Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 83 (1999)

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DOI: https://doi.org/10.5169/seals-62920

Damping Wind and Traffic-Induced Oscillations of the Rio-Niterói Bridge

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Abstract

Brought into service in March 1974 the 13.3 kilometers long Rio-Niterói bridge spans across the Guanabara bay in Rio de Janeiro. Most of it is a prestressed concrete structure but its three central spans (of 200 - 300 - 200 meters) are bridged by remarkably long and slender continuous steel twin box girders, as illustrated in Figs. 1 and 2. The central navigation span is the largest steel girder span in the world and together with the side and link spans weigh 13,100 tonnes of steel and make a total length of 848 meters[1].

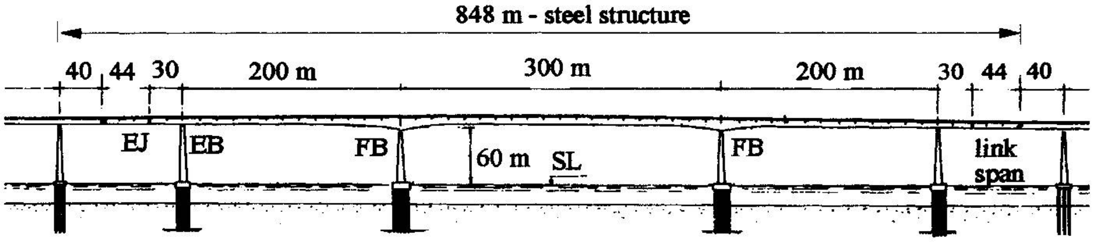
A recurrent aeroelastic aspect of this very slender steel bridge - with average girder height to span length ratio close to 1/45 - is its across-wind vertical bending motion. Cross-winds of relatively low velocities have often set into vortex-induced oscillations the lightly damped twin-box-girders. Because of this behaviour, the bridge has to be closed to traffic of any vehicle, for the sake of user's confort and overall safety, whenever cross winds reach velocities near 50 km/h (~14m/s). For sustained wind velocities close to 60 km/h the bluff box section bridge experiences vortex-induced oscillations in the first vertical bending mode with amplitudes that may well reach values about 250mm at the center of the navigation span. Theoretical-numerical and experimental results from wind-tunnel tests on a sectional model [1-2], plus astonishing images documented by video-cameras installed on the bridge for traffic control, corroborate the previous statements. Large vertical oscillations that left people panic-stricken were first reported on relation to a storm that occurred in August 17, 1980, and more recently in October 16, 1997 and February 17, 1998, when oscillations lasted 5 to 7 minutes. This deterrent aspect of the world largest steel box-girder bridge was explored to develop the conceptual design of feasible passive control devices [1,2] to attenuate the observed oscillation amplitudes - due to the action of winds as well as traffic of heavy vehicles on irregular pavement and joints - and, consequently, to upgrade user's confort and the serviceability of this bridge, that has an average daily traffic of 100,000 vehicles

An appraisal of the actual bridge dynamic behaviour is made by a mathematical 3D FEM model calibrated in terms of experimentally measured frequencies and associated oscillation modes [1]. The derived modal equations, including correlated aeroelastic forces, are further combined with a multi-objective optimization technique [1,2] to assist in designing simple mechanical and robust tuned-mass-dampers. A feasible mechanical arrangement is given by small masses TMD's distributed along the center span. Table 1 presents the structure's modal parameters and the TMD's

characteristics, whose performance is demonstrated through comparison of numerical results obtained for time responses of the original and controlled structure (Fig. 3).

Table 1 - Structure and Passive TMD's characteristics

Characteristics	Structure $( )_B$	16 TMD's $( )_A$	Ratios $( )_A / ( )_B$
Frequency (Hz)	0.32	0.29	0.9
Mass, m (ton)	5×10^3	50.0	0.01
Damping, ξ (%)	1.0	7.5	7.5



Legend: EB = Expansion Bearing; FB = Fixed Bearing; EJ = Expansion Joint; SL = sea level

Figure 1 - Elevation of Central Spans of Rio-Niterói Bridge

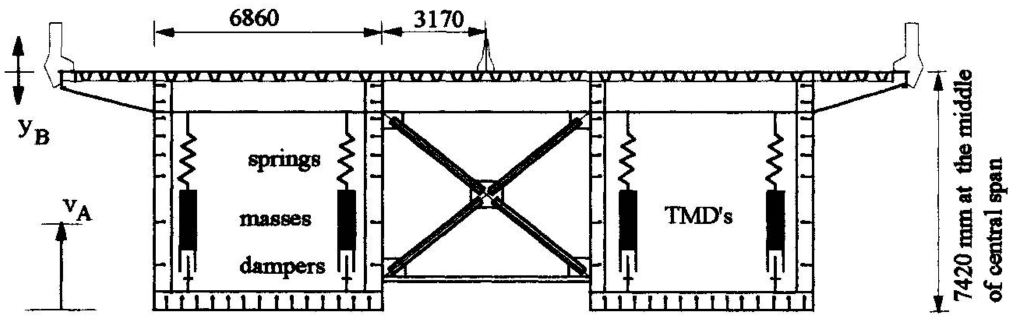


Figure 2 - Typical Cross Section with Tuned-Mass-Dampers located in the middle of central span

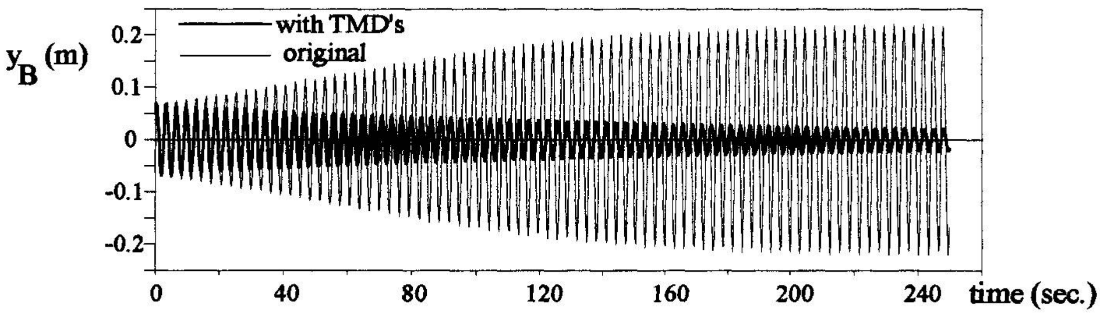


Figure 3 – Amplitude response in the first bending mode (middle of central span)

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