# A Unified Approach for the Aeroelastic Analysis by Elimination of Frequency Dependence of Aerodynamic Force

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## Summary

A unified approach for the aeroelastic analysis of bridge decks is presented. The aerodynamic transfer functions are approximated as a linear function with the coefficients determined through minimization of the weighted error between the exact and approximated transfer function. Using the proposed approximation, the dependence of the aerodynamic transfer function on frequency is eliminated, and a popular time marching algorithm is adopted for the aeroelastic analysis in the time domain. For the frequency domain analysis, a complete set of modal frequencies and modal shapes can be evaluated in a single eigenvalue analysis.

**Keywords:** Aeoelastic analysis; Aerodynamic forces; Frequency dependency; Unified approach; Weighting function; Time domain; Frequency domain

## 1. Introduction

For aeroelastic analyses of bridge decks under wind action, numerous approaches have been proposed since Scanlan and Tomko[1] defined self-excited forces using flutter derivatives. The difficulty in aeroelastic analysis basically arises from the frequency dependence of self-excited forces. For the frequency-domain aeroelastic analysis, an iterative procedure is required to solve the nonlinear eigenvalue problem, which is referred to as branch method[2]. The critical issue in the time-domain approach is the elimination of the frequency-dependent characteristics of the aerodynamic forces, for which the convolution integral is usually utilized. The impulse response functions are formed with the identified flutter derivatives through optimization in the frequency domain, and the aerodynamic forces are expressed as convolutions between the impulse response functions and the deck motion. The rational function approximation (RFA) has been the most popular approach for forming impulse response functions for the convolution integral[3]. Despite its popularity, however, Caracoglia and Jones[4] reported on the potential limitations of the RFA method on its applicability to bluff sections. Recently, Jung et al. [5] proposed a new algorithm for evaluating impulse response functions through a domain-discretization approximation to overcome the shortcomings of the RFA.

Although the convolution integral approach and the branch method can be successfully applied to time-domain and frequency-domain analyses, respectively, for various types of sections, they are based on different approximations. The impulse response functions used for the convolution integral become inconsistent with the given flutter derivatives of a section through optimization, while the aerodynamic forces are evaluated at only one assumed frequency in the branch method. Therefore, the consistency between results of a time-domain analysis and a frequency-domain analysis cannot be generally guaranteed.

This paper presents a new unified approach for the aeroelastic analysis of a bridge structure by approximating each component of the aerodynamic transfer functions in frequency domain. Using this approximation, the equation of motion for an aeroelastic system becomes a set of simple

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