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Time Domain Approach on Gust Response for Long Span Bridges

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1. INTRODUCTION

Oscillations of very long and flexible structures under wind action is complicated by the presence of turbulence that assessment of wind loading and the consequent response on such structures leads to the extensive use of wind tunnels. Numerical investigations on structural stability under wind, on the other hand, tends to consider mainly the mean wind speed and the response analysis to turbulent wind are commonly performed in the frequency domain. The motivation of the present study revolves around the random oscillation of the full scale wind tunnel tests under gusty wind which indicates a need to perform the response simulation in time domain. In this study, the three-dimensional response of a very long suspension bridge under turbulent wind was numerically investigated considering the time-space correlation of the fluctuating wind at different points along the bridge.

2. RESPONSE SIMULATION UNDER GUSTY WIND

The proposed response simulation under gusty wind for long span bridges is based on the time domain and covers three main aspects, namely the wind, the aerodynamic forces and the structural response.

Wind. Depending on the local topography as well as the orientation of wind with respect to the bridge, wind characteristics may vary along the span, so that the present numerical simulation considers such time-space correlation of wind. Time histories of wind at different nodal points are generated using stochastic models such as multi-dimensional autoregressive and autoregressive moving average models which are obtained from the target spectra and coherence functions. Good agreement between the target and that of the generated series was obtained.

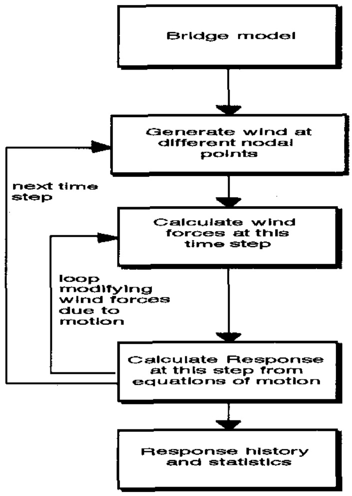

Figure 1 Gust response analysis

Aerodynamic Forces. The system of external forces used in the equations of motion is taken as to consist primarily of the wind forces derived from the quasi-steady formulation at an instant of time. In the force model the aerodynamic force is modified by (a) the structural motion which alters the instantaneous wind velocity, and (b) the relative wind velocity and the structural displacement which change the previous angle of attack. Thus, at an instant of time the aerodynamic forces are functions of the relative wind velocity and effective angle of attack at that instant.

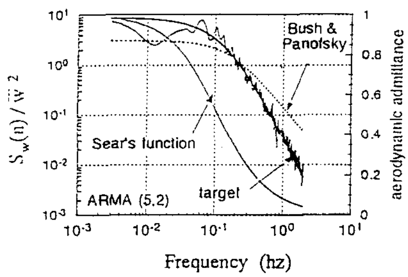

Figure 2 Spectrum of generated series

Structural Response. The response analysis procedure is shown in Figure 1 where the equations of motion are integrated at small time increments (step-by-step time integration). The flow of analysis begins with a target wind spectrum which is used to simulate the fluctuating wind velocities. At an instant of time, the wind velocities are converted to aerodynamic forces causing the bridge to respond (here, the forces are nonlinear functions of motion and angle of attack). The response then modifies the aerodynamic forces at that instant. In this way the instantaneous bridge motion can be followed and time histories of response obtained.

3. NUMERICAL INVESTIGATION

The response of a 2000 m class suspension bridge under gusty wind was investigated using the procedures described previously. The bridge was idealized as a three-dimensional frame model with masses lumped at the nodes. Experimentally derived quasi-static coefficients were fitted with polynomials to express its non linearity with angle of attack. The variation of wind along the span was considered using a coherence function and the effects of scales was included using an aerodynamic admittance function.

By using an autoregressive moving average model wind was generated at nodal points and comparison between target spectra and coherence function is shown in Figure 2. The response is followed for about 4200 seconds and the response statistics taken at every 600 seconds is shown in Figure 3. The instantaneous displacement of the deck in one cycle of motion in the horizontal direction is shown in Figure 4. Response mean and root mean square values for the whole span are shown in Figure 5.

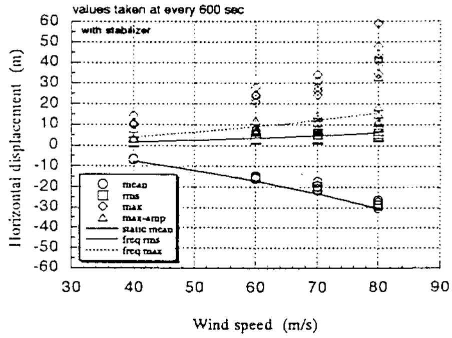

Figure 3 Response statistics of central node at different mean wind speed

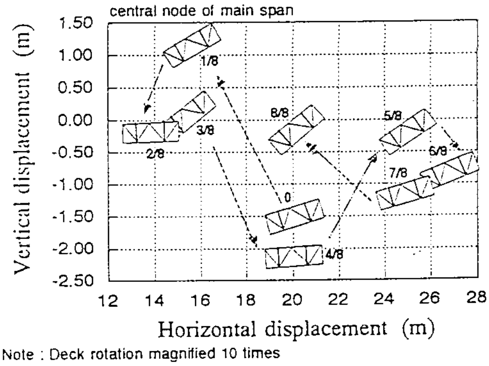

Figure 4 Response of central node in one cycle of motion

4. CONCLUSIONS

A numerical approach to perform the three-dimensional response of long span bridges under gusty wind was formulated in the time domain and applied to a 2000 m class suspension bridge. Generation of fluctuating wind velocities was done using stochastic model and proven effective with reduction in computational efforts. Response histories of the bridge deck was obtained at different mean wind velocities and shows a coupled random motion under gusty wind. The effectiveness of the time domain approach in dealing with the problem of response under gusty wind is seen in the instantaneous coupled motion of the bridge.

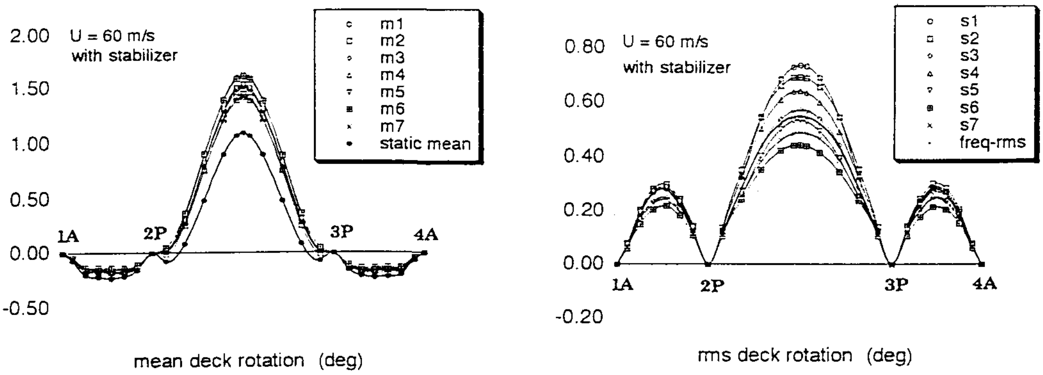

Figure 5 Mean and root mean square response of the deck