Second monitoring and surveillance of the response of a cable-stayed bridge

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Abstract

The Tampico bridge was the second cable-stayed bridge built in Mexico. It is located in the northeast state of Tamaulipas on a highway along the Gulf of Mexico. The bridge crosses the Panuco River and carries four lanes of traffic with sidewalks and a central barrier. Its total length is 1543 m distributed in three sections: a main cable-stayed span of 878 m length and two bridge viaducts. The viaduct on the left shore is 476 m long and the one on the right shore is 189 m. A hybrid type of deck was constructed. Steel box girders were used on most of the central span (360 m) and pre-fabricated prestressed concrete box girders for the remaining part of the deck. The cable-stayed system comprises 44 cables arranged in a semi-fan layout.

Regarding the importance of this bridge, just before its opening in 1988, the Bridge Department of the Ministry of Communication and Transportation decided to carry out an experimental program in order to determine the dynamic properties of the superstructure. Natural frequencies and mode shapes were calculated from acceleration time histories recorded during ambient vibration testing. From the results of a pullback test, damping characteristics were obtained as well (Muria-Vila et al, 1991; AEIC, 1988).

Currently, new live loads, wind conditions, temperature and mass changes, corrosion effects, relaxation of cable forces and prestress losses may have modified the structural properties of the bridge. A surveillance of its structural integrity can be accomplished by evaluating its current dynamic response.

In this paper the results of a new and extended experimental program are presented (Gomez et al, 1998). The same locations of the recording points, used in the 1988 field-testing program, are used in this study.

The extended program considered static loading. This was produced by five trucks, six axles each, positioned on different arrays along the length of the main central deck, between pylons 13 and 14. The average weight of the trucks was 65 t and the maximum static load applied to the bridge was 326 t. A simultaneous recording of vertical displacements at the bottom of pier 13 and longitudinal strains at some dowels of the deck was carried out.

Ambient vibrations are used to calculate natural frequencies of the superstructure and to derive frequency functions (transfer, coherence and phase angle functions). From the analysis of these functions modal shapes are derived.

Based on modal assurance criteria such as MAC and COMAC factors (Allemang and Brown 1982; Lieven and Ewins 1988), the mode shapes obtained during the 1988 monitoring program are compared to the ones derived in 1998.

Time histories of accelerations produced by dynamic loads were also recorded. The response of the bridge under different arrays of trucks running at different velocities was studied. Comparison of the ambient and dynamic responses is presented and evaluated in terms of changes in natural frequencies of the deck.

Vibrations produced during the ambient and dynamic tests were registered using several arrays of accelerometers oriented in different directions. Time history data was recorded for each event of the instrumentation program (Gomez et al, 1998). However for the dynamic testing, time histories of strains and displacements were also recorded. A well known random signals analysis (Bendat and Piersol, 1986) was used to process ambient vibration records. An average of different number of readings and a suitable "windowing process" was taken to calculate frequency responses: power spectrum, transfer, coherence and phase angle functions. Emphasis was placed on the determination of natural frequencies of the superstructure and pylons and mode shapes of the superstructure.

In addition to the measurement of accelerations on the deck, acceleration records were registered on the whole set of stays. These vibrations were produced by pulling a rope tied to the cable. Based on the theory of cable vibrations, this information was used to derive their natural frequencies and to calculate the magnitude of their tension forces. These values are compared to those obtained by means of hydraulic jacks, devices regularly used for this type of measurements.

In spite of some differences observed, the whole sets of the two testing agreed fairly well, although a general trend in the reduction of frequency values was observed. On the other hand, the results calculated numerically showed a fair agreement with the values experimentally obtained.
The work presented is part of an entire structural safety evaluation program of the Tampico bridge. Results of this study and the numerical model will be used to propose maintenance and corrective actions in order to enhance the behavior of the bridge.

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