Nonlinear Coupling in Cable-Supported Bridges for Non-Analogous Modes

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Abstract

It has been shown that the nonlinear differential equations representing the structural system of a suspension bridge exhibit nonlinear modal coupling that can lead to large torsional vibrations of the bridge deck. Such nonlinear coupling could play a role in the stability of cable-supported bridges under wind effects. Therefore, this paper presents an investigation of nonlinear modal coupling in cable-supported bridges with an emphasis on coupling between pairs of non-analogous modes, i.e., modes having a weak correlation along the bridge deck between the vertical displacement and torsional rotation. A procedure for assessing nonlinear coupling that relies on nonlinear generalized stiffness parameters is utilized for this purpose. Results of nonlinear generalized stiffness analysis for suspension bridges indicate that non-analogous modes have a weaker nonlinear coupling compared to analogous modal pairs.

Keywords: cable-supported bridges; suspension bridge; finite element analysis; nonlinear static analysis; geometric nonlinearities; structural dynamics; modes of vibration.

1 Introduction

The first few decades of the 20th century were marked by a rapid increase in span length for suspension bridges. This went on until dynamic wind effects were observed on some of the suspension bridges designed in this era, even those by prominent engineers like Othmar Amman and David B. Steinman. The collapse of the Tacoma Narrows Bridge is obviously the event that triggered what has been more than 80 years of research on the dynamic effects of wind on bridges. Going from wind tunnel testing, finite element analysis to computational fluid dynamics, this research has made possible super long-span bridges like the Çanakkale Bridge and Messina Strait Bridge. As span lengths are getting longer, nonlinear structural phenomena in cable-supported bridges could play a role on the safety and stability of these bridges when subjected to wind effects. Similar to what happened in the case of dynamic wind actions at the beginning of the 20th century, nonlinear structural phenomena have been omitted in the design process due to a lack of information about them.

Regarding nonlinear structural phenomena, there have been some demonstrations of nonlinear mode coupling made by mathematicians using

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