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Live Load Monitoring of the I-10 Twin Span Bridge

INTRODUCTION

The bridge selected for the case study is the new I-10 Twin Span Bridge (TSB) located in southern Louisiana. Being a vital part of Interstate 10, the new TSB crosses the Lake Pontchartrain connecting Slidell and New Orleans. The new TSB was built after the original span suffered extensive damage from Hurricane Katrina in 2005. The construction of the new TSB started in 2006 and was completed in 2011. It was the largest public work project in Louisiana history.

Overloaded trucks often cause serious damage and safety threats to bridges. Compared to the standard design traffic/live loads in design specifications, such as AASHTO HL 93, the actual characteristics of overloaded trucks, such as truck weight and types, are very difficult to predict or define in advance because they are site specific. Therefore, it is important to investigate the characteristics of overloaded trucks and their actual impact on bridges that were typically designed against the standard design traffic loads. Bridge condition assessment and live load capacity evaluation are the principal components of the Federal Highway Administration's (FHWA) National Bridge Inspection Program (NBIP). The objective of the NBIP program is to more accurately evaluate bridge capacity in order to ensure the safety of traveling public. Accurate bridge load rating is also an important factor for decision making regarding bridge rehabilitation/replacement, load posting, and overload truck permitting.

OBJECTIVE

The objectives of this project were to develop a data interface tool for data processing; develop a strategy for truck characterization; determine the effects of traffic loads on the instrumented components of the bridge; and develop a methodology for performance assessment of the instrumented bridge.

SCOPE

The new I-10 TSB was instrumented with strain gages for both the superstructure and the substructure. The main effort of this research was to validate the bridge performance monitoring system that is capable of capturing the live load information and its effects on the performance of the instrumented bridge components, through developing data interface tools. The tasks of this research included a literature review assessing the existing instrumentation, collecting and processing data, analyzing data, developing a methodology to assess the performance of the bridge, and predicting the future performance of the bridge using the developed strategy.

METHODOLOGY

The monitoring data of the I-10 TSB was first processed using the wavelet decomposition to extract the live load effect data and then the Bayesian method was adopted to predict the future maximum stresses of the bridge. The prediction results show that the predicted maximum stresses obtained using the Bayesian method are significantly higher than those obtained using the conventional method. The difference is caused by the uncertainty inherent in the parameters. The maximum stresses of exterior girders generally increase faster with the increase of return period than those of interior girders due to the different tail behavior

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between the maximum stress distributions of exterior and interior girders. Finally, the condition assessment of the bridge was conducted using the proposed framework. The design capacity envelops and service LE envelops were developed based on the design calculation and the finite element modeling of the bridge. The condition assessment results show that the bridge is performing as designed under the current condition and that the future condition of the bridge is safe except that certain girders closes the slow lane may be overstressed in the future. Furthermore, a NOR BWIM system was developed. The developed NOR BWIM system is a potential solution to achieve the live load monitoring using the current instrumentation of the I-10 Twin Span Bridge.

CONCLUSIONS

Based on the study using the developed methodology, the following conclusions can be drawn:

1. The Bayesian method provides a systematic framework of uncertainty quantifications for extreme value analysis. Compared with the conventional method, the Bayesian method is able to quantify the uncertainties of parameters in terms of posterior distributions and incorporate the uncertainties into the prediction through the posterior predictive distribution;
2. The prediction results on the I-10 TSB show that the predicted maximum live LEs obtained using the Bayesian method are higher than those obtained using the conventional method especially for longer return periods. This difference is caused by the uncertainties inherent in the distribution parameters;
3. The condition assessment results on the I-10 TSB show that the bridge is performing normally under the current condition and that the bridge will be safe during its remaining life from the design perspective except that certain girders close to the slow lane may be overstressed in the future (75-year return period);
4. Numerical results show that the proposed algorithm can identify the TP and the axle weights of vehicles and that considering the vehicle's TP can significantly improve the identification accuracy of axle weights. However, the identification accuracy of axle weights decreases significantly as the road surface condition becomes worse;
5. Vehicle axle identifications can be achieved through a wavelet analysis of bridge global responses. This approach has obvious advantages over existing axle identification methods in that it requires fewer sensors.

RECOMMENDATIONS

Based on the condition assessment results, the I-10 Twin Span Bridge is currently safe and performing as designed. Nevertheless, results also indicate that the exterior girders under the slow lane could be overstressed in the future. Thus, it is suggested that the future inspection pay special attention to these exterior girders. Furthermore, as the monitoring duration increases, the newly obtained data should be processed using the developed software and included to update the prediction in order to get more reliable predictions. In addition, when the monitoring period becomes sufficiently long, the non-stationarity of the traffic should be considered using the proposed method for long-term assessment in order to more accurately account for the traffic effects.

The project was intended to monitor the live load information. However, due to the failure of the installed WIM system, live load information cannot be achieved, which motivates the development of a nothing-on-road (NOR) bridge weigh-in-motion (BWIM) system in this study. Numerical simulation and experimental study on a bridge in Louisiana show that the developed NOR BWIM system is able to identify the vehicle speed, axle spacing and weight using only the strain sensors installed at the mid-span of the bridge. This suggests that the developed NOR BWIM system may provide a potential tool to achieve the live load monitoring of the I-10 Twin Span Bridge utilizing the current instrumentation. Nevertheless, the implementation of BWIM system requires field tests to calibrate the influence surfaces. It is thus recommended that a load test be conducted to explore the feasibility of achieving the live load monitoring using the current instrumentation of the I-10 Twin Span Bridge. The load test can also provide information to calibrate the finite element model of the bridge, which can help further reduce the uncertainty and achieve more reliable condition assessment of the I-10 Twin Span Bridge.

Figure 1
Damaged original twin span (left) and the new twin span (right)