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Active Tendon Actuators for Cable-Stayed Bridge

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Abstract

Improvements in materials led to the construction of progressively longer, structurally more efficient and slender bridges. But consequently, structures are more and more flexible. Deck and cable vibrations have become a major issue in cable-stayed bridge design. Their increasing span length makes them more sensitive to flutter instability as well as to wind and live load induced vibrations. It is a difficult problem to assess because of the highly non-linear behaviour of cables with sag. Avoiding significant levels of wind excited oscillations, resulting in levels of vibration, and in the worst case in flutter instability is a new challenge for the designers. In the long term there is a potential for serious fatigue damage. In the short term, excessive levels of vibration hamper the traffic and bother the end-user comfort.

To minimise vibrations, passive damping devices for stay-cables have already been developed and used. The dashpot damper delays the appearance of vibrations, but only until a certain level of excitation. As regards elements of cable-tie systems, although used on actual bridges, their long-term behaviour to fatigue has still to be proved. But these damping devices mitigate only the cable vibrations, not the structure vibrations. Tuned Mass Dampers have also been studied in order to reduce structure vibrations. Their efficiency is limited by the geometrical constraints of the deck cross-section. In addition, all these passive devices are tuned on theoretical simulation results, which can be partly far away from the real world, and fit only with previous predefined scenarios. Finally, these devices do not take into account the ageing of the structure components, and consequently the variation in time of the structure behaviour.

The present work concerns the development of Active Tendon Actuators for use in cable-stayed bridge in the framework of the ACE research project partly funded by the EC Brite-EuRam programme. The aim is for the active tendon actuators to increase the structural damping in order to mitigate vibrations. The application of active actuators to flutter control has already been considered theoretically and application to active damping has been studied with more or less success. The proposed technology uses an alternative control strategy developed by Université Libre de Bruxelles, partner of the ACE project. The control strategy is based on a force sensor collocated with the active tendon actuator. The technique has a strong physical support and the effectiveness has been confirmed by simulations and demonstrated experimentally on a small-scale laboratory mock-up.

The project aims to:

a) improve the understanding of the induced vibrations of cable-supported structures;
b) develop an appropriate software package capable of analysing the behaviour of cable-supported structures;

c) develop an active system to control induced vibrations of cable-supported structures;
d) develop the appropriate actuators; and
e) validate the active control system with a large scale mock-up and measurements of existing structures.

The main critical points of the project are outlined here. This concerns the following issues:

- the active control strategy having been validated on a small scale mock-up, extensions to more complex structures are investigated on a small scale mock-up and on a large scale mock-up.
- as regards the large scale mock-up and also real structures, the key element is the actuator. Two solutions will be explored and tested.
- the design of the active control system requires important improvements of the current structural dynamic algorithms.
- an experimental on a large scale cable stayed bridge mock-up will be carried out to validate the active control system and the structural dynamic algorithms.
- experimental measurements on existing structures will also be used.
- a technical and economic comparison of this method of upgrading with other techniques will also carried out.

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