Dynamic Analysis of Cable-Stayed Bridge under Construction Considering Hoisting Deck Segment Motion

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Summary

In this study, we perform dynamic response analysis for cable-stayed bridge system under construction including hoisting deck segment motion as well as pylon-cable-deck vibration. In order to consider the interaction between the bridge, derrick-crane and the hoisted deck segment, we formulate nonlinear equations of the motion for bridge-segment coupled system. Analysis results show that vortex induced resonant vibration of the bridge-segment coupled system can occur for a specific stage of the construction and hoisting motion, which results in excessive displacement response of the hoisted deck segment. As a feasibility study, we develop a vibration controller for the time-varying pendulum motion period of the hoisted deck, which consists of a combination of the multiple optimal controllers. The effectiveness of the proposed control method is presented by investigating the acceleration and displacement response of the system with respect to safety and workability criteria.

Keywords: cable-stayed bridge, hoisting motion, derrick-crane, vibration control

1. Dynamic Analysis of Cable-Stayed Bridge under Construction Considering Hoisting Deck Segment Motion

For cable-stayed bridges constructed by the cantilever method, the bridge system during construction is very vulnerable to wind-induced vibration due to its unstable configuration before the decks are fully connected. During construction by cantilever method, new segments are lifted by derrick crane and welded to the deck. In the meantime, the system is very vulnerable to dynamic wind effects and the welding process can be disturbed by the wind loads.

In this study, we perform dynamic response analysis for cable-stayed bridge system under construction including hoisting deck segment motion as well as pylon-cable-deck vibration. In order to consider the interaction between the bridge, derrick-crane and the hoisted deck segment, we formulate nonlinear equations of the motion for bridge-segment coupled system. The equations are developed from a reasonably simplified two-dimensional plane model for cable-stayed bridge with a derrick crane mounted, which can simulate mass hoisting and jib angle change(Figure 1).

Analysis results show that vortex induced resonant vibration of the bridge-segment coupled system can occur for a specific stage of the construction and hoisting motion, which results in excessive displacement response of the hoisted deck segment.

https://doi.org/10.2749/222137809796078379

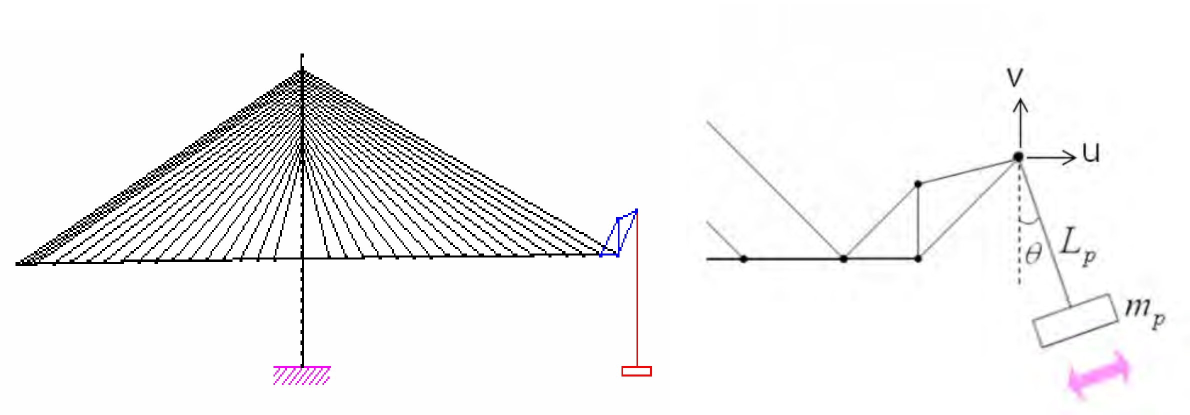

Figure 1. 2-D model bridge-crane structure considering the pendulum motion

Also, we installed TMDs at the end of the bridge deck and the top of the pylon, to see the effect of controller on the pendulum motion of the derrick crane. As a result of this analysis, we confirmed that the pendulum motion by the vibration of the bridge can be controlled by existing control methods, but if the resonance occurs with pendulum motion itself the vibration can not be controlled by controlling the bridge vibration and need to be controlled by some convertible control system.

As a feasibility study, we designed a convertible control system for the coupled system. Since the deck segment is hoisted, the length of the crane cable varies with time and so does the period of the pendulum motion period of the hoisted deck. Thus, we developed a controller for the time-varying nonlinear system, which consists of a combination of the multiple optimal controllers. This active controller was installed at the hoisted segment additionally. Figure 2 shows control performance of proposed control system in 2 resonance cases. It was identified that proposed control system reduces the displacement of hoisted segment which is not controlled by only TMDs when the resonance occurs with pendulum motion itself.

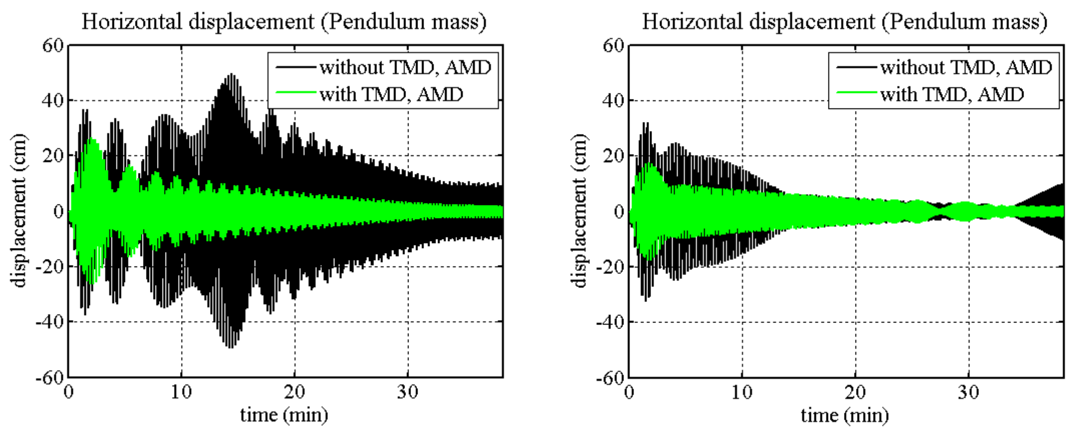

Figure 2. Control performance of proposed control system in 2 resonance cases