A Damper System for Mitigation of Suspension Bridge Flutter

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Summary

A floating system using a continuous girder between two anchor blocks is often adapted for increasing the span length of suspension bridges. The flutter instability of the floating system due to winds is thus of great critical interest. This paper proposes a new control system to mitigate the flutter of the floating-type suspension bridge. The proposed control system consists of vertical dampers installed between the pylons and the bridge deck. The linear evaluation model is developed using the equations of motion generated around the deformed equilibrium position. Using the analytical model, performance of the proposed control systems is studied and compared to a traditional system with joints at the pylons. It is shown that the proposed control system improves the overall stiffness and stability of the bridge. A control strategy using semi-active or active dampers is also proposed to enhance the controllability of the floating-type suspension bridge against flutter instability.

Keywords: Flutter, Suspension bridge, Floating system, Vibration control, Damper

1. Introduction

2. Suspension Bridge Flutter

3. Vertical Damper System

The damper system proposed in this paper is composed of 4 vertical dampers installed between the pylon legs and stiffening girders for floating type suspension bridge as schematically shown in Fig. 2. This damper system is to control the vertical and torsional displacements of the girder as well as to improve the structural damping of the bridge. Since the stiffening girder rotate when torsion is acted on, the vertical damper may be installed at both sides of the girder as show in the figure. This system can add to the rotational-stiffness thereby increasing the resistance for dynamic rotation by which the velocity is considered at damping effect.

4. Active Control Design

A semi-active or active damper system instead of the passive one may be installed to enhance the controllability. Based on the description of the bridge provided in the previous section, the linear evaluation model is developed using the equations of motion generated around the deformed equilibrium position. The FEM model described is used directly in cases when the vertical dampers are employed between the pylon legs and stiffening girders. If semi-active or active dampers are employed at these locations, the model is needed to modify. Then, the static analysis is performed in

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FEM Program, and the element mass and stiffness matrices are output to MATLAB for assembly.

The element mass and stiffness matrices generated in FEM are summed at each node to assemble to global stiffness and mass matrices within MATLAB. The model resulting from the finite element formulation has a large number of degrees-of freedom and high frequency dynamics. Thus, some assumptions are needed to make regarding the behaviour of the bridge to make the model more manageable for dynamic simulation while retaining the fundamental behaviour of the bridge. From model reduction, the equation of motion of the semi-active or active control system for mitigation of suspension bridge flutter may be expressed as

$$\hat{\mathbf{M}}\ddot{\mathbf{x}} + \hat{\mathbf{C}}\dot{\mathbf{x}} + \hat{\mathbf{K}}\mathbf{x} = \mathbf{\Lambda f} - \Gamma\ddot{x}_b \qquad (7)$$

where $\hat{\mathbf{M}}$, $\hat{\mathbf{C}}$, $\hat{\mathbf{K}}$ are the mass, damping, and stiffness matrices of the bridge respectively, $\mathbf{f}$ is the the vectior of control force input, $\mathbf{\Lambda}$ is a vector defining how the forces produced by the control devices enter the structure, Γ is a vector zeros and ones defining the loading of the ground acceleration to the structure and $\ddot{x}_b$ is the ground acceleration. The damping in the system is defined based on the assumption of modal damping.

Fig. 11 provides the SIMULINK model used for evaluation of proposed control strategies. In order to enhance the applicability of the semi-active or active damper system, the following procedures are adopted. The sensors, devices, and algorithms to be used in the control strategy must be defined clearly. The sensors and control devices interface with the bridge model through measurements and connection outputs designated as y_m and y_c respectively. Additionally the components of the evaluation output vector are defined and designated as y_e .

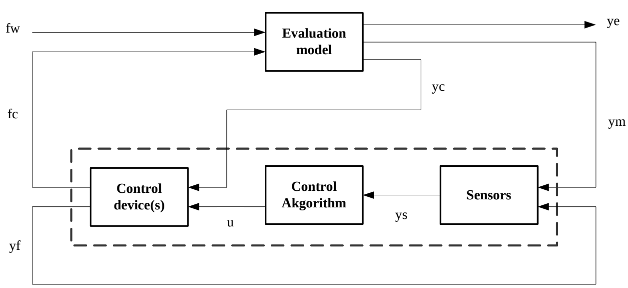

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Fig. 11: Block diagram representation of the control system

5. Conclusions

One of the main problems that have to be faced for a long span suspension bridge is the flutter stability. In this study, a new damper system is proposed to mitigate the flutter of a floating-type suspension bridge. To verify the effectiveness of the proposed system, linear evaluation model is developed for a 480+1450+380 span suspension bridge in the floating system. The numerical results are shown that the proposed control system improves the overall stiffness and stability of the bridge, thus demonstrating the system’s efficacy if the vertical damper are selected properly. A control strategy using semi-active or active dampers is also proposed to enhance the controllability of the floating-type suspension bridge against flutter instability.