

Experimental investigation of wind effects on ground-level and urban vertiports

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Summary

Vertiports are a crucial infrastructure component for vertical take-off and landing systems that are emerging technologies for urban mobility. In this study, the effect of the surrounding environment on the wind field over the surface of the vertiports was investigated through wind tunnel testing. The wind field over the surface of the vertiport was obtained using a Cobra probe measurement at a 3D grid of points and particle image velocimetry (PIV) measurements. Ground-level and urban vertiports were studied, and potential mitigation measures to minimize undesirable wind effects, such as wind shear, turbulence, and vortex regions, were explored. The results highlight the importance of upstream barrier geometry for surface vertiports as well as the role of shielding from adjacent buildings and spatial configuration in urban vertiports. The measurement data from this study can serve as a benchmark for validating computational wind engineering analyses of wind effects on vertiports.

Keywords: *Surface vertiport, Urban vertiport, Particle image velocimetry (PIV)*

1 INTRODUCTION

The term 'vertiport' is defined as 'an area of land, water, or structure that is used or intended to be used for the landing, take-off, and movement of vertical take-off and landing (VTOL) - capable aircraft' in the guideline for vertiports by European Union Aviation Safety Agency (2022). Surface vertiports are VTOL facilities located at ground level, typically on open land or repurposed transportation areas, while Urban vertiports are VTOL facilities located within dense city environments, often elevated on rooftop of buildings. VTOL systems, such as drones and air taxis, are getting wide interest around the world for urban air mobility, medical transportation, cargo services, and other applications. With the increasing demand and interest for the widespread use of VTOLs, vertiports are crucial infrastructure components for take-off and landing of VTOL systems. In addition to providing take-off and landing space, surface vertiports provide additional facilities for maintenance, battery exchange, and customer handling services. Since the passenger demand increases with the population density, a large portion of the vertiports are being planned in developed areas with complex surroundings. Moreover, vertical take-off and landing maneuvers are very sensitive to turbulence. This makes the selection of the vertiport location and assessment of wind around the vertiport one of the most important steps in urban air mobility planning for a safe and efficient operation of the VTOLs. The significantly small size of VTOL systems in comparison to helicopters makes them highly susceptible to wind flow interference in their take-off and landing zones. This requires an in-depth investigation of the wind flow around approach, take-off, and landing zones to ensure operational safety and to avoid undesirable effects that may lead to overall inefficiency.

Authoritative organizations in aviation such as European Union Aviation Safety Agency, Federal Aviation Administration, and Civil Aviation Safety Authority of Australia, have recently

published documents containing specifications and guidance for vertiports' design and operation (Australian Government Civil Aviation Safety Authority, 2024; European Union Aviation Safety Agency, 2022; Federal Aviation Administration, 2022). The authorities provide technical guidance for addressing vertiport's design and operation-related issues, such as physical characteristics, obstacle limitation surfaces, visual aids. In European Union Aviation Safety Agency (2022), the importance of wind and turbulence is highlighted within sections dedicated to take-off and climb, and approach paths' definition, alternative vertiport placements, and hazard area definitions.

Previous research on vertiports mostly focused on vertiport number and location optimization for efficient performance and integration with other urban transportation systems (Lim and Hwang, 2019; Jin et al., 2024; Macias et al., 2023). Very few studies focused on climate and wind analysis for optimal vertiport locations (Giersch et al., 2022; Maksoud et al., 2025).

A relevant study on the wind field and flow disturbance over an urban vertiport was done by Bernyk et al. (2023). They used particle tracking velocimetry on a wind tunnel test of a scaled model, highlighting the need to account for the surrounding geometry, i.e., buildings and design details, to be able to characterize the wind fields for the site problem correctly.

This study focuses on the wind field characteristics above ground-level and urban vertiports. The effect of different upstream barriers on surface vertiports is investigated, considering two atmospheric boundary layer profiles, Sea and Open country. In addition, the effect of shielding by adjacent buildings and the spatial configuration of the vertipad on the rooftop in an urban area is investigated for urban vertiports. Since computational wind engineering will be a crucial tool to investigate wind effects on vertiports in different complex environments, the results of this study can serve as a benchmark for validation, as the experimental data will be available through an open portal.

2 METHODS

The investigation on ground-level and urban vertiports was done through wind tunnel testing of scaled models in the Giovanni Solari Wind Tunnel at the University of Genova. Atmospheric boundary layer profiles representative of sea and open-country terrains were simulated to study surface vertiports, while an urban boundary layer profile was simulated to study urban vertiports. The wind field over the surfaces of the vertiports was obtained using Cobra probe measurements and particle image velocimetry (PIV). The cobra probe measurement was done on a 3D grid of points above the surface of the vertiport to obtain the spatial variation of mean wind speed and turbulence intensity. The PIV measurements were performed on four horizontal and lateral planes to obtain parameters such as the mean wind speed and its gradient.

The effect of the upstream barrier on the surface vertiport was studied by measuring the wind field over the surface of the vertiport with a low-rise building—representative of a gate or passenger terminal—positioned upstream. Different measures to mitigate the flow disturbance caused by the presence of the upstream barrier, such as a solid plate, a porous plate, a guide vane attached to the roof of the low-rise building, and trees, were explored. The considered configurations of the upstream barrier with the mitigation measures are described in Figure 1a. For the urban vertiport case, the effects of elevation of the vertipad above the rooftop and its location relative to the rooftop surface were investigated by measuring the wind field over the vertipad under five configurations of vertipad spatial arrangement on the rooftop. The considered configurations of the vertipad are summarized in Figure 1b. To investigate the effect of shielding by an adjacent building, all the

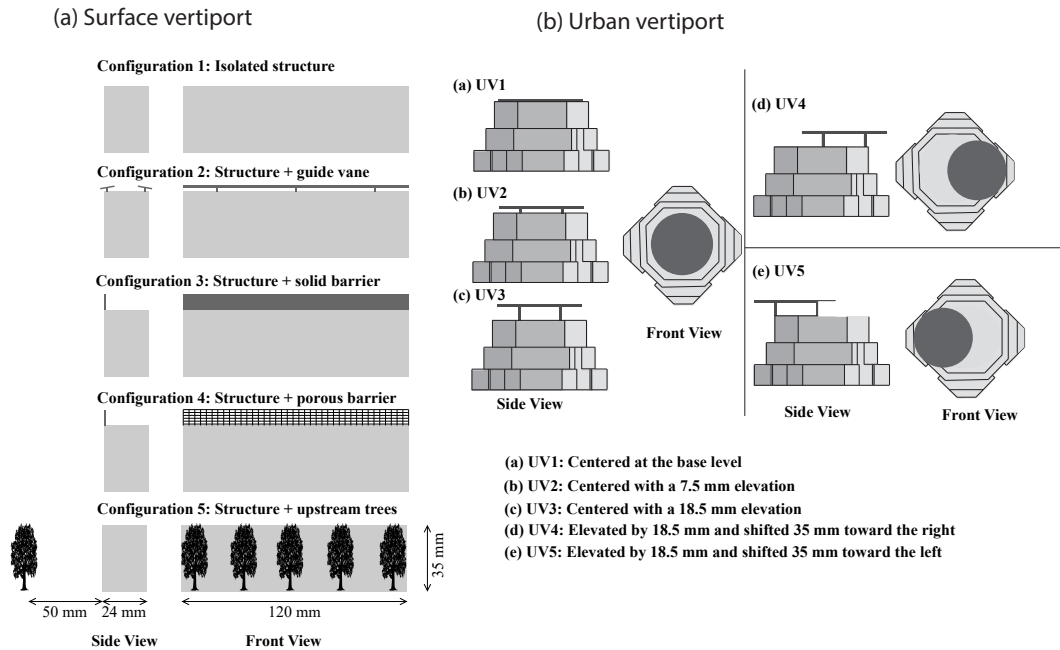


Figure 1: Configurations of upstream barrier for the surface vertiport (a) and vertipad location for the urban vertiport (b): incoming wind direction left to right

considered configurations were studied under both free-stream and shielded conditions.

3 RESULTS AND DISCUSSION

The Cobra probe measurements on a 3D grid of points above the surface of the vertiport were analyzed to obtain the spatial variation of mean wind speed and turbulence intensity to identify wind shear and turbulence. The PIV measurement data were analyzed to obtain mean wind speed and its gradient contours to identify wind shear, flow separation, and overspeed regions.

For the case of the surface vertiports, the geometry of the upstream barrier has been found to strongly affect the vertical profile of the mean wind speed and turbulence intensity, while the effect of the atmospheric boundary layer profile (Sea vs. Open country) was minimal. The provision of guide vanes attached to the roof of the upstream barrier has significantly decreased the wind shear and turbulence intensity over the surface of the vertiport.

Results from the Cobra probe and PIV measurements for the considered configurations of the urban vertiport indicate that the upstream exposure condition (shielded vs. free) is the dominant factor controlling mean velocity and turbulence levels, producing larger differences than those due to vertiport configuration alone. Nevertheless, the vertiport configuration influences the characteristic flow profiles: under free exposure, elevating the vertiport mitigates interaction with the rooftop separation zone at the building edge, thereby improving local flow attachment; under shielded exposure conditions, optimal performance is achieved when the vertiport is attached and centered on the rooftop.

4 CONCLUSIONS

The wind field over the surface of ground-level and urban vertiports was investigated through wind tunnel testing, measuring the relevant wind parameters through cobra probe and PIV measure-

ments. The results indicated that wind shear, turbulence intensity, and flow disturbances are highly influenced by the geometry of the upstream barrier for surface vertiports and by shielding from adjacent buildings for urban vertiports. The installation of guide vanes on the roof of the upstream barrier buildings in surface vertiports as well as adjusting the elevation of the vertipad above the roof surface in urban vertiports has shown a favorable effect on the flow over the surface of the vertiport, reducing both turbulence and wind shear.

The wind tunnel investigation data, which will be made available through an open-access portal, can serve as an important benchmark for validation of computational wind engineering studies aimed at assessing vertiport aerodynamics.

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