Multiple Controllers of Wind-Induced Oscillations of a Long Span Bridge

Ronaldo BATTISTA
Professor, Instituto COPPE
Director, CONTROLLATO Ltd.
Rio de Janeiro, Brazil
controllato@controllato.com.br

Michèle PFEIL
Associate Professor
Instituto COPPE
Rio de Janeiro, Brazil
mpfeil@coc.ufrj.br

Nilton VELIHOVETCHI
Technical Manager
Concessionaire PONTE SA
Rio de Janeiro, Brazil
nilton.velihovetchi@ponte.com.br

Ariel MACIEL
Mechanical Engineer
Concessionaire PONTE SA
Rio de Janeiro, Brazil
ariel.maciel@ponte.com.br

Summary

A new system of multiple synchronized dynamic attenuators (MSDA) has been installed in the Rio-Niterói bridge to prevent that cross-winds of relatively low velocities set into vortex-induced oscillations the lightly damped and remarkably long three continuous spans of the world's largest steel twin-box-girder bridge. The conceptual design of this passive control system, together with its main geometric and physical characteristics, are briefly described herein. A short account is given on how an experimentally calibrated mathematical-numerical model for the aeroelastic problem, combined with optimization techniques, were used to assist in designing feasible mechanical control devices to upgrade the serviceability of this bridge and users' comfort. The performance of the MSDA system is demonstrated through experimental measurements and comparisons of numerical results obtained for time responses of the original and the controlled structure.

Keywords: bridges; dynamic control, wind oscillation, experimental measurements

1. Brief description of the bridge structure

The 13.3 km long Rio-Niterói Bridge spans 8.8 km across the Guanabara bay in Rio de Janeiro. Most of it is a pre-stressed concrete structure but its three central spans (200 - 300 - 200 meters) are bridged by remarkably slender continuous steel twin box girders, as seen in Fig. 1 and illustrated in Figs. 2 and 3. The central navigation span stands at around 65 m above sea level and is the largest steel box girder span in the world. Together with link spans the steel structure weighs 13,100 tones and makes a total length of 848 meters.

2. Aeroelastic scenarium

Approaching open-ocean S-W winds blow in a direction perpendicular to the bridge axis, and are in this region, the strongest: 90 – 100 km/h wind gusts and winds with relatively lower speeds in the range of 50-70 km/h have high probability of occurrence. Having no upstream obstacles to generate oncoming turbulence, the steel bridge is subjected to aeroelastic forces produced by smooth quasi-laminar air- flow. For sustained cross-winds velocities around 55 - 60 km/h (15 – 16.5 m/s) the bluff box section bridge experienced for many years vortex-induced oscillations in its lightly damped first vertical bending mode with amplitudes reaching values from ±0.25m to ±0.60m in the middle of central span.

Fig. 1- Bridge view from the mouth of Guanabara bay

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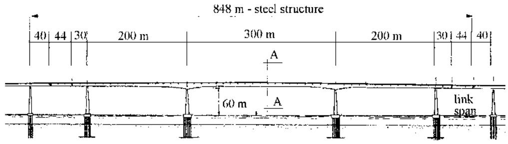

Fig 2- Elevation of bridge central spans

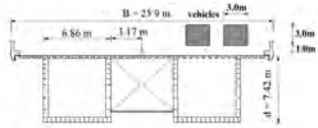

Fig. 3- Cross-section

Because its recurrent aeroelastic behaviour, the bridge had till recently to be closed to traffic of any vehicle, for the sake of users' comfort and overall safety, whenever cross winds reached velocities near 50 km/h (~14m/s). In several of these events, which have occurred once or twice every year since 1974 (when the bridge was brought into service) until 2003 the sustained relatively low wind velocities around 55 km/h lasted 10 to 15 minutes and astonishing images of the induced oscillations were captured by video-cameras installed on the bridge for traffic control.

3. Design and performance of the MSDA control system

These deterrent aspects of the world largest steel box-girder bridge were explored to conceive and design feasible passive control devices to prevent that cross-winds of relatively low velocities set into vortex-induced oscillations the slender structure.

A short account is given on how an experimentally calibrated 3D mathematical-numerical model for the aeroelastic problem, combined with a multi-objective optimization techniques, were used to assist in designing a new system of multiple synchronized dynamic attenuators (MSDA) to upgrade users' comfort and the serviceability and overall safety of the Rio-Niterói bridge, that has nowadays an average daily traffic of around 200,000 vehicles.

A brief description is given of the mechanical and robust dynamic control devices (see Fig. 4) together with their main geometric and physical characteristics. The performance of this passive control system, installed in the bridge in September 2004 to attenuate wind induced oscillation amplitudes, is demonstrated through experimental measurements and comparisons of numerical results obtained for time responses of the original and the controlled structure.

Fig. 4. View in perspective of the MSDA inside one of the box-girders.