Aerodynamic testing of triplet-deck bridge

The aerodynamic challenges linked to the clear span of the bridge deck on cable-stayed bridges need to be solved before construction of the bridges takes place. When the 853 m long first bridge over the Tacoma Narrows strait collapsed into the sea in 1940, the cause of failure was flutter occurring during a fresh breeze. The collapse boosted research into methods of increasing the critical wind velocity for flutter and led to the development of new design principles. One of these principles was, and still is, to increase the torsional rigidity and the torsional frequency of the bridge deck. The problem is, however, that an increasing span length will reduce the torsional rigidity of the bridge deck.

What is flutter?
Flutter is a physical phenomenon according to which the bridge deck oscillations are powered by the wind and where the self-induced forces of the bridge deck has an effect on the wind flow due to the interaction of the ambient wind with the bridge deck causing increasing vibration amplitudes with each oscillation. In other words, a positive feedback occurs between the bridge deck and the wind flow present around the oscillating bridge deck. The energy input thus exceeds the amount of energy absorbed by the structural damping of the bridge during each oscillation cycle. This may lead to rapid and severe failure of the bridge deck.

New cross section design
Since the 1970s, bridge designers have known how to increase the critical flutter velocity by means of perforated bridge decks or double girders. Examples of using twin-deck bridges to increase the critical flutter velocity are the Stonecutters Bridge and the Xihoumen Bridge in China.

However, the critical flutter velocity still tends to become lower when increasing the span of long suspension bridges because of the smaller separation between the torsional and the vertical frequency. During wind loads, this results in a coupling of the torsional movement of the bridge deck with its vertical movement. Moreover, the static wind pressure leads to a reduction of the torsional frequency. This creates a coupling between torsion and vertical modes of vibration leading to classical flutter.

Non-flutter design principles for triplet-deck bridges
If the torsional frequency from the beginning is *lower* than the vertical frequency, it is possible to prevent the occurrence of classical flutter. The hypothesis is that the torsional and vertical frequencies will be further separated from each other during wind loads thus creating an aerodynamic decoupling of the two modes of vibration.

The present project intends to study a conceptual design of a triplet-deck bridge where the torsional frequency is lower than the vertical frequency.

Wind tunnel tests

In the spring of 2016, PhD student Michael Styrk Andersen from the University of Southern Denmark will perform a wind tunnel test at FORCE Technology to determine the static and dynamic properties of wind-induced bridge deck motions. The project is supported by COWIfonden, FORCE Technology and the University of Southern Denmark.