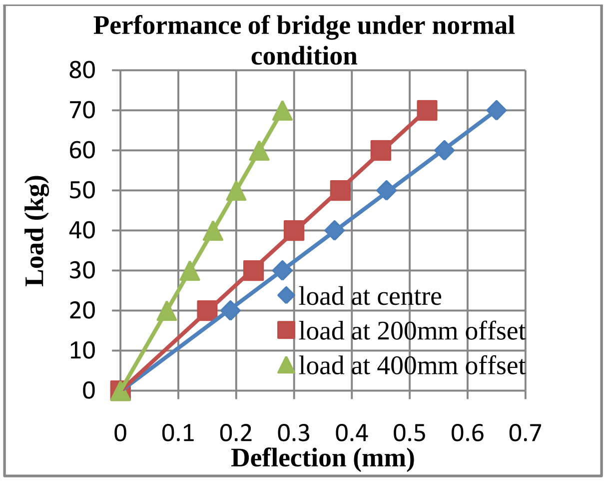

Fig. 10: Variation of deflection (analytical) under normal condition

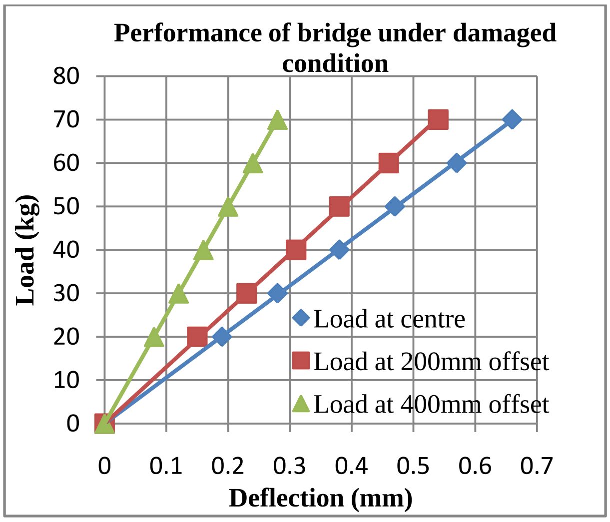

Fig. 11: Variation of deflection (analytical) under damaged condition

The relationship between the load and deflection in either case (experimental and analytical) and further, for both the conditions- normal and defect member condition, seems to be linear in all the cases. When unloaded the deflection at the respective point is found to become zero. This trend exhibits an elastic behavior of the bridge structure.

Although the trend in the observed response (i.e., deflection) is found to be same, there is slight differenceobserved in the results obtained experimentally and analytically. The response observed experimentally is on higher side by 14.34%, 15.1% and 40% respectively for three different positions of loads considered in the present study (i.e., centre, 200 mm offset and 400 mm offset) when compared with that obtained analytically in case of the response evaluated under normal conditions. Similarly, this variation is found to be 16.14%, 17.68% and 40%, respectively for three different positions of loads considered in the present study in case under defect condition.

The deflection being on higher side as observed in case of experimental study could be attributed to the various reasons such as looseness of joints, inconsistent tightening of joints, measurement of least count of the equipment (dial gauge or deflection sensor having least count of 0.01mm), inconsistency in placement of dead weights, improper support at hinge and roller end, misalignment of superstructure, misalignment of substructure etc. Further, due to possible inadequacy in simulation of joints and boundary conditions in analytical process and limitation of software, the deflection might have been less in case of the analytical solution. Alternatively, if these stray local effects are simulated in analytical program, it may be possible to see both experimental and analytical data would match.

Further, when the effect of conditions of the members is considered on the response,it is observed that there is no significant difference between the response obtained in view of the normal and damaged condition of some of the members of the model bridge.Nevertheless, the deflection obtained for defect condition of the members is slightly on higher side. The deflection obtained under defect condition in case of experimental studies is found to be 3.46% higher for the case of central load. Similarly, for remaining two cases of loading, the deflection is found to be 2.22% and 1.56%, respectively. Further, when the values of deflection obtained analytically are compared, it is found that the deflection obtained in case under defect condition is on higher side by 1.69% for the central loads. When the load moves from centre at 200 mm offset distance, this variation is observed to be 1.36% and at the end, when the load moves another 200 mm offset distance (total 400 mm offset) , there is no difference at all between either values indicating perfect agreement between the deflection obtained analytically in case of normal condition and defect condition. It gives an indication that the local change is not giving any significant global change.

7. CONCLUSION

Within the available resources and limited facilities the health of a model bridge structure was monitored to assess the behaviorin view of the possible damage in some of the members. The study reveals thatthe deflection parameter does not show any significant change in the performance globally; but,locally (in terms of strain)there might be change in the section. This change could be assessed by applying strain gauges sensorsat the locations of the damage which forms the part of the future scope of the present study.

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