NUMERICAL INVESTIGATION OF BOTTOM PLATE SLOPE EFECTS ON AERODYNAMIC RESPONSE OF A HEXAGONAL SHAPED BRIDGE DECK

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1. INTRODUCTION

Long span bridges are susceptible to various aeroelastic phenomena. The vortex shedding excitation is one of the most frequently exhibited phenomenon and very important from serviceability point of view. When the after body vortex frequency matches with the natural frequency of the bridge, the bridge shows limited amplitude vibration is known as a vortex shedding excitation. To suppress formation of the after body vortex and to reduce the along wind load, bridge decks are often shaped hexagonally to make it streamlined as shown in Figure 1. However, sometimes practically constructed bridges exhibit vortex shedding instability even though they are shaped hexagonally. Still the bridge deck shape effects on aerodynamic response are not fully clear. In a hexagonal deck shape there are a number of important parameters to influence aerodynamic performance such as top plate slope (*T*), bottom plate slope (*B*), side ratio (*R*) of bridge deck and type of handrail. In past works these parameters were not considered on a detailed way and their effects on bridge deck response were not fully clarified. Therefore detailed parametric study is required on these important parameters to facilitate the bridge deck design procedure and to shape the bridge deck efficiently. In this work, detailed numerical investigation of bottom plate slope (*B*) effects on aerodynamic response of a hexagonal shaped bridge deck is carried out. Computational Fluid Dynamics (CFD) is employed for this parametric study on bridge deck shape. The bottom plate slope (*B*) is varied from 12° to 50° for a specific top plate slope (*T*), yet the top plate slope (*T*) is varied from 30° to 50°. Aerodynamic performance is measured based on mean and rms value of global parameters. The mean value of global parameters will give general idea about the flow behavior and rms value will provide information regarding the dynamic behavior of the bridge deck section. Simulations are performed at Reynolds number (R_e) of 1.2 x 10^4.

2. NUMERICAL DESCRIPTION

The flow around the object is modeled by Unsteady Reynolds-Averaged Navier-Stokes (URANS) equation and OpenFOAM v2.2.0 is used as a solver. The governing equations are shown as follows;

$$\frac{\partial \overline{U}_i}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial \overline{U}_i}{\partial t} + \overline{U}_j \frac{\partial \overline{U}_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \overline{P}}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial \overline{U}_i}{\partial x_j} + \frac{\partial \overline{U}_j}{\partial x_i}\right) - (\overline{u'_j u'_i})\right] \tag{2}$$

The vectors $\overline{U}_i$ and x_i are averaged velocity and position vectors respectively, t is time, $\overline{P}$ is the averaged pressure, ρ is the density, and μ is the molecular viscosity. Due to time averaging process, the new variable $\rho\overline{u'_j u'_i}$ appears. This is known as Reynolds stress. This needs modeling to close the equation. Turbulence modeling is attained by the k-ω-SST model (Menter 1994).The computations are performed in a two dimensional domain with a dimension of 48D by 25D, where D is the depth of the bridge deck. The object is placed 18D downstream of the inlet. At the outlet of the domain pressure boundary condition, at the top and bottom of the domain slip boundary condition and at the body non-slip boundary condition are implemented. For further information regarding numerical setup, interested readers can be referred to Haque *et al.* 2014.

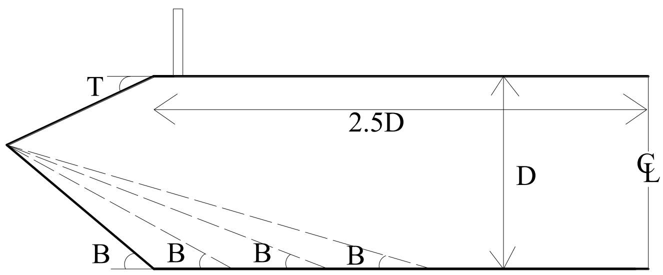

Figure 1. Schematic view of the bridge deck section.

Keywords: Vortex shedding, Aerodynamic response, Side ratio, Hexagonal shape, Reynolds number, Global parameter.
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3. RESULTS AND DISCUSSIONS

Figure 1 shows the schematic view of the bridge deck section considered in the present work. The top plate slope (*T*) is varied from 30° to 50° with an interval of 10°. The bottom plate slope (*B*) is varied from 12° to 50° with an interval of 5°. The bottom plate slope (*B*) is varied by varying the bottom width of the deck without changing the nose tip position to maintain the same side ratio (*R*) for a specific top plate slope (*T*). The top plate slope (*T*) is changed by changing the nose tip position horizontally without altering the nose tip position vertically. The nose tip vertical position is kept at 0.5D in all the cases. Simulations are performed both with (WH) and without (WOH) handrails. A handrail with 100% solidarity ratio is utilized. Static simulations are performed at Reynolds number (R_e) of 1.2 x 10^4 to evaluate the aerodynamic performance of the bridge deck. Figure 2 represents the top and bottom plate slope effects on mean drag (C_D) and moment (C_M) coefficients. As can be seen both the drag and moment coefficients increase when handrail is attached to the deck section. The top plate slope influences the mean value of the moment noticeably, yet doesn't influence the drag value significantly. On the other side, for the bottom plate slope (*B*) reverse behavior is observed. Larger top plate slope decreases the mean moment value, while smaller bottom plate slope decreases the mean drag value. Based on mean value it can be said that a smaller bottom plate slope (*B*) and a larger top plate slope (*T*) should be selected to reduce static aerodynamic loading. However, dynamic loading is the prime concern for a long span bridge and the main concern of the paper. Root mean square (rms) values of drag and moment coefficients are plotted in Figure 3 to check the dynamic behavior of various deck shapes. Figure 3 depicts that the top plate slope (*T*) doesn't have any effect on rms value of the global parameters, yet the bottom plate slope (*B*) affects the rms value significantly. A bottom plate slope (*B*) of 15° or smaller than 15° would be a wise choice to shape the bridge deck to have less aerodynamic response, when a solid handrail is attached. In future, surface pressure and velocity distribution around the bridge deck will be plotted to explain and understand the aforesaid aerodynamic response.

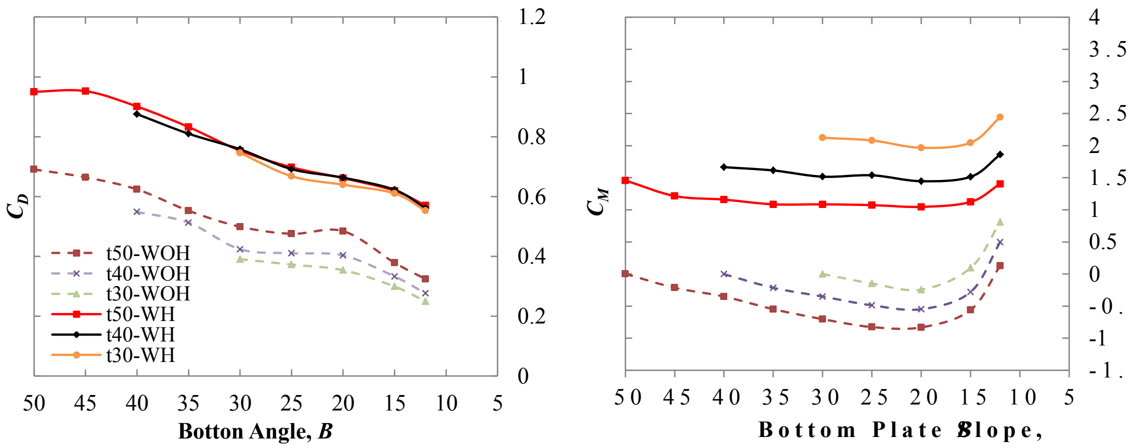

Figure 2. Mean value variation of the global parameters for various top (*T*) and bottom plate slopes (*B*): (a) Drag force coefficient (C_D) and (b) Moment coefficient (C_M). Results are shown for with (WH) and without (WOH) handrail.

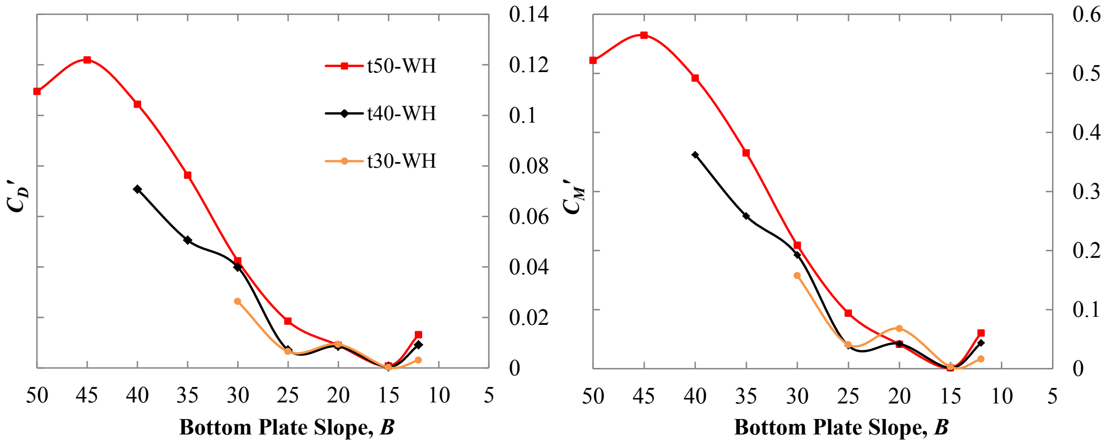

Figure 3. rms value variation of the global parameters for various top (*T*) and bottom plate slopes (*B*): (a)drag force coefficient (C_D) and (b) Moment coefficient (C_M). Results are shown for bridge deck with handrail (WH).

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