

FULL BRIDGE MODEL STUDY OF A PASSIVE AERODYNAMIC FLUTTER SUPPRESSION SYSTEM

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1. INTRODUCTION

The aerodynamic flutter control methods, by means of additional surfaces, can change the flow-structure interaction and suppress flutter. The proposed passive control system (Fig. 1) consists of flaps attached directly to the bridge deck. The control flap rotations are govern by control cables and prestressed springs. The asymmetric cable connection system (Fig. 1a) requires changes in its configuration when the wind direction changes. The performance of the symmetric cable connection system (Fig. 1b) is independent of wind direction. The aim of this paper is to investigate the effectiveness of the proposed system for suppression of wind induced instabilities in long-span bridges.

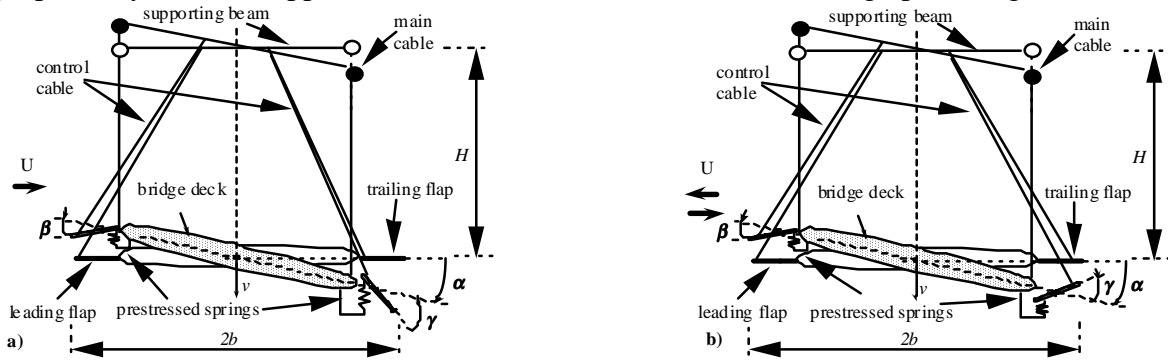


Fig. 1 Passive bridge deck-flaps control system: a) asymmetric cable connection system; b) symmetric cable connection system.

2. SECTIONAL MODEL

The deck of a sectional model of the control system has two structural degrees of freedom: vertical, v , and torsional, α . For sufficiently large prestressing moments and stiffness of the supporting beam, the rotations of the flaps, β and γ , are proportional to the torsional motion of the deck:

$$\beta = t_\beta \alpha, \quad \gamma = t_\gamma \alpha \quad (1, 2)$$

The time domain formulation of self-excited forces is obtained from the Theodorsen and Garrick solution for a wing-aileron-tab combination using Rational Function Approximation (RFA)¹⁾.

3. FULL BRIDGE MODEL

The basic assumptions of the used simplified full bridge model are: hangars are inextensible and the forces they apply to the deck are distributed loads, and dynamics of the towers are ignored. The finite element for the deck-flaps system (Fig. 2) has 18 structural degrees of freedom. Additional degrees of freedom corresponding to the aerodynamic states are added at each node. For full bridge model of the passive control system, the motion of the flaps is govern by torsional as well as horizontal motions:

$$\beta = t_\beta \alpha + t_\beta (h_d - h_c) / H, \quad \gamma = t_\gamma \alpha + t_\gamma (h_d - h_c) / H \quad (3, 4)$$

where h_d is the horizontal displacement of the deck, and h_c is the common horizontal displacement of the main cables. H is the vertical distance between the main cables and flaps.

4. NUMERICAL SIMULATIONS

The analyzed suspension bridge has main span of 3000 m, and side spans of 1000 m each. The deck has width of 30 m. The frequencies and damping ratios of first few modes are listed in Table 1. For sectional study, the second vertical and the first torsional mode are chosen. For the uncontrolled system, the sectional model gives the flutter wind speed of 54 m/s and the divergence wind speed of 71 m/s. The FEM model yields 58 m/s and 71 m/s, respectively.

The simulations of the controlled system were conducted for flaps of width 1.0 m, 2.0 m and 3.0 m. For the full bridge model, the flaps were assumed to be located on 30%, 50% and 100% of the main span.

The results for the sectional model of the asymmetric cable connection system are shown in Fig. 3a.

The sectional model exhibits very high improvement in critical wind speed. The analysis conducted on the full bridge model, whose example for 2.0 m wide flaps is shown in Fig. 3b, showed, however, that this improvement is limited due to large sensitivity to lateral motions. The maximum improvement in critical wind speed for this system is 70 m/s (21%).

The results of the simulations for the sectional model of the symmetric cable connection system are shown in Fig. 4, for the sectional and full bridge model, respectively. The results obtained from sectional study are close to those of the full bridge model, indicating that the symmetric cable connection system is not sensitive to lateral motions. The highest improvement in critical wind speed up to 70 m/s (21%) was found for very small flaps of 1.0 m.

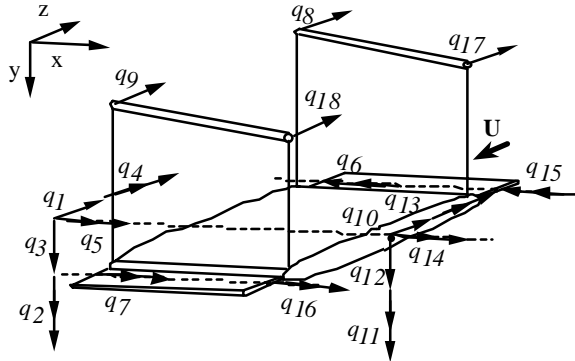


Fig. 2 Finite element for the deck-flaps system.

Table 1 Modal properties of the bridge.

mode	frequency (rad/s)	damping ratio
1st horizontal symmetric	0.204	0.016
2nd horizontal antisymmetric	0.353	0.011
3rd horizontal symmetric	0.481	0.010
1st vertical antisymmetric	0.412	0.010
2nd vertical symmetric	0.413	0.010
3rd vertical symmetric	0.611	0.009
1st torsional symmetric	0.905	0.010
2nd torsional antisymmetric	1.418	0.013
3rd torsional antisymmetric	2.199	0.018

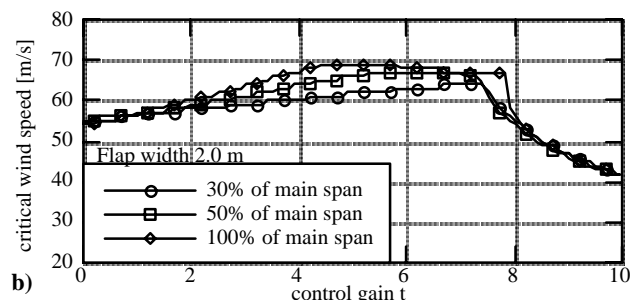
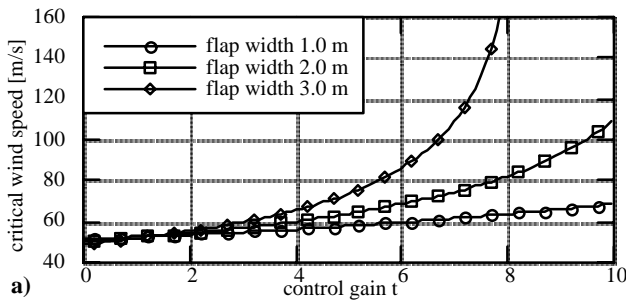


Fig. 3 Critical wind speed vs. control gain for the asymmetric cable connection system: a) sectional model; b) full bridge model.

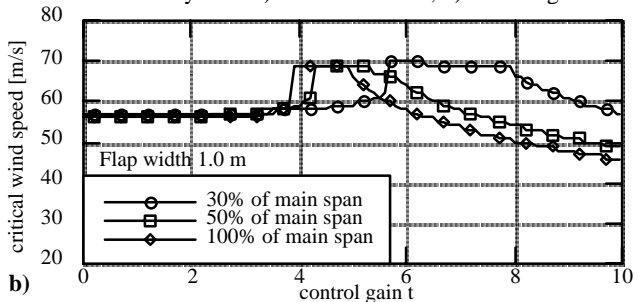
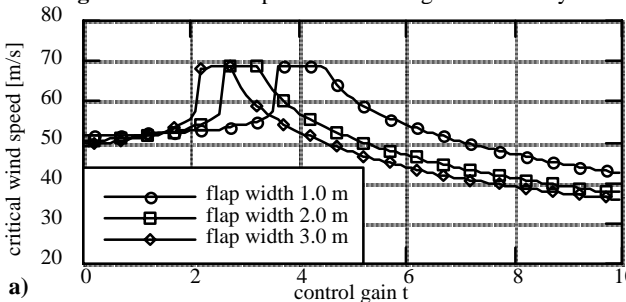


Fig. 4 Critical wind speed vs. control gain for the symmetric cable connection system: a) sectional model; b) full bridge model.

5. CONCLUSIONS

In this paper the passive aerodynamic bridge deck-flaps control system for suppression of wind induced instabilities in long-span bridges is studied. The two configurations of control system are proposed: the asymmetric and symmetric cable connection systems, respectively. The asymmetric cable connection system improves critical wind speed by 21% and requires changes in its configuration when wind direction changes. The symmetric cable connection system also improves critical wind speed by 21%, uses small flaps and is independent of wind direction. These advantages suggest the symmetric cable connection system to be a superior choice.

6. ACKNOWLEDGMENT

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REFERENCE

- 1) Omenzetter P., Wilde K., Fujino Y.: Suppression of Wind Induced Instabilities of a Long Span Bridge by a Passive Deck-flaps Control System. Journal of Wind Engineering and Industrial Aerodynamics, (under review).