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An Analytical Study of Existing Railway Bridge to Determine the Effect of Increasing Speed on Dynamic behavior

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Abstract* — In past few years, the interest in dynamic behavior has increased due to introduction of high speed train all over world. Currently HST (High Speed Train), is under construction more than ten countries including India. Existing bridges in India are not designed for HST. Under current design practice, dynamic impact factor is used for consideration of dynamic impact but it is a function of loaded length only. However dynamics response of bridge involves a number of parameter like frequency characteristics of bridge structure (i.e. the length, mass, rigidity of individual member), the frequency characteristics of vehicle (i.e. the sprung and unsprung masses, the stiffness of spring), the damping in bridges and vehicles, track irregularities, and the velocity of vehicle and so on. This paper presents the result of analytical study undertaken on existing Railway Bridge which concludes that the dynamic analysis is required after cutoff velocity of vehicle.

I. INTRODUCTION

The global High Speed Train (HST) network is one of the great feats of modern engineering, and proves to be the best form of transportation ever invented. The global high speed train network is rapidly expanding across continents world wide- delivering fast, efficient mobility to numerous nations every day.

HST is currently in operation in more than 20 countries (including the UK, France, Germany, Belgium, Spain, Italy, Turkey, Japan, China, Korea, and Taiwan). HST is under construction in more than 10 countries (including China, Spain, Saudi Arabia, Turkey, France and Italy); and in development in another 14 countries (including Qatar, Morocco, Russia, Poland, Portugal, South Africa, India, Argentina, Mexico, and Brazil). HST has been in operation in Japan for 50 years carrying more than 9 billion passengers without a single fatality.

One of the first proposals to introduce high-speed trains in India was mooted in the mid-1980s by then Railway Minister Madhavrao Scindia. A high-speed rail line between Delhi and Kanpur via Agra was proposed. An internal study found the proposal not to be viable at that time due to the high cost of construction and inability of travelling passengers to bear much higher fares than those for normal trains.

The Indian Ministry of Railways' white-paper "Vision 2020", submitted to Indian Parliament on December 18, 2009, envisages the implementation of regional high-speed rail projects to provide services at 250–350 km/h, and planning for corridors connecting commercial, tourist, and pilgrimage hubs.

II. Codal provision for dynamic effect of train in India

Current design practice for Railway Bridge in India is done according to guidelines given in steel bridge code and bridge rules. According to steel bridge code, the dynamic effect of moving load is considered by increasing live load by impact factor or coefficient of dynamic coefficient. This factor depends on many factors like the type of loading, speed, type of structure, material of structure, loaded length etc. But for simplicity an impact factor is specified by the Bridge Rules in India involving only one parameter, i.e., the loaded length. All the other parameters are considered as constants in the expression for impact factor. For Broad Gauge and Meter Gauge steel railway bridges carrying a single track, the Coefficient of Dynamic Augment (CDA) is given by the following expression-

III. $$CDA = 0.15 + \frac{8}{6+L}$$

Where L is defined as given below:

a) L is loaded length of the span in meters for the position of the train giving the maximum stress in the member under consideration. For the design of chord members, it will be the whole span of the truss and for the web members only part of the span is to be loaded.

b) L is taken as 1.5 times the cross-girder spacing for finding stresses in the stringers (rail-bearers).

c) L is taken as 2.5 times the cross-girder spacing for finding moments in the cross girders (floor-beams).

III. Analysis of existing bridge

The existing bridge which is considered in this study is located on Lalpari River at Rajkot-Morbi highway. The bridge is bolted, continuous steel girder with seven span of length 10.363 m each. The super structure is made of plate girder, 1.25

m deep and 1.86 m wide. The side plate is stiffened with horizontal and vertical stiffeners. Laterals are provided at top level made of L-sections.

The software package SAP2000 has been used to model the plate girder railway bridge. Fig. 1 shows extruded view of Lalpari Bridge. In order to validate the software package, the moving load analysis is carried out on simply supported beam which is subjected to a single point load moving from one end to the other end. The results are shown in fig. 2.

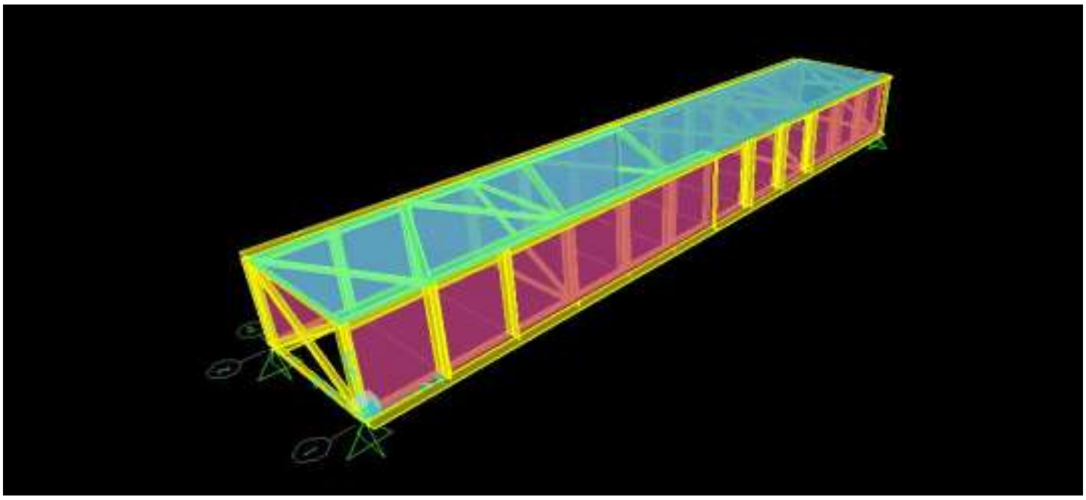

Figure 1extruded view of model

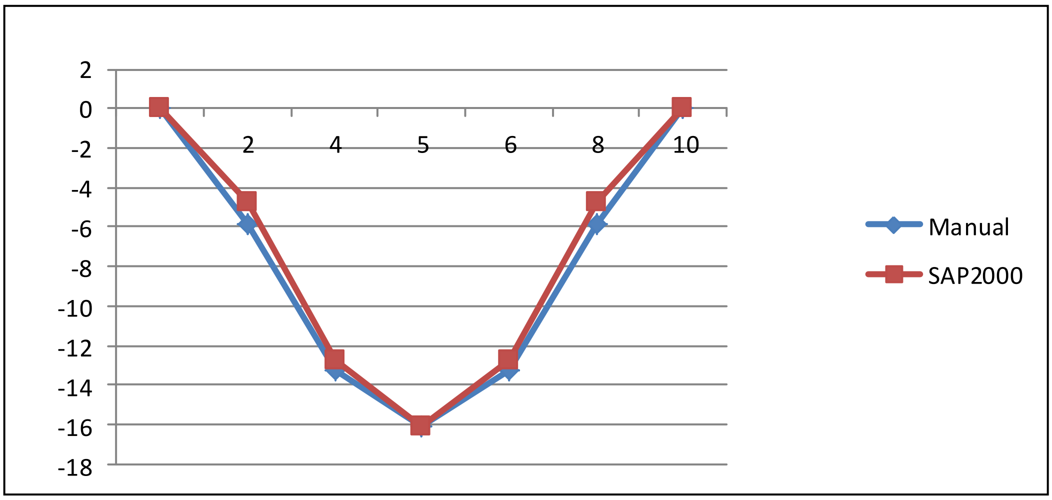

FIGURE 2 COMPARISON BETWEEN SAP2000 RESULTS AND MANUAL RESULTS

IV Train definitions

For analyzing above mentioned bridge the moving load analysis is carried out by train descriptions. Trains are classified on the basis of their usage like passenger train and goods train. for present study MBGT(Modified Broad guage train) model has been considered as per Bridge rules. Trains are modeled as a series of concentrated axle loads moving across the bridge.

V Moving load analysis and dynamic analysis

After completing the modeling of existing Railway Bridge, moving load analysis and dynamic analysis is performed in CSiBridge 2015.

In moving load analysis, multi-step static analysis is performed to get displacement at mid span considering coefficient of dynamic augment as per bridge rules.

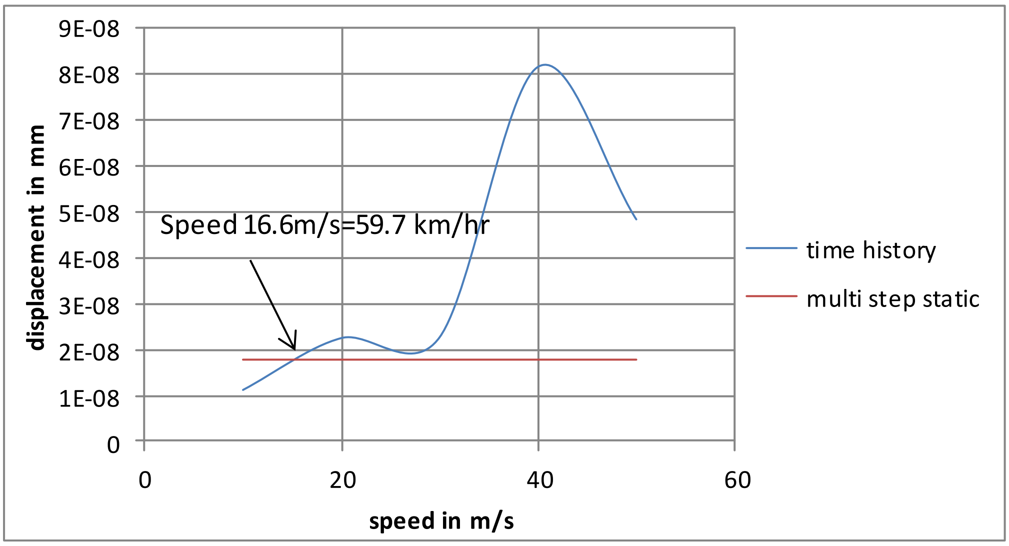

FIGURE 3 VARIATION OF MID SPAN DISPLACEMENT DUE TO PASSAGE OF MBGT WITH RESPECT TO VELOCITY

The parameters which are involved in moving load analysis mainly are (a) duration of loading i.e. the time required of a train to pass over the bridge (b) time step for discretization of the load. For *multi-step static* analysis speed of the train (*v*) and time step (*dt*) are considered as 10 m/sec and 0.05 sec respectively for finding the stress histories. The minimum spacing between two wheels (*lw*), considering all the trains is 1.7 m. For getting all the cycles in the stress history time step should be less than (*lw*/*v*). Dynamic analysis is performed using linear direct integration Time history for different speed of train.

IV. Cut off velocity

When the response of static analysis crosses the response of dynamic analysis then the corresponding velocity is named as cut-off velocity.
The cut off velocity is found from fig.3 is 59.7 km/hr for particular bridge.

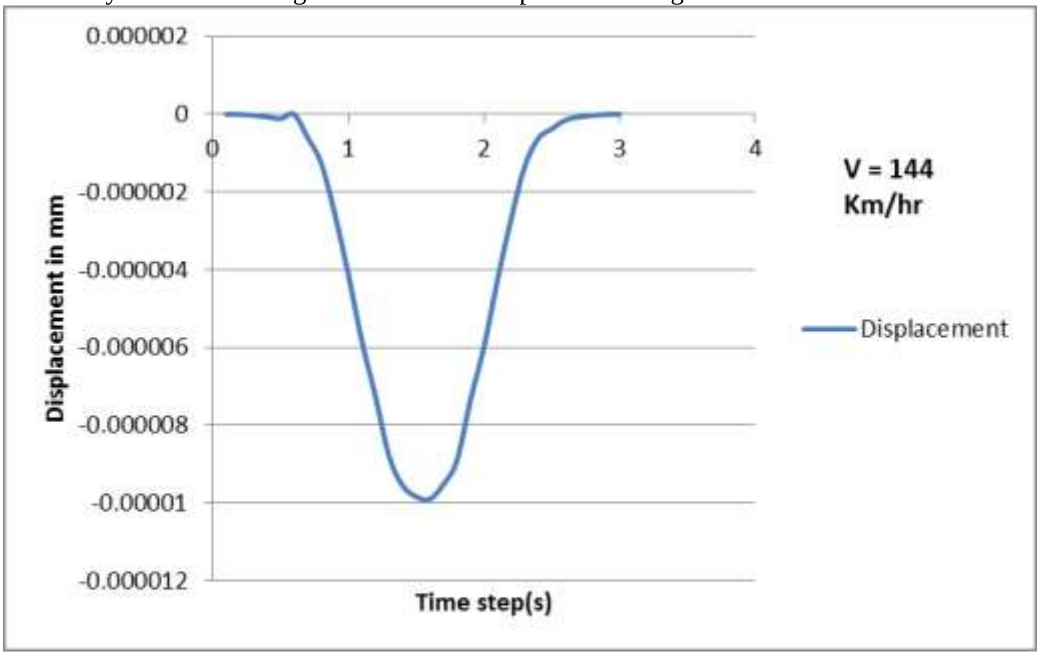

FIGURE 4MID SPAN DISPLACEMENT WITH RESPECT TO TIME STEP

Fig. 4 shows the mid span displacement with respect to time. The maximum displacement occurs when the train is at the middle of the bridge.

VI Conclusion

After analyzing the above bridge at different speed, the following conclusion can be drawn up.

1. Mid span displacement of the bridge is varying with speed as per dynamic analysis.
2. The cut off velocity of existing bridge is 59.7 Km/h. static analysis is adequate upto this speed. Dynamic analysis is required to permit higher speed on same bridge.
3. Mid span displacement of bridge is varying with different position of train.
4. For present speed of train, static analysis is safe.

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