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A topographic study for Julsundet Bridge Project

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SUMMARY:
This paper presents a topographic study conducted for the Julsund long span bridge in Norway's fjords. The study combines wind tunnel tests and numerical simulations focusing on a 10 km diameter area. A Boundary Transition Section (BTS) model is designed through preliminary Computational Fluid Dynamics (CFD) simulations and then tested in the boundary layer test section of Politecnico di Milano Wind Tunnel. Sixteen wind directions are tested, providing data on mean wind properties, turbulence intensities, and wind spectrum along the bridge deck and towers. Results highlight the impact of fjords on wind characteristics, with significant turbulence intensity levels and flow deflection. The findings offer essential insights for the design process, including stability considerations and lateral wind scales, contributing to a comprehensive understanding of local wind conditions at Julsundet.

Keywords: topographic effects, wind tunnel tests, CFD

1. INTRODUCTION

When designing long-span bridges, having an accurate prediction of the wind effects is essential to guarantee a safe and optimized design. This can be even more important in case the site is a hilly region characterized by relevant mountains. For cases like that, the bridge will be sensitive to wind conditions strongly affected by topographic effects. New design strategies proposed to account for terrain-induced effects by means of large measurements campaigns (Castellon et al., 2022). However, during the design stage, information about the wind characteristics are somehow incomplete due to the installation of the sensors (usually on land and far from the bridge) and with a limited measuring period (Fenerci et al., 2023). Therefore, it is usually required to supplement those measures with topographic tests performed through wind tunnel tests or numerical simulations (Lystad et al., 2018).

Referring to the design of one of the crossing bridges of Norway's largest fjords, the Julsund Bridge, a topographic study has been carried out and here presented. To have an accurate description of the wind field, a dedicated topographic study has been performed in the Politecnico di Milano Wind Tunnel; a 10 km diameter surround area is reproduced in the wind tunnel test section, assuming a length scale of 1:1000, allowing a proper representation of the elevations closest to the site of the Julsund bridge, being the ones expected to have the highest impact on the local wind flow conditions.

2. METHODOLOGY

The objective of the present study is to measure local wind properties due to terrain effects at

Julsundet (Norway). A 10 km diameter area is considered, as depicted by the blue circle in Figure 1. Due to the relatively tall mountains in the truncation area, a boundary transition section (BTS) model is used. Specifically, a set of preliminary steady-state CFD simulations are performed to design the BTS model to minimize the discrepancies with respect the expected full-scale conditions.

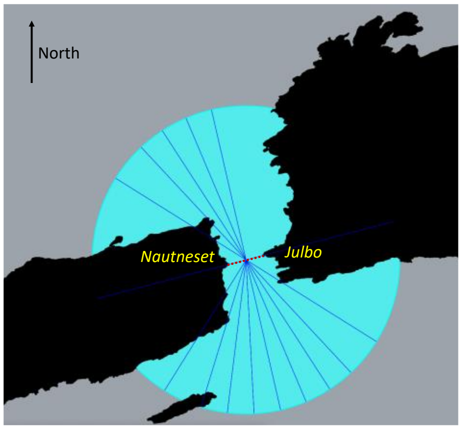

Figure 1. The 10-km diameter area considered for the topographic study.
The lines mark the incoming wind directions tested.

During the experimental tests, 16 different incoming wind directions are considered. The wind directions include those perpendicular and parallel to the bridge axis and 10, 20, 30 and 45 degrees yawed to the normal axis in northwest, southwest and southeast sectors.
Among others, the most interesting outputs for design purposes are the mean angle of attack over the deck axis (at 76.52m from water level) for stability issues and the lateral scales of the wind. For the towers (271m high), the flow field over the tower development can be measured, allowing the investigation of the buffeting response of such structures. In addition, results from the topographic study can be integrated with the full-scale measurements obtained from two masts (Furevik et al, 2020), installed in 2014 on the sides of the fjord, allowing to extend such local measures to the whole bridge.

Figure 2. The terrain model in the wind tunnel test section.

2.1. Measured quantities

Under each wind direction, the mean wind speed, mean wind direction, turbulence intensity and wind spectrum (u, v, w) are measured at 50m resolution along the bridge deck and two bridge towers. The wind coherences are also established using 3 separation lengths, i.e. 25, 50m, and 75m distance along the bridge axis. All the velocity measurements are carried out by means of multi-hole pressure probes able to resolve 3-components of velocity and local static pressure in real time (Cobra Probes). Acquisition time is well above 10 minutes full-scale, to obtain statistically meaningful quantities.

3. RESULTS

As an example of the results to be shown in the full paper, Figure 3 shows flow measures along the deck location, for two different incoming wind directions. Specifically, the first subplot shows the magnitude of the velocity vector normalized with respect to the reference velocity measured by a pitot tube placed at the beginning of the turning table at tower height. Second subplot shows the turbulence intensities variation along the deck and the third and fourth ones report yaw and pitch angles. Such angles are defined with respect to the inlet wind direction: yaw angle is in the horizontal plane, and it is positive if counterclockwise with respect to inlet wind; pitch angle is in vertical plane and it is positive if upward with respect to inlet wind. In Figure 3, blue markers refer to the incoming wind normal to the deck axis. Due to the effects induced by the orography, the flow is subjected to a slight acceleration resulting in normalized velocities over 1 along the deck axis. Along wind turbulence intensity is about 8% and the mean angle of attack (pitch angle) is null, except for the closest location to the Nautneset tower, where it becomes -5°. Considering instead the wind direction 302° (red markers in Figure 3), the effects due to the fjords becomes relevant: the sheltering effects on the Nautenest side results in a drop of the mean wind speed and a very turbulent flow, with Iu ≈ 50%. The approaching flow on the Nautneset side is deviated by the fjord, as highlighted by a -25° yaw angle.

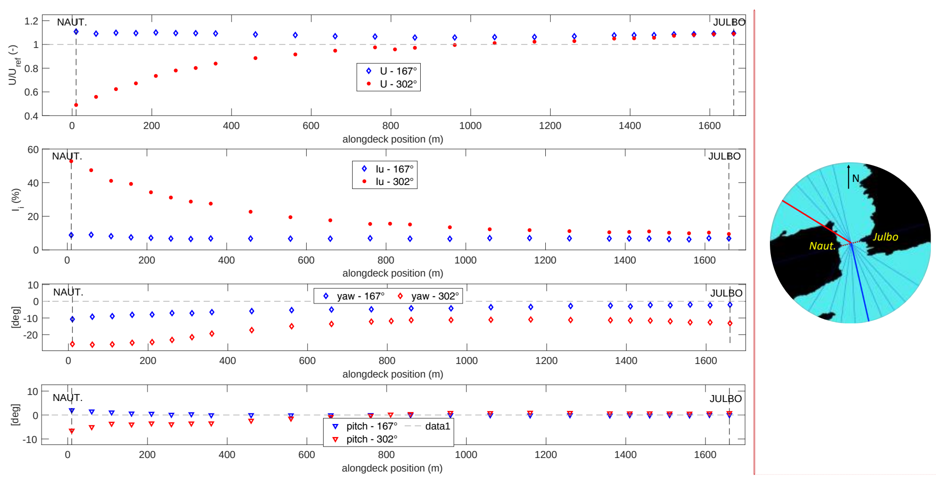

Figure 3. Results from velocity measurements along the deck axis. Incoming wind directions are depicted in the right figure.

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To better visualize the effects induced by the fjords, the CFD study, carried out preliminary to the wind tunnel tests, can provide mean flow pattern visualization. Figure 4 shows the flow behavior over the Nautneset fjord for incoming wind equal to 302°.

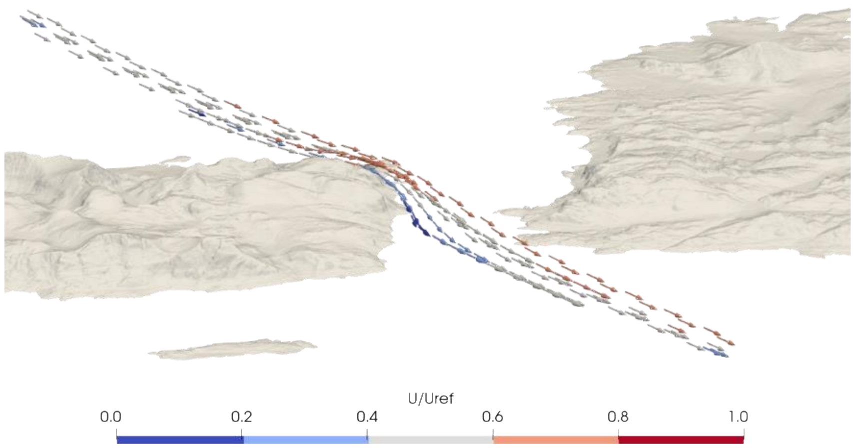

Figure 4. Streamlines visualization for incoming wind direction 302°.

6. CONCLUSIONS

The topographic tests have allowed to assess the flow characteristics at the Julsundet bridge location, including the relevant effects due to the surrounding fjords that are well captured with the experimental tests. Specifically, the fjords are responsible for high turbulence intensities levels and strong flow deflection both in the horizontal and vertical planes. The output of the results can provide important information for the design of the bridge. In addition, the flow characteristics here presented can be used to have a proper interpretation and extension of the full-scale measurements from masts.

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