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WIND BARRIERS ON BRIDGES: THE EFFECT OF WALL POROSITY

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1 INTRODUCTION

Wind-induced accidents of road vehicles can result in the loss of lives and property (1, 2). This fact motivated engineers to make efforts on improving the ride comfort and safety of passengers in moving vehicles in regard to wind effects.

Previous studies focused mostly on wind-induced instability of vehicles on roads (3, 4, 5, 6, 7). Some efforts were also made to improve the protection on bridges, as the vehicles on bridges are extremely exposed to strong wind gusts (1). Štrukelj et al. numerically studied the effects of wind barrier geometry on resulting wind forces on vehicles. They also tested a part of barrier prototype in the wind tunnel in terms of thermal and mechanical endurance. While usually very helpful for improving traffic safety, wind barriers have negative influence on aerodynamic characteristics of bridge itself. An attempt to reach the compromise between those two contradictory demands was made by Wang et al. (8) for the purposes of designing the Hangzhou Bay Bridge in China. They suggested an optimal design of wind barrier which does not significantly deteriorate the aerodynamic stability (e.g. flutter, vortex resonance, etc.) of this bridge.

The negative effects of strong winds on traffic experienced also the designers of the Rijeka-Zagreb highway in Croatia, as well as commuters between those two cities, as this highway was often closed for traffic through the past due to safety requirements. Major threat to traffic poses a strong, cold, north-easterly wind Bora, blowing over the Dinaric Alps along the eastern Adriatic coast. Its most prominent feature is strong gustiness. In severe bora cases mean hourly wind speeds exceed 17 m/s (9, 10, 11; 12, 13), while gusts may reach values of up to 69 m/s (14).

The aim of this study is to investigate the possibilities of protecting the vehicles on viaducts in parts of the newly reconstructed Rijeka-Zagreb highway. The effects of wind barrier porosity on a flow field at the viaduct Bukovo are presented in this paper.

2 WIND TUNNEL MODEL

Viaduct Bukovo is located about 20 km from Rijeka downtown in direction of Zagreb. It consists of two bridge decks; the existing one and a new one, which is currently under construction. As the construction of the existing bridge does not allow the placing of the wind barrier due to static reasons, only the protection of a new bridge was investigated. The final goal is to propose a wind barrier design, which would enhance the safety and comfort of passengers , especially in trucks. The wind tunnel tests presented in this paper were preceded by numerical simulations (15). Wind tunnel model of both bridges (Figure 1) was manufactured from wood, exactly matching the prototype in all details at the scale of 1:66, which corresponds to a length of about 30 m in full scale. It is a 2-D section with width to length ratio approximately 3:1. There was no indication of the disturbance introduced by the boundary conditions at the model sides.

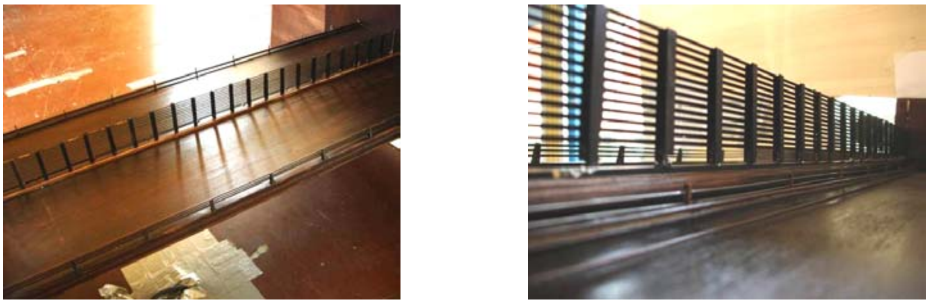

Figure 1. – Wind tunnel model of the viaduct Bukovo

3 THE BOUNDARY LAYER WIND TUNNEL TESTS

Experiments were carried out in the Boundary Layer Wind Tunnel of CRIACIV in Prato, Italy. Detailed description of this tunnel can be found in (16). During the tests the flow field on the road plane was measured using the Particle Image Velocimetry (PIV) technique. The measuring domain is shown in Figure 2.

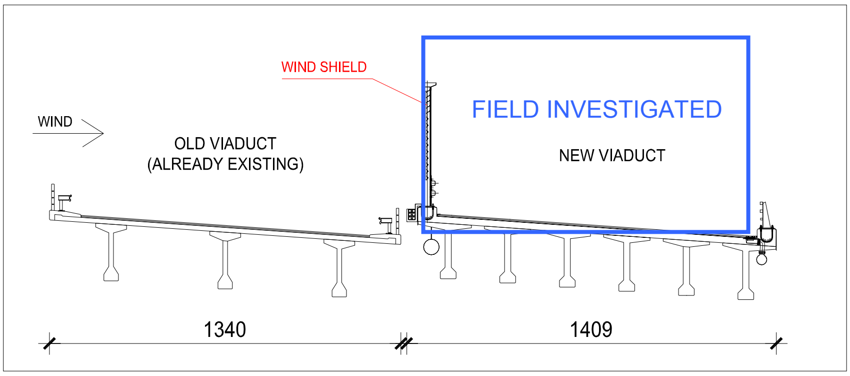

Figure 2. – Bukovo viaduct, made of two bridge decks

The barrier walls were composed of horizontal bars (L profile, orientation toward wind → <), which were adjusted for two pillars at the distance of 2.5 m. The height of barrier wall models corresponds to a 4 m height in full scale. Three different porosities of barriers (30%, 43% and

53%) were investigated, with wind normal to the barrier in the horizontal plane and at the vertical angle of attack 10°. Bridge models with barriers were exposed to a turbulent oncoming flow, reproducing the flow conditions from the full scale. The incoming wind turbulence was generated using a grid positioned at the inlet of the wind tunnel test section. Longitudinal turbulence intensity in all three configurations was 17%, where the variance of velocity fluctuations was normalized with mean freestream velocity in an undisturbed flow. The incoming wind profile was acquired using a Pitot-Prandtl tube and a hot wire anemometer. The flow field on the bridge deck behind the wind barrier was measured using the PIV system. Approximately 200 instantaneous velocity fields were acquired in each configuration. Tests were performed following standard wind-tunnel modelling procedures (17, 18, 19).

4 RESULTS AND DISCUSSION

Mean velocity field for three porosities of wind barrier are presented in Figure 3. The result in each configuration was obtained by averaging 200 instantaneous velocity fields and normalizing it with mean freestream velocity.

a) b) c)

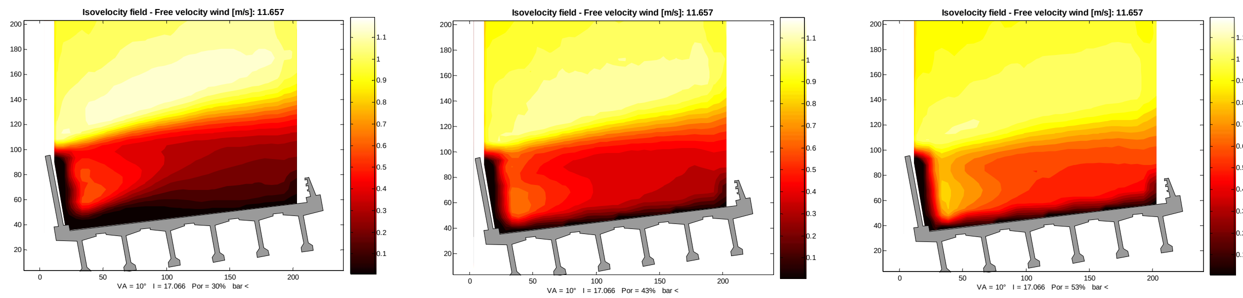

Figure 3. – Mean velocity field with barrier wall porosity: a) 30%, b) 43%, and c) 53%

A significant reduction of mean velocity (up to 50%) can be obtained if a wind barrier is placed on the bridge. In all configurations there is a region of higher velocities immediately behind the barrier, which decrease further downwards. The obtained velocity fields illustrate the trend of increasing the velocities in protected region behind the barrier with increasing the barrier porosity. Simultaneously, velocities in the region above barrier tend to be lower.

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