Development of triple box girder

Interaction between wind and bridge deck on large cable-stayed bridges is a decisive factor regarding the design of the box girder and its mechanical properties. If you increase the span, you reduce the torsion stiffness of the bridge deck, which entails that the frequency of torsion oscillations approaches the frequency of bending oscillations. For traditional cable-supported box girders, this results in a drop in the critical flutter wind speed.

Flutter

When the critical flutter wind speed occurs, the wind's interaction with the bridge deck intensifies the oscillations, leading to the potential collapse of the bridge deck. It means that focus must be on the design of the actual box girder if you want to construct suspension bridges with very long spans in the future. Since it is possible to prevent flutter by reducing torsion frequency, this can be utilised to achieve aerodynamically stable solutions. When you eliminate the problem with flutter, static divergence becomes the main challenge in the pursuit of aerodynamic stability.

Static divergence

Static divergence on a suspension bridge occurs due to second-order effects caused by loads and suctions on the bridge deck due to the wind. During storms and hurricanes, torque occurs along the longitudinal direction of the box girder. This rotates the bridge deck and thereby increases the lift force. The stiffness of the bridge deck on very long suspension bridges is primarily secured by the main cables. The lift force on the bridge deck reduces the tensile stress in the main cables, thereby reducing stiffness. The bridge deck continues its rotation and yet again increases lift force on the bridge deck. In case of divergence, hangers are subjected to pressure and, at worst, the bridge deck may collapse.

Triple box girders

To avoid static divergence, you can increase the distance between the main cables to increase torsion stiffness. You can also optimise the layout of the box girders to reduce lift, drag and torque. If you also want the torsion frequency to be lower than the bending frequency, the majority of the cross-section mass must be located on the exterior side of main cables. That means increasing the total width of the cross-section.

This reduces the requirements for torsion stiffness in the actual box girder, and it may be possible to reduce the cross-section height of the box girder, which reduces horizontal wind forces. It is also possible to minimize the mass between the main cables.

If you achieve a satisfactorily high critical wind speed for static divergence, the door opens on a number of new layouts for the box girder for long suspension bridges, which – depending on the project and span – may be cheaper than the traditional box girder solution.

Therefore, in cooperation with FORCE Technology and the University of Southern Denmark, a series of wind tunnel tests are carried out to uncover the static and dynamic response of a triple box girder that is designed based on the above reasoning. Different combinations of torsion and bending natural frequencies are studied, corresponding to different locations of the main cable.