High-speed Railway Bridge Monitoring Case Report: Nanjing Dashengguan Yangtze River Bridge

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ABSTRACT: This case report summarizes the rigid hanger' dynamic characteristics analysis and fast warning method of hanger anomalies based on long-term monitoring data collected from the structural health monitoring (SHM) system installed on a high-speed railway bridge. The present short report is not published formally here, it is a summary of the authors' previous studies and the details can be found in the previous work [1-2].

Test Structure and Measured Data

The monitoring object, Nanjing Dashengguan Yangtze River Bridge, is a high-speed railway continuous rigid arch bridge with the design speed of 300 km/h, as illustrated in Figure 1 [1]. The traffic was opened in the year of 2011; this bridge is the first six-track railway arch bridge and it has the highest loading capacity and longest main span of 336m in the world. As shown in Figure 2 [1], there are three rows of hangers in the bridge, and each row owns 21 hangers in a main span.

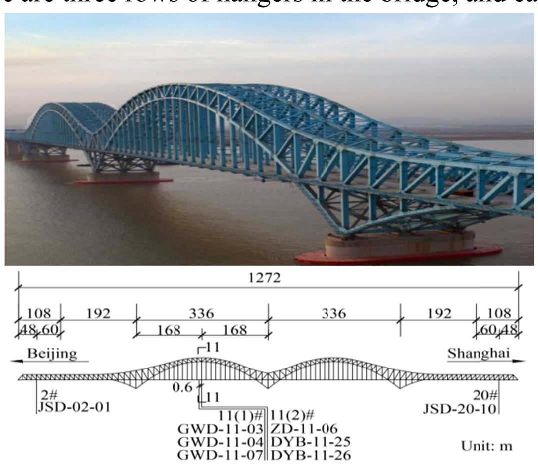

Figure 1: Nanjing Dashengguan Yangtze river bridge

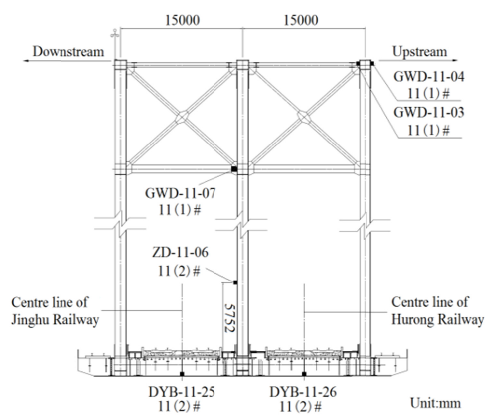

Figure 2: Sensor layout diagram in section #11

An SHM system, which contains temperature sensors (GWD in Figure 2), steel dynamic strain sensors (DYB in Figure 2), velocity sensors (ZD in Figure 2), and accelerometers (JSD in Figure 2), was established for the long-term monitoring of the bridge. The detailed sensor layout is described in Figures 1~2 [1]. Here 11# hanger is the middle one in the middle row of the left main span.

SHM Methodology and Results

The hanger's vibration responses and their influence factors (including environmental factors and train load cases) were measured from the SHM system. The objective of this study is to help understanding the rigid hanger's dynamic performance in real environment and to propose a fast warning method for hanger anomalies. Therefore, the hanger's dynamic characteristics analysis under different influence factors and the establishment of hanger's reference service condition database have been conducted. Firstly, several dynamic parameters which are important for structural performance, and the factors which have influences on dynamic parameters, are selected in this study. Then, the hanger's dynamic parameters and the influence factors are extracted based on the long-term monitoring data. Finally, two studies have been finished: the characteristics of different dynamic parameters are analyzed, and the hanger's reference service condition database is established for fast warning of hanger anomalies.

Dynamic characteristics analysis: transverse dynamic displacement

With the train load cases classification, Ding et al. [2] obtained the probability density distributions (Figure 3 [2]) of 11# hanger's (Figure 1) transverse dynamic displacement amplitude. The train load case is an important factor for hanger's dynamic characterisitics. The hanger's three vibration parameters [2], i.e. dynamic displacement amplitude, dynamic load factor and vibration amplitude, in each load case in the longitudinal and transverse directions have obvious probabilistic characteristics. Correlations between the hanger's longitudinal/transverse dynamic displacement and the main girder's transverse dynamic displacement in each load case are investigated. Influences of the carriageway and carriage number on the hanger's three parameters and their statistical trends are analyzed. Moreover, the temperature is found to be an influence factor for hanger's transverse dynamic displacement. From Figure 4 [1] it can be seen that the train-induced 11# hanger's transverse dynamic displacement changes amplitudes (TDDCA) in all the eight train load cases show inverse correlations with the temperature.

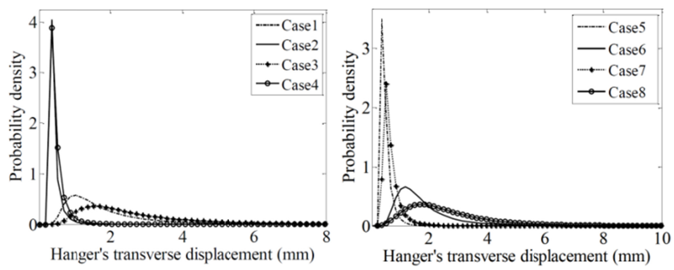

Figure 3: Probability density fitting curves of the 11# hanger's transverse dynamic displacement amplitudes for eight train load cases

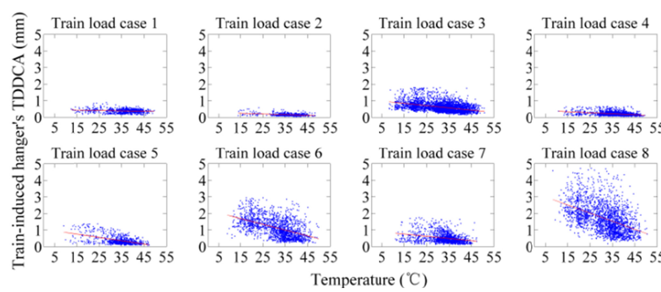

Figure 4: Correlation between the temperature and the hanger's train-induced TDDCA for eight train load cases

The hanger's reference service condition database and fast warning for anomalies

In above analysis, the influence of train load cases on hanger's dynamic characteristics has been studied, and the correlation between the temperature and train induced hanger's TDDCA has been found. Then, the hanger's reference service condition database can be established [1]. Take train load case 3 for example, the basic procedures can be summarized as follows: (1) extract the hanger's train-induced TDDCA and influence factors when the bridge is in normal service condition; (2) exclude the effect of influence factors; (3) obtain the hanger's reference displacement condition database in different environmental conditions and train load cases. Based on the hanger's reference condition database and the warning threshold line (Figure 5 [1]), the hanger anomalies can be warned fast.

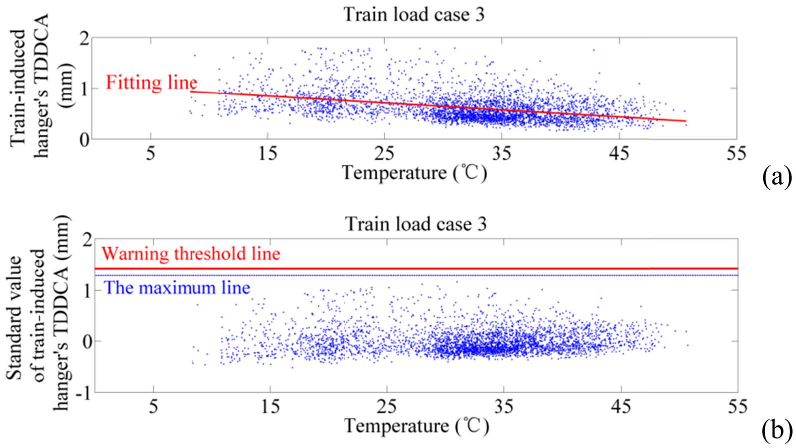

Figure 5: Reference service condition sub-database of the hanger's TDDCA in train Load Case 3: (a) the trend and correlation between the temperature and the hanger's train-induced TDDCA; (b) the reference correlation and the warning threshold after removing the trend.

Lessons Learned

In the case report of the rigid hanger's dynamic performance analysis and anomalies warning, several lessons are learned and concluded:

(1) The dynamic performance of hangers is influenced obviously by train load cases and the temperature; the influences are analyzed and they have different statistical properties. It is necessary to consider the influences in order to obtain accurate structural dynamic analysis results. This study lays a good foundation for the further analysis of train-induced hanger vibration and control.

(2) After the establishment of a bridge member's reference service condition database based on plenty of field monitoring data collected in the normal service status, fast warning for the anomalies of the member can be conducted. The fast warning method for rigid hangers [1] can be similarly applied in fast warning of other members in high-speed railway bridges.

Acknowledgements

The authors would like to express their gratitude for financial support from the National Natural Science Foundation of China (51508070), the National Key Basic Research Program of China (2015CB060000), and the National Natural Science Foundation of China (51778106). Also, the authors would like to thank the bridge owner and manager for the support throughout the research.

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