Proposal of nonlinear buffeting analysis framework for long-span bridges using Volterra series-based non-stationary wind force model

Khawaja Ali

CTI Engineering International Co. Ltd., Tokyo, Japan

Aleena Saleem

Yokohama National University, Yokohama, Japan

Contact: khawaja.ali@ctii.co.jp

Abstract

This paper presents a nonlinear framework to simulate the buffeting response of long-span bridges under Typhoon winds by using a Volterra series-based wind force model. First, the non-stationary wind fields are generated around the bridge using evolutionary power spectrum of the measured wind speeds. Subsequently, the nonlinear buffeting load model is formulated in time-domain by employing the Volterra series. Then, these Volterra kernels are identified from flutter derivatives. At last, the wind forces are applied to 3D fishbone finite element model of a suspension bridge and nonlinear buffeting analysis is performed. The time history analysis results show a good agreement in the simulation of Typhoon-induced buffeting response when compared with the measurement data of bridge displacements. Also, the analysis results are compared with the simulation results obtained from the existing wind load models to show the efficacy of the proposed framework.

Keywords: long-span bridges; Typhoon; aerodynamic nonlinearity; non-stationary; buffeting response; Volterra series; flutter derivatives; evolutionary power spectrum; finite element model.

1 Introduction

The accurate prediction of dynamic response of long-span bridges, especially built in the Typhoon prone regions, is of paramount importance for their safe and robust design. It has been observed that the real measurement data of bridge displacements and Typhoon wind speeds exhibit the nonlinear relationship with time-varying characteristics [1]. On the other hand, the existing aerodynamic wind load models cannot reproduce the actual Typhoon-induced response with time-varying nature because of their inability to consider the concurrent effects of aerodynamic nonlinearity and non-stationary Typhoon winds existing in the wind-bridge interaction (WBI) on the bridge response. In fact, WBI is a fade memory system and shows a nonlinear behaviour under non-stationary winds of large varying angles of attack [2]. The main source of this nonlinearity existing in WBI is due to the flow separation around the bridge deck of bluff nature because wind flow around deck cannot accommodate the sudden changes of the deck profile. Other sources of nonlinearities are the amplitude dependency of aerodynamic loads, non-proportional and nonlinear relationship between amplitudes of wind velocity and bridge response and hysteretic nature of aerodynamic loads against the attack angles [3]. The quasi-steady (QS) model