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Span Evolution and Aerodynamic Challenge of Suspension Bridges

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ABSTRACT

Suspension bridges as the longest bridge have experienced with span length increase for 140 years. Long-span suspension bridges are becoming lighter, more flexible, and lower damping, which result in more sensitive to wind actions. The most challenging problem among wind-induced responses identified is aerodynamic instability or flutter, and some control measures have to be adopted to flutter stabilization. There are four successful aerodynamic countermeasures, including central vertical stabilizer firstly installed in Runyang Bridge built in 2005, side horizontal stabilizers recently adopted in Nansha Bridge in 2018, central slotted twin-box girder firstly applied in Xihoumen Bridge in 2009, and the combination of central slot and vertical stabilizer used in Akashi Kaikyo Bridge in 1998. The twin-box girder of Xihoumen Bridge has been further studied up to 3,000m, and the widely-slotted twin-box girder has been proposed to a 5,000m suspension bridge.

Keywords: Suspension bridge; span evolution; aerodynamic challenge; flutter control; aerodynamic countermeasures.

1 INTRODUCTION

Human beings have been building bridges in girder, arch, cable-stayed and suspension types to cross streams and rivers. Among these four types of bridges, suspension bridge has the greatest bridging capacity, and can meet with the maximum demand on bridging wide sea strait. In order to accommodate huge size marine vessels and to avoid from building deep water foundations, span lengths of suspension bridges have been gradually increased for 140 years from the 486m spanned Brooklyn Bridge built in 1883 to the 2,023m Canakkale Bridge in 2022 (Wikipedia, 2023. The span length evolution of suspension bridges is challenging engineering limit and realizing human dream.

With the rapid increase of span length, suspension bridges are becoming lighter, more flexible, and lower damping, which result in more sensitive to wind induced problems including aerodynamic instability, aerostatic divergence, stochastic buffeting, vortex-shedding vibration, etc. The most challenging problem among wind-induced responses is aerodynamic instability or aerodynamic flutter, and some flutter control measures have to be adopted to flutter stabilization, in particular for the span length longer than 1,200m (Ge, 2009. Four successful aerodynamic countermeasures have been summarized, including central vertical stabilizer, side horizontal stabilizers, central slotted twin-box girder and the combination of central slot and vertical stabilizer. The twin-box girder solution has been further studied and compared to single box and thin plate girders up to 3,000m. Finally, the widely-slotted twin-box girder has been proposed to a 5,000m spanned suspension bridge (Ge, 2011.

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