CFD-BASED INVESTIGATION OF WIND-STROKES OVER HIGH-WAY-BRIDGE IN THE-SECTION "POČITELJ – ZVIROVIĆI" (BH)

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Abstract: There is almost everlasting debate on possibilities of investigation-tools for their applications in prospective-fashion (while solving the engineering-tasks) and – against this fact – use of these engineering tools, while correcting the existing technology-problems. An unique chance to compare the needs of traffic-intentions (while setting the modern road communications through the southern of Bosnia and Herzegovina) verses the natural occurrences in the atmosphere (such is a strong north wind in this geographic region) offers the high-way-section Pocitelj-Zvirovici. Exactly in such cases (and before the actual construction of this high-way-bridge) "for the sake" of prospective engineering, the tool for CFD (the tool for performing the Computational Fluid Dynamics) was applied to engaged the problem. Both as steady-state explorations while applying the k-epsilon turbulence-treatment, but also as the time-dependent CFD-based mode, we explored the wind-strokes of 10m/s, 20m/s, 30m/s and 40m/s, an unexpected and unwanted strong gaseous flows over the bridge, detecting in this way the traffic-safety edge-points. These results, coming from the explorations performed by the CFD-tool are explained and discussed.

Key words: *Traffic-safety, Highway-bridge, wind-stroke, CFD (Computational Fluid Dynamics)*

1. INTRODUCTION

While establishing the modern road- and railway infrastructure, that is not only impressive in construction way, but it is also needed for accurate and important trafficking – one confronts the reality that is always surrounding such objects: the nature of our planet[1-4]. To the spite of evaluations[5-8] and certain suggestions[9], every new object of traffic infrastructure that is exposed to rather strong atmospheric influences, is presenting the safety risk and calls for exploring in large-scale fashion. Such investigations, due to the ever-stronger software and hardware tools[10-12] are performed not only through the physical measuring[13], and scaled testing[14], but also more frequently by applying the CFD (Computational Fluid Dynamics)-based approach[12]. The latter research-approach[15] did find application in wind-exploring[16, 17] and traffic-safety[18] which is the research-pathway of the work presented in this paper, offering very satisfying results accomplished in attempts "prospective engineering" for particular explored cases of fluid phenomena[19].

All of these research attempts that have been brought up into the CFD-community, do report on good capability of the numerical approaches used in handling the reactive flows in straight enclosed traffic objects. Besides the slight denivelation of a few percent, the geometry of the arbitrary tunnels was relative a simple one.
Therefore the aim of the study performed, is the exploration of the (accidental) wind-strokes over such a bridge that, as a segment of to-be-constructed high-way for sure, turn up as an element of this modern traffic road-communication and suggesting some counter-measures serving the overall traffic-safety.

2. NUMERICAL APPROACH

2.1.Treatment of turbulence – Mathematical model in this study

For turbulence-modelled conservation equations, for mass and momentum , employing a time-averaged *k-ε* turbulence model (a CFD-mode that was applied in this study) the governing integro-differential equations must be discretised in both space and time[20, 21]. These equations, together with the equations of state for an ideal gas, form here a closed set of coupled equations. These are again discretised and solved on a three-dimensional, finite-volume Cartesian mesh. In choosing the numerical method we[22] rely on the standard of the finite volumes [21, 23, 24]. The spatial discretisation of time-independent equations employed a segregated solution method. The linearised equations result in a system of linear equations for each cell in the computational domain, containing the unknown variable at the cell centre as well as the unknown values in surrounding neighbour cells. This mechanism for a scalar transport equation[22] is also used to discretise the momentum equations as well; in the same mode for the pressure field (if face mass fluxes were known) and the velocity field will be obtained in same way as well. In case that the pressure field and face mass fluxes are not known, FLUENT uses a co-located scheme, whereby pressure and velocity are both stored at cell centres. A need for interfacial values includes an application of an interpolation scheme to compute pressure and velocity out of cell values. The integration over the arbitrary volume (a cell in a computational domain) can be performed yielding the discretised through an arbitrary surface of a face. Executing these numerical steps, the equations can express the state for each other cell in the computational grid. This again will result in a set of algebraic equations with a sparse coefficient matrix. In this way the segregated solver is handling “the updating” of a single variable field by considering all the cells of the domain at the same time, solving the governing equations sequentially (segregated one from another). Subsequently, the next field of another variable will be solved by again considering entire cells at the same time, etc The computational loop for the converged solution solution had about 5500 iterations.

3. PROCEDURE OF INVESTIGATION

The estimation of the boundary conditions in this CFD-based investigation was supported by the experience of some previous studies. So were the bridge surrounding-space characterised as open (pressure) atmospheric boundaries with minor pressure increase or pressure-drop of 2Pa, respectively. All zones from around the road-bridge as open (pressure) boundary, was used for initializing the values for the velocity and pressure in the computational domain and global temperature was set to 293K.

The bridge-body and bridge-road-elements as well, were presumed to be non-adiabatic in the area where the objects of interest (the investigated bridge-crown) is situated. This decision was based on some reality-oriented investigation on modern bridge-construction, denoting for the thermal conductivity of a reinforced concrete to be (λ =*2,3W/mK*).

3.1.The explored bridge

The cross-section shapes of this high-way viaduct are distinguished as ones between the major carrier-pylons and as the bridge-crown-shapes that are mounted onto the “bridge-legs” of this traffic steady-object. Standing under the angle of ca 3.1° the road-treks of this bridge have the bow-length of 954m and their arch-radius is 983m.

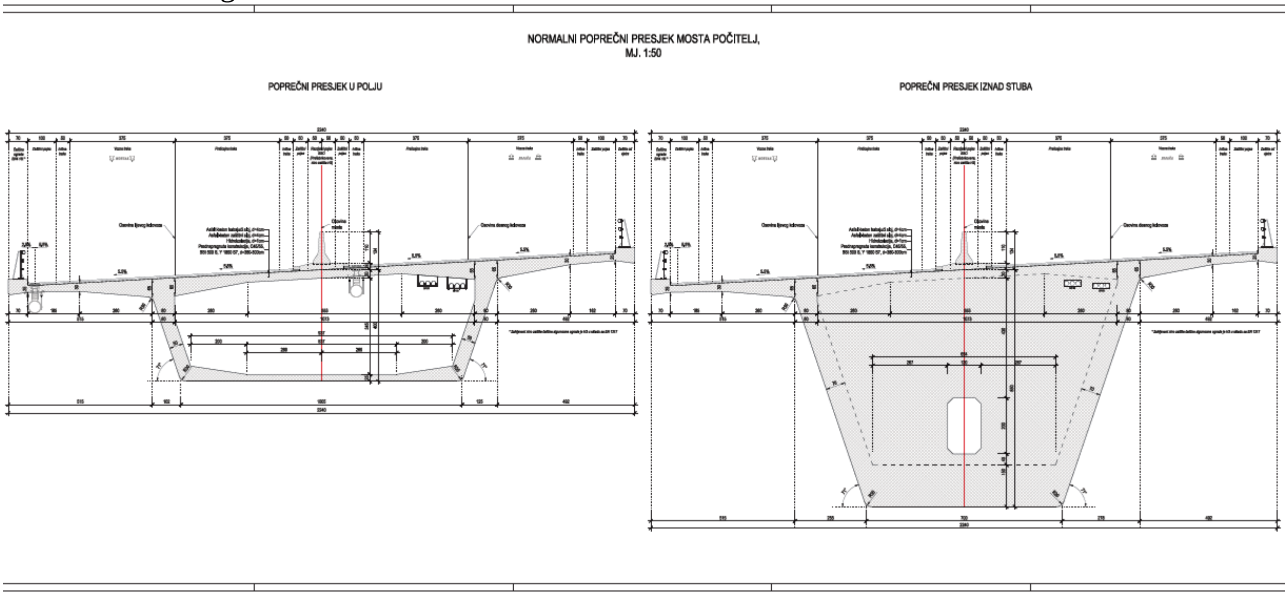

Fig. 3.1.1 The cross-section of the crown in the free-air as well as the pylon-crown

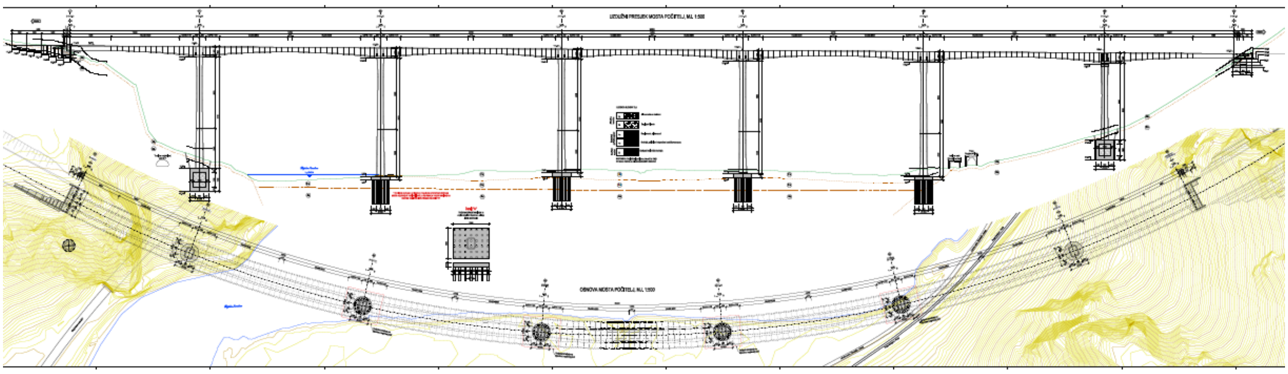

Fig. 3.1.2 The constructive disposition of the high-way bridge “Počitelj-Zvirovići”

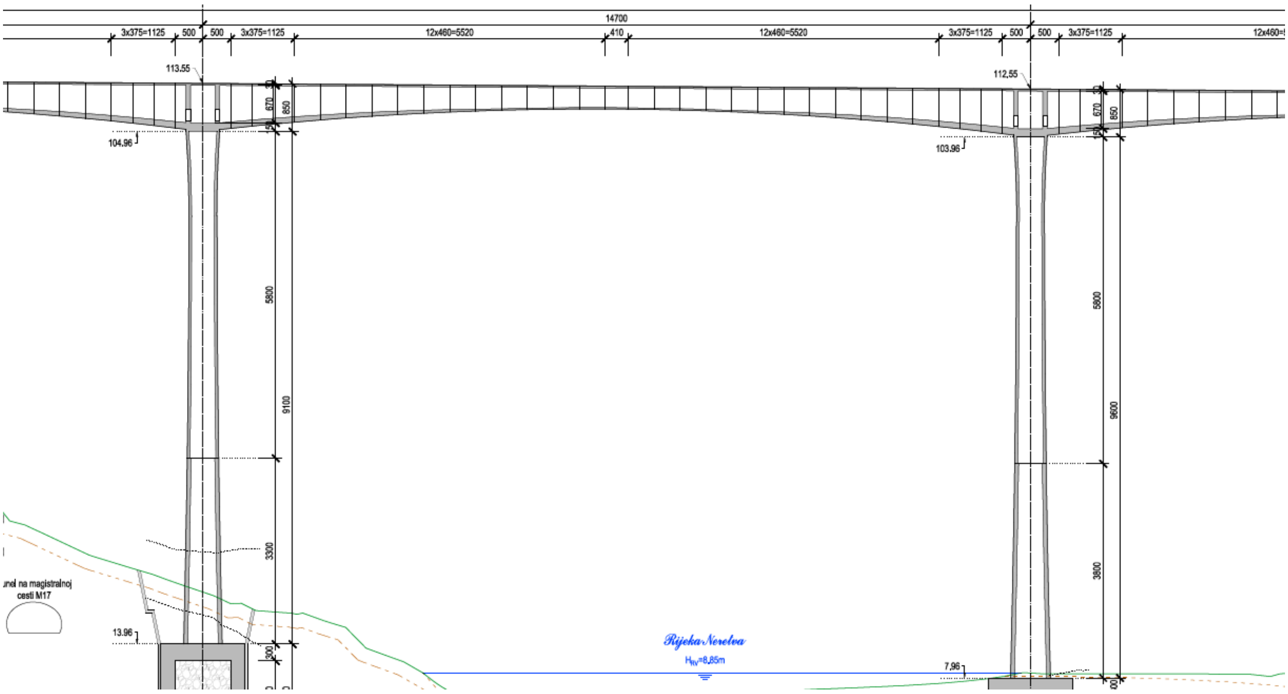

Fig. 3.1.3 A side-view of one section while crossing the river Neretva and following shore-terrain

Going partly over the river-bed and partly over the terrain-valley, the highway-bridge “Počitelj-Zvirovići” is demonstrating it´s highest section to be of 96m. The wide-range between the six major pylons is set to 147m.

3.2.Computational domain

The area in which the computation with applied mathematical model approach and additional numerical discretisation was performed is the very volume, that a fluid can take, without the walls, where the solid-body was the shape of the explored road-bridge. Therefore the computational domain of the section “Pocitelj-Zvirovici” was set to be 30m x 22m x 14,5m.

3.2.1 The highway-bridge “POČITELJ-ZVIROVIĆI”

The mesh of this computational domain (Fig. 3.2.1.1 and Fig. 3.2.1.2) is characterised through hexahedral cells of a random structure. In this case a denser grid was also applied in the area around the zones where particular mechanical-fluid phenomena are expected, having so more grid-points to support the major occurrences. Such unstructured hexahedral mesh (sized here to 350mm) was installed in such zones of whole computational domain. However, the following parts of the 954m long bridge are also meshed with unstructured hexahedral cells in the explained way having subsequent increased cells size up to 400mm, 800mm and 1200mm as distance from the bridge-bode towards the open-space was growing.
The “Počitelj-Zvirovići” bridge-body and the road-elements were in the computational domain defined as non-adiabatic walls. The fluid-domain is air, with the ambient conditions and no fluid-movement, but from the side of expected wind-strokes. The computational fluid-sides were designed as opened pressure boundaries.

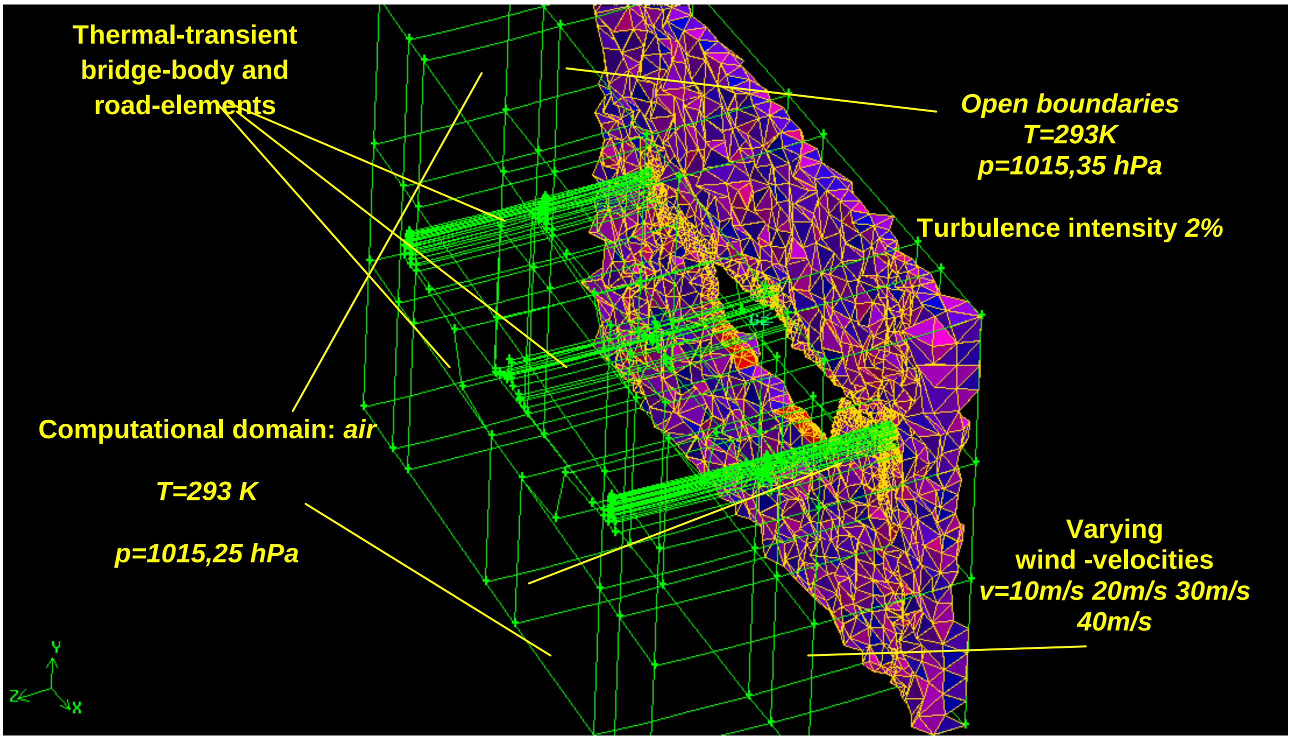

Fig. 3.2.1.1 The unstructured hexahedral mesh is applied over the "Pocitelj-Zvirovici" highway-bridge – here, at one fourth of it's length, around the zone of the fuel pool

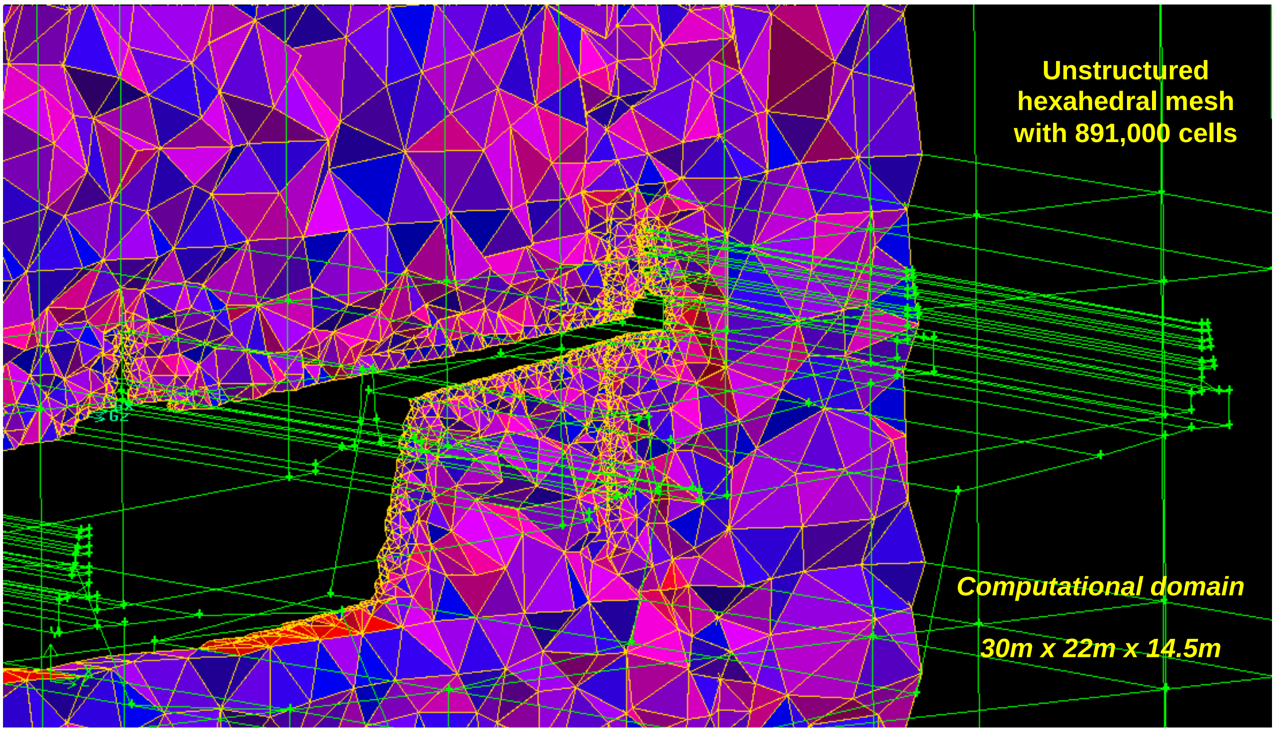

Fig. 3.2.1.2 The meshing-detail over the "Pocitelj-Zvirovici" highway-bridge – here, demonstrating the solution around the road-fence

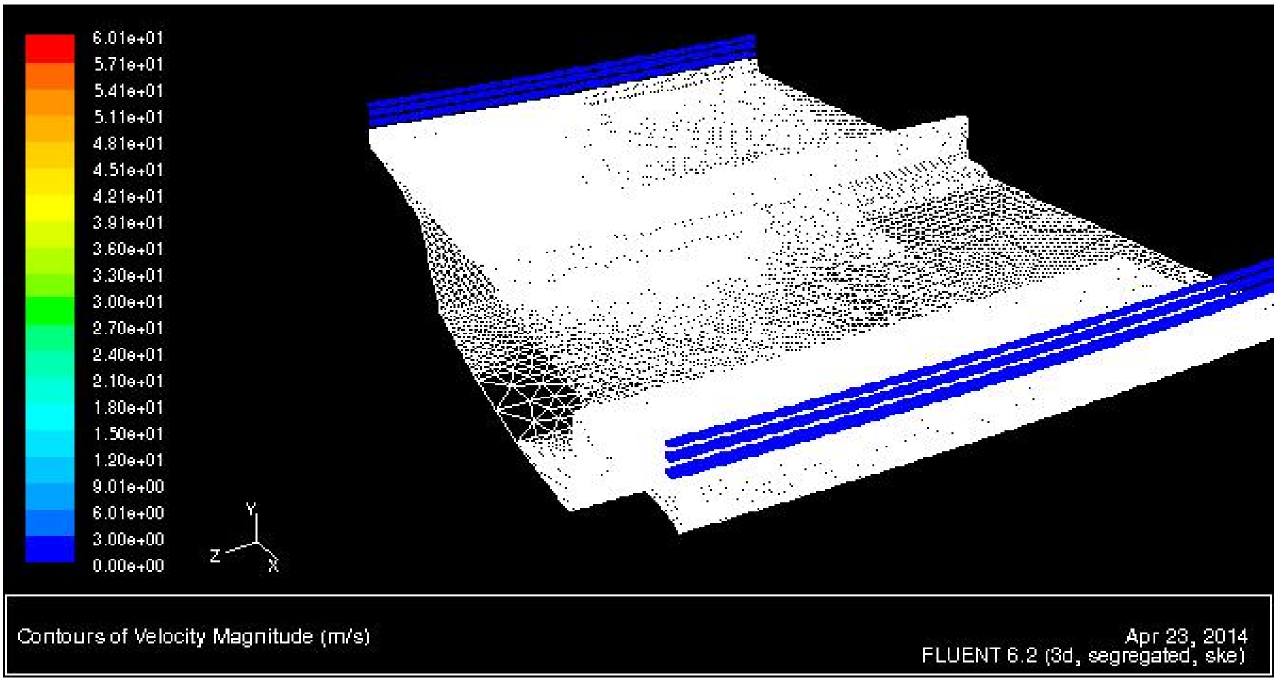

Fig. 3.2.1.3 The meshing-detail of the Bridge-segment “Pocitelj-Zvirovici”

4. DISCUSSION OF THE OBSERVED PHENOMENA

Consulting the meteorological survey of the State Weather-Service of Bosnia and Herzegovina[25], we performed several investigation-scenarios by varying computationally-aided, simulative conditions of the unwanted wind-strokes: from both south and north side of the Highway-bridge “Pocitelj-Zvorovici”. More influencing North-wind presented by the sophisticated CFD-based research, points up to the wind-flow disturbing panel-fences along it´s road-sides[26].

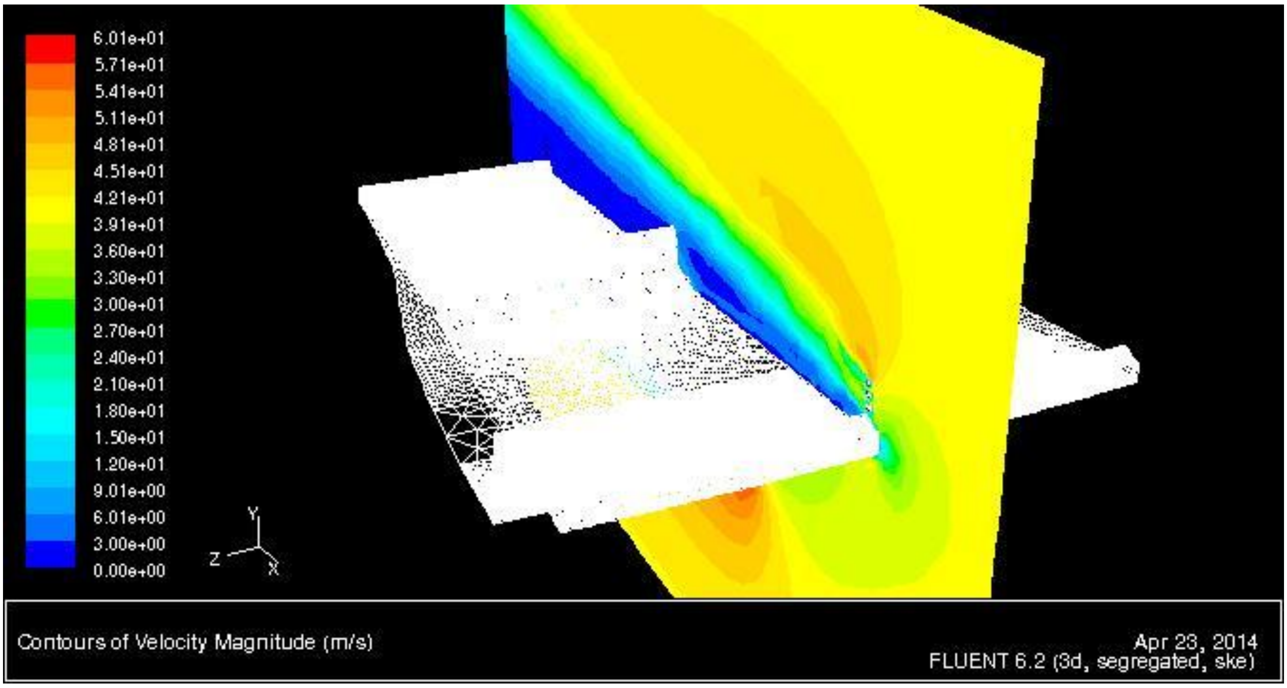

Fig. 4.1 The computationally-aided research of the wind-stroke, with the velocity of above 140km/h: After the “Stau-punkt”-zones the air, as every gaseous fluid, increases it´s propagation.

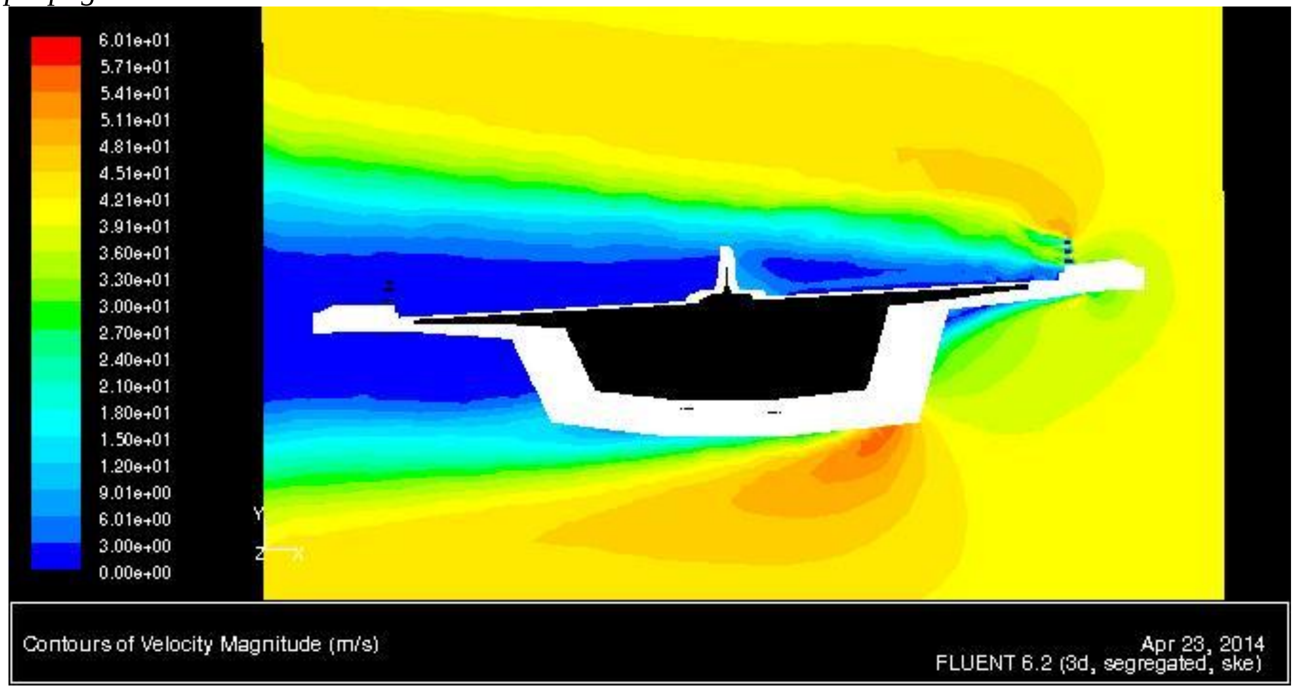

Fig. 4.2 The mentioned dangerous increasing of wind-velocity after the obstacle in form of traffic-road security-fence is visible.

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