Suppression of train-induced vibrations of continuous truss bridge by hybrid TMDs

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Summary Steel truss bridges possess the advantages of light weight, high strength, and ease in construction, they therefore are often utilized in railways for crossing streams or chasms. However, because of the existence of clustered frequencies of vibration, there may occur multi resonant peaks in the impact response of continuous truss bridges subjected to high speed trains. To overcome this problem, a hybrid tuned mass damper (TMD) system will be employed to mitigate the train-induced vibrations of the continuous truss bridges. By modeling a continuous truss bridge as a combination of beam and truss elements and the train over it as a sequence of moving loads. The numerical results indicate that the proposed hybrid TMD system can effectively suppress the main resonant peaks of the continuous truss bridge due to the train loads moving at high speeds.

Extended Summary

This paper deals with the vibration suppression of railway bridges subjected to the passage of high-speed trains. In a practical design, the impact factor is used to evaluate the dynamic amplification effect of a bridge due to the action of vehicles moving over it. In this study, the impact factor I is defined as the ratio of the maximum dynamic to the maximum static responses of the beam under the action of the moving loads minus one. It has been indicated that for a bridge subjected to the moving action of a single truck with constant speed v, the impact factor may be linearly related to the speed parameter S, which represents the ratio of the driving frequency ($= \pi v/L$) implied by the moving loads to the fundamental frequency ω of the bridge (Yang et al. 1995).

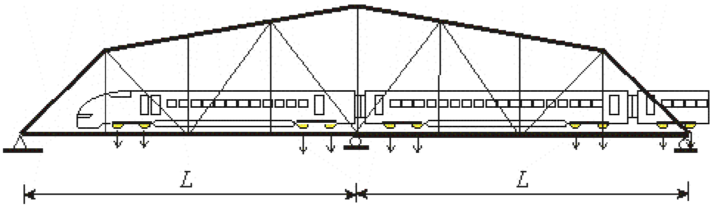

Fig. 1 Continuous truss bridges subjected to high speed trains

As shown in Fig. 1, a two-span continuous truss bridge with equal spans and simple supports subjected to a Shinkansen (*SKS*) train is considered. By modeling the truss bridge as a combination of beam-column and truss elements and the train moving over it as a series of moving loads, the *vehicle-bridge interaction* finite element program developed by the author (Yau, 1996) is employed to obtain the impact response of the truss bridge.

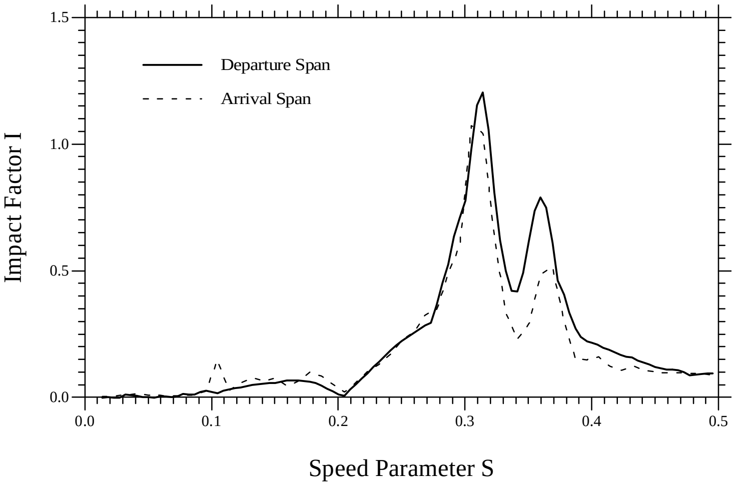

Fig. 2 Impact response of continuous truss bridge.

Fig. 2 shows that the displacement impact responses solved for the midpoint of each span of the truss bridge have been plotted against the speed parameter S. As can be seen, there exist two resonant peaks for the impact response curves of the arrival span and the departure span of the continuous truss bridge. This is mainly due to coincidence of some of the excitation frequencies implied by the moving wheel loads at different speeds with the fundamental or higher frequencies of the truss bridge. Besides, it is observed that the impact factor for the departure span is larger than that of the arrival span. This can be attributed to the uplift action caused by the departure of the last moving load from the arrival span and entrance into the departure span. For this reason, only the impact response of the departure span will be considered in the illustrative example.

To effectively reduce both two resonant peaks of the continuous truss bridge due to vehicles moving at high speeds, a hybrid tuned mass damper (TMD) system is proposed for suppressing the train-induced responses of the truss bridge. Since the first two resonant peaks affect the departure span of the truss bridge, the hybrid TMD system is composed of *dual* TMD subsystems, namely, TMD-1 and TMD-2, as depicted in Fig. 3, each of which consists of a TMD tuned to one of the first two resonant frequencies of the truss bridge. Using the *minimum-maximum amplitude criterion* proposed by Randall et al. (1981) and enforcing the resonant peaks of interest to be equal to each other, one can determine the allocated mass and optimum parameters for the hybrid TMD system (Yau and Yang 2004). Because the response contribution of the first mode of the continuous truss bridge is greater than that of the second mode, the modal mass ratio with respect to the fundamental mode will be adopted for the hybrid TMD systems mounted on the truss bridge. On the other hand, an increase of the TMD mass ratio will result in a better control of the vibration of the main structure. However, the self-weight of the TMD will induce as well additional deformation on the main structure. Therefore, a small modal mass ratio 0.01 is adopted for the sum of the masses of all hybrid TMD systems attached to the continuous truss bridge in the example.

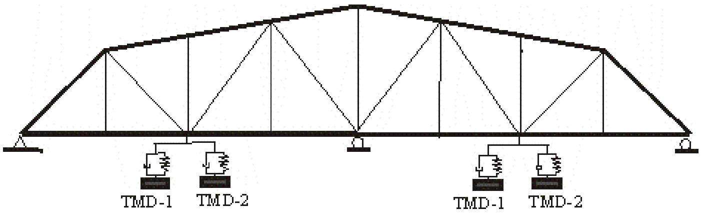

Fig. 3 Continuous truss bridge model with hybrid TMD systems

By mounting the proposed hybrid TMD systems on the midpoint of each span of the truss bridge, the impact response of the departure span for the truss bridge is depicted in Fig.4. As can be seen, the hybrid TMD system proposed considering only the contribution of the first and second modes is quite effective for suppressing the resonant responses of the continuous truss bridge subjected to high speed trains.

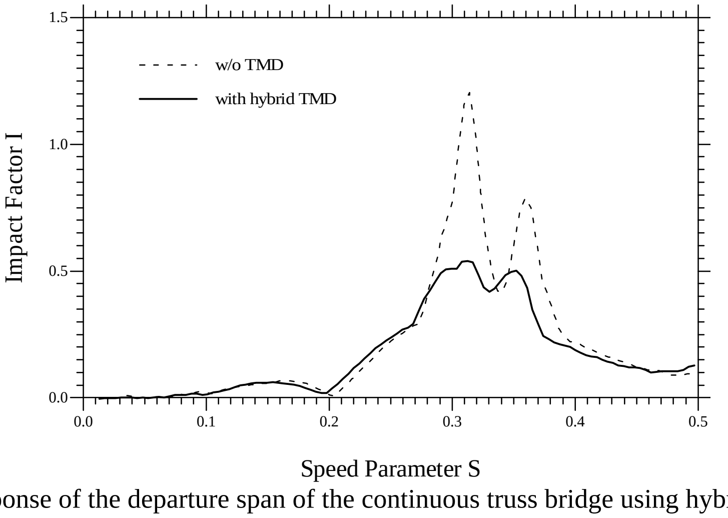

Fig. 4 Impact response of the departure span of the continuous truss bridge using hybrid TMD system.

References

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