Aeroelastic instability of cable-stayed bridges

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ABSTRACT

Although the original concept of cable-stayed bridges dates back more than two centuries, the modern techniques used in this typology were initiated at the second half of last century, due to the innovations of pioneers like Dischinger, Homberg, Telford, Leonhardt, Finsterwalder or Morandi. Since then, it has been time enough for the appearance of little scars on the structural typology of bridges held by cables, some of them actually hurting, as the collapses of the suspension bridges of Brighton in 1836, of Menai's strait in 1839, of Wheeling in 1854 and the most known collapse of the bridge over the Tacoma strait in 1940. All these accidents have a common origin: the wind action was not resisted by the structure. The present scientific and technological development of the civil engineering allows assuring the security of this kind of structures against environmental actions. It shows the deep but not whole understanding of the phenomena in action with these structures.

The collapse of the bridge over Tacoma's strait led to a period of intense investigation that gave birth to aeroelasticity in civil engineering. This is the discipline that studies the behaviour of a deformable body immersed in a fluid in movement and the relation between the forces caused by the fluid and the deformation of the body. One of the most dangerous aeroelastic phenomena, due to its catastrophic effects, is flutter**.** This phenomenon consists in the appearance of growing amplitude/range oscillations on the deck of the bridge because of a critical speed of wind. These movements lead to the final collapse of the structure. The techniques that allow studying the flutter of a bridge are diverse and nowadays are in process of reaching maturity, which reveals the youth of this branch of science.

As a consequence of the improvements introduced with the development of aeroelasticity science from the 60's of 20th century, the great cable-stayed bridges have longer spans. It must be remarked the length of the span of bridge of Sutong in China of 1088 m. It is partly due to the advances in calculation methods and the incorporation of innovative techniques such as the deck in aerodynamic section. The present situation shows a promising scenario. Nowadays, structural engineering is capable of proposing ambitious projects, guaranteeing its structural security.

This work is divided in three parts clearly differentiated. The first part consists in a bibliographical review in order to know the state of the art and to introduce the reader to aeroelastic phenomena, particularly to the flutter in long span bridges. This way, the concept of aeroelasticity will be defined. Also the critical speed and the natural frequency of long span bridges will be formulated. In the second part of the work, the cables of cabled-stayed bridges will be sized. Setting limits to the value of tensions produced by the effects of loads and the process of tauting (it will be studied by means of a tauting simulation by freezing), the area required by the cables in order to resist will be obtained. The third part consists in an analysis of the structural response of different models of cables-stayed bridges to the aeroelastic instability caused by the flutter. The original model will be the cabled-stayed bridge in Manzanal del Barco (Zamora). This model will be modified by introducing different typologies of towers, decks and lateral spans in order to determine the influence of theses typologies in the flutter speed. The structural analysis of each of the seven solutions that will be studied will provide the natural frequencies of bending and torsion, and they will be used to evaluate the critical speed by means of a simplified parameter formulation (Selberg formulation).

The information obtained will allow to obtain the ideal combination of structural elements (deck, towers, cables distribution,…) that reduces to the minimum the aerodynamic wind effects. Reaching maturity in the design process is necessary for these beautiful and at the same time complex structures in order to achieve great brilliance.