LATERAL ASYMMETRY AND TORSIONAL OSCILLATIONS OF THE ORIGINAL TACOMA NARROWS BRIDGE

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The failure of the original Tacoma Narrows Bridge has been discussed and modeled extensively [1]. The central span was notable for its high span/depth ratio of 350 and its high span/width ratio of 72, as well as its light weight. The bridge exhibited some large vertical oscillations after its construction, but these motions did not seem to cause significant damage.

Along each side of the central span, the deck was connected to the main suspension cable by 55 groups of four vertical hangers, and by two diagonal stays at midspan. The stays were steel cables, in part, which had minimal pretension. They provided a constraint against torsional motion of the deck. The bottom ends of the stays were connected to the top of the plate girder on the side of the deck, and the top ends were attached to the bottom of a cable band (collar) that was 0.7 m long. Longitudinal motion of the cable at midspan was restrained by the tight-fitting band around it.

On November 7, 1940, four months after the bridge was opened to traffic, the cable band on the north (leeward) side of the deck loosened, causing a lateral asymmetry in the structure. The cable began to move through the band. About 500 of the 6,308 wires in the cable broke on the top side, and the longitudinal oscillations of the cable through the band reached a steady-state amplitude of 0.5 m. This led to torsional oscillations of the deck, and after about 700 cycles the bridge collapsed.

In the present study, a two-degree-of-freedom model of a section of the deck is analyzed first. The vertical and torsional motions of a rigid bar are resisted by vertical springs and dashpots representing the hangers, and by a torsional spring and a dashpot representing the resistance of the rest of the deck. Either a vertical harmonic force or an aerodynamic moment proportional to the angular velocity are applied, to represent effects of the wind. Initially the hangers are symmetric, and then a sudden change is applied to the stiffness or damping on one side. The resulting vertical and torsional motions are examined.

Next, a four-degree-of-freedom model is considered. In addition to the vertical and torsional motions of the deck, the cables are assigned concentrated masses that move vertically. These masses are restrained by vertical springs connected to fixed points above, as well as by the hangers connected to the ends of the horizontal bar below. The effect of a sudden change of stiffness or damping is investigated.

Finally, a continuous model of the central span, hangers, and suspension cables is developed. The deck is modeled as a linearly-elastic beam exhibiting bending and torsion. The hangers and diagonal stays are represented by discrete linear springs. Horizontal and vertical components of the cable motions are included. The wind is assumed to apply an aerodynamic moment to the deck. Slipping of the north cable through the central cable band is modeled, and large motions of the system are analyzed. A Galerkin-type procedure is utilized to obtain numerical solutions to the nonlinear partial differential equations of motion, and time histories of the oscillations of the deck and cables are obtained.

Reference

[1] R. Scott, *In the Wake of Tacoma*, American Society of Civil Engineers, Reston, Virginia, 2001.

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