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Conditions for occurrence of vortex shedding on a large cable stayed bridge: Full scale data from monitoring system

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ABSTRACT

Monitoring systems are nowadays usually provided on large bridges, the decision being taken as early as the initial design process. After completion they are very valuable for providing data about the actual behavior of the structure under real wind, which can usefully be compared with design models. The Charilaos Trikoupis Bridge, between Rion and Antirion in Greece, was equipped with a very complete monitoring system including accelerometers on the deck, pylons and cables along the four spans as well as anemometers. This system is perfectly maintained by permanent staff of the bridge owner, and gives information about the bridge's structural health which is regularly used for maintenance purposes. This smart system continuously records only sparse data, with a complete dynamic check being performed every 2 h. This monitoring system was also designed to trigger detailed recording following specific events. From recorded data, cable vibration has been observed after bridge completion and the bridge owner suppressed this within several months by installing dampers between the deck and the cables. Limited-amplitude vertical vibration of the deck in the third mode was also observed on some occasions. The bridge owner asked a foreign laboratory to process two years of monitoring data in order to fully understand the origin of this vibration and evaluate whether treatment would be necessary.

1. Introduction

Civil engineering structures like slender bridges are prone, on many occasions, to deformation under service loads. When such a deformation is repeated over time and corresponds to an oscillation around a mean state, we can speak about vibration. Traffic, temperature, earth movement and wind apply loads to such a bridge, the structure of which returns to its stable state after the load ceases, with various typical periods, i.e. various frequencies. For this reason vibrations are not exceptional on a bridge (O'Connor and Shaw, 2002), they are just part of its normal behavior and only need to be observed and analyzed to check that the do not exceed security thresholds. Vibrations induced by wind draw special attention because apparently negligible loadings can produce very visible consequences.

Vortex shedding is one of these phenomena that produce anxiety, mainly because it leads to detectable amplitude movements of the structure when the origin, a moderate wind, does not appear at first glance to produce a risk. This is particularly true for large bridges because the large number of users leads to numerous testimonies when the deck is prone to visible vertical displacement. This movement usually corresponds to small amplitude of movement but, on such a long line-like structure, this leads to large amplitudes of displacement at a low frequency, which can be clearly observed by anyone.

Two key issues relating to vortex shedding excitation on a bridge deck are users' comfort if the acceleration becomes noticeable and the risk of fatigue on the most excited structural elements due to repeated solicitation.

2. Monitoring system and data mining

The monitoring system of the Charilaos Trikoupis bridge was designed specifically to monitor vibration of the deck in flexural bending and torsion as well as vibration of stays, combined with measurement of the wind speed at the top of the pylons. The monitoring system was perfectly maintained by GEFYRA staff after the bridge was opened to traffic; sensors were changed very rapidly if they went out of service RPT ADV (2009), leading way to a monthly serviceability rate generally equal to 100% and never less than 90% over the period of study RPT GSA (2011). This study uses records from a triaxial accelerometer model 3703G3FE 3 by

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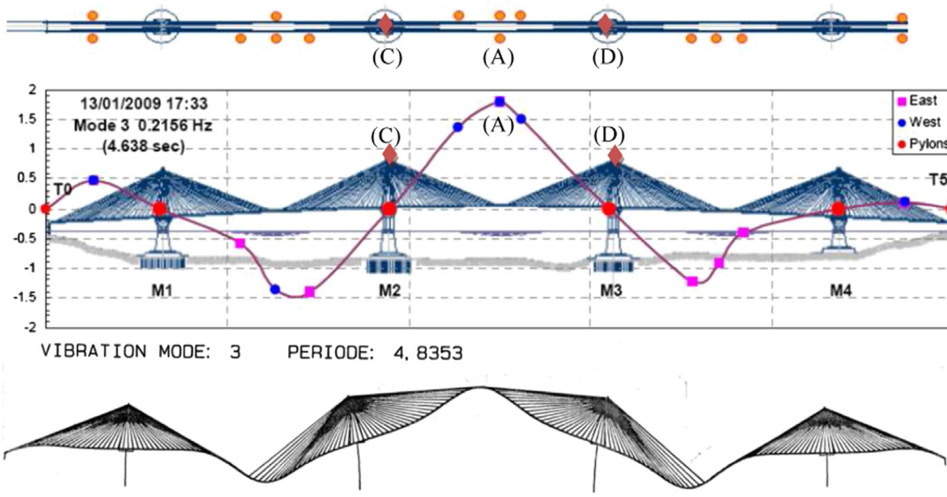

Fig. 1. Sensors locations and 3rd vertical mode shape of the RION ANTIRION Bridge.

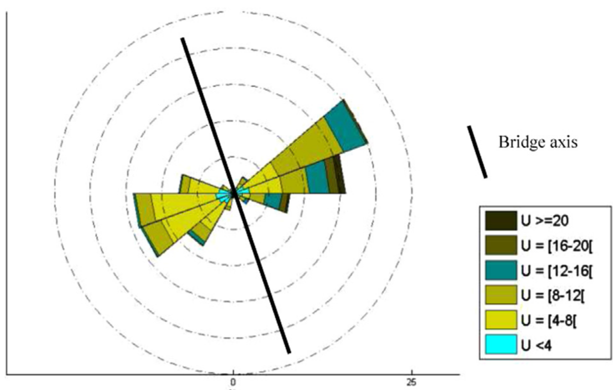

Fig. 2. Rose of wind mean speed (m/s) and direction, M1M2 anemometer, year 2009.

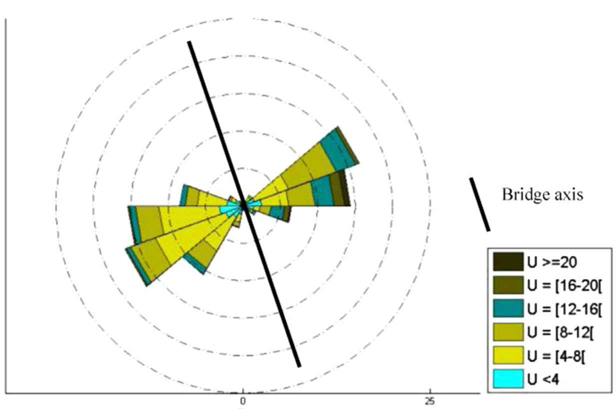

Fig. 3. Rose of wind mean speed (m/s) and direction, M1M2 anemometer, year 2010.

PCB, situated at mid span between pylons M2 and M3, denoted accelerometer(A) in this paper Fig 1.

The monitoring strategy combines an alert mode, with high frequency recording of all sensors signals when thresholds are exceeded, and steady-rate records for checking good working order of the system. This second part of the recorded data was mined in order to extract the vortex shedding occurrences which usually lead to vibration levels much lower than thresholds for alert.

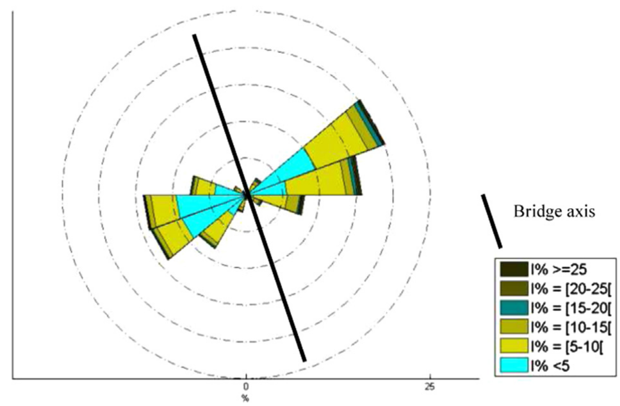

Fig. 4. Rose of wind turbulence intensity, M1M2 anemometer, year 2009.

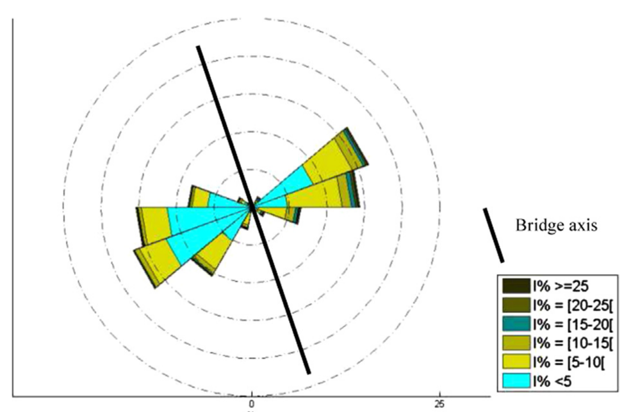

Fig. 5. Rose of wind turbulence intensity, M1M2 anemometer, year 2010.

These steady rate records are of two kinds: every 2 h a high-frequency record of all sensors for 60 s duration is done, and every 30 s the instantaneous value of all sensors is also recorded in a separate file. Processing two-hourly records, hereafter named “Dynamic files” gives a number of vortex shedding occurrences corresponding to excitation of the third flexural bending mode, but not all of them because some occurrences of the phenomenon can last less than 2 h. It was assumed that many occurences of