

Experimental database of simulated wind fields and aeroelastic response of lattice towers in the WindEEE Dome

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SUMMARY

This paper introduces a new database of simulated wind field measurements and aeroelastic response of the scaled models of two triangular telecommunication lattice towers of real heights 50 m (T50) and 90 m (T90) respectively. The database comprises: (i) wind field characterization tests, (ii) aeroelastic tests of the T50 and T90 tower models and (iii) aerodynamic tests on rigid sectional models of the top section of T50. The wind tunnel tests were conducted within the ERIES-BOLT (Behaviour of Telecommunication Lattice Towers to Thunderstorm Winds) project and is made available through the Zenodo repository at: <https://doi.org/10.5281/zenodo.12627184>.

Keywords: WindEEE dome, downburst, aeroelastic wind tunnel test, force balance, sectional test, lattice tower

1. INTRODUCTION

The ERIES-BOLT project addresses a critical research gap in the field of wind engineering, i.e. the lack of validated laboratory simulations of the response of slender structures to downburst winds. This is achieved through a series of wind-tunnel tests of simulated wind fields and wind-induced response of lattice towers. Furthermore, the project investigates the fundamental differences in the dynamic behaviour of these structures under downburst winds compared to traditional atmospheric boundary-layer winds.

The wind tunnel tests were conducted in the Wind Engineering, Energy and Environment (WindEEE) Dome, at WindEEE Research Facility, Western University, Canada (Hangan, 2014) which can reproduce various complex flows such as tornado (Refan et al., 2014), downburst (Romanic and Hangan, 2020), and full/large-scale synoptic winds (Birhane et al., 2020). The experimental database acquired within the ERIES-BOLT project serves as a critical benchmark for validating and improving downburst-structure interaction CFD models and provides a foundational dataset for developing data-driven models for rapid prediction of non-stationary wind loads and structural response.

2. SIMULATED WIND FIELD CHARACTERIZATION TESTS

Four wind field characterization tests were performed as follows: (1) Atmospheric Boundary Layer (ABL) flows, (2) downburst-like outflows (DB), (3) simultaneous downburst-like outflows with prevailing ABL (DBABL) flows, and (4) downburst-like outflows with radial trip profiles (TDB). The vertical profiles of the outflow wind were measured at various radial distances from the centre of the bellmouth indicated by a non-dimensional parameter, r/D where r is the radius from the center of the bellmouth to the location of the Cobra probe stand. Figure 1 shows examples of wind speed records for the following test cases: (a) ABL flow profile and (b) DB outflow profile at radial distance $r/D = 1.6$.

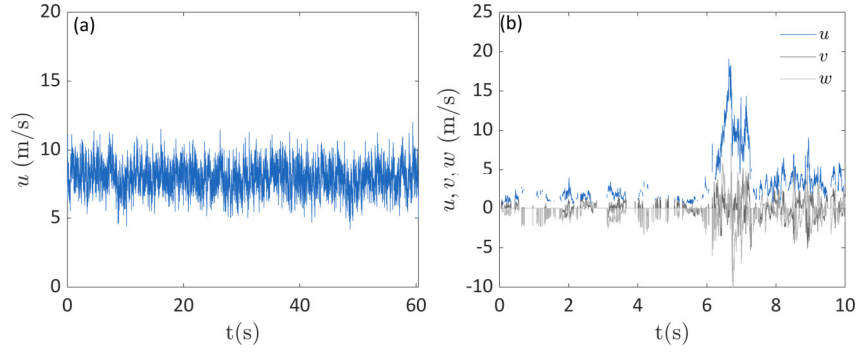


Figure 1: Wind speed (u) measured at $z = 500$ mm for (a) ABL flow profile and radial and transversal and vertical wind speed components (u, v, w) measured at $z = 500$ mm for (b) DB outflow profile at radial position $r/D = 1.6$.

3. AEROELASTIC TESTS

The aeroelastic models of two triangular telecommunication lattice towers of full-scale heights 50 m (T50) (Calotescu et al., 2025) and 90 m (T90) (Fig. 2a) were tested under ABL, DB (Fig. 2b), DBABL and TDB flows. Both models were built to a geometric scale of 1:100 (50 cm and 90 cm respectively). The scales were chosen to obtain reasonable sizes for tower members. The models were positioned on an ATI Mini40 F/T, 6-component force balance to measure 6 base loading components including $F_x, F_y, F_z, M_x, M_y,$ and M_z . Two 3-axis ADXL 335 accelerometers were placed on bracing components of each model.



Figure 2: (a) Aeroelastic models of towers T50 (left) and T90 (right) and (b) DB visualization of the T50 model

The aeroelastic tests measurements reported in the database include the wind speed records at the height of the model, the force balance loading reactions ($F_x, F_y, F_z, M_x, M_y,$ and M_z) and the accelerations of the model at two different levels (top and mid-height of the model). Figure 3 shows accelerations measured by the accelerometer placed at the top of the T50 model corresponding to the flows reported in Figure 1.

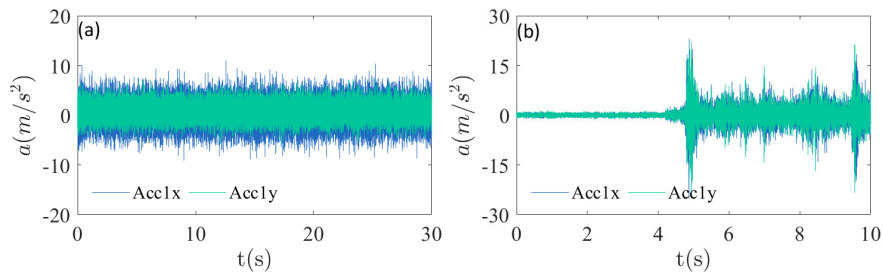


Figure 3: T50 accelerations during test cases: (a) ABL flow and (b) DB outflow at radial position $r/D = 1.6$.

4. AERODYNAMIC TESTS

The aerodynamic tests were performed on a 1 m tall section representing the top part of the T50 tower at a scale of 1:10. The model was equipped with a platform, ladder and three panel antennae and was constructed of brass, steel, 3D printed nylon, PolyJet 3-D printed material, and steel bolts. The antennas, platform and central ladder are all removable. The model was mounted on a 12.7 cm diameter steel pipe and connected to a JR3 30E12A4 six-component force balance, allowing for the simultaneous measurement of forces and moments. The reference velocity was monitored using a Cobra Probe at mid-height.

The model was tested in three distinct configurations (MC): MC1 – bare structure with base plate, MC2 – bare structure with base and top plate, and MC3 – structure equipped with ladder, railings, and antenna. Tests were performed for various angles of attack (θ) for each configuration. Figures 4a-d show examples of data records reported in the dataset for the aerodynamic tests performed on the sectional model of tower T50 while Figure 4e shows the sectional model used for configuration MC2.

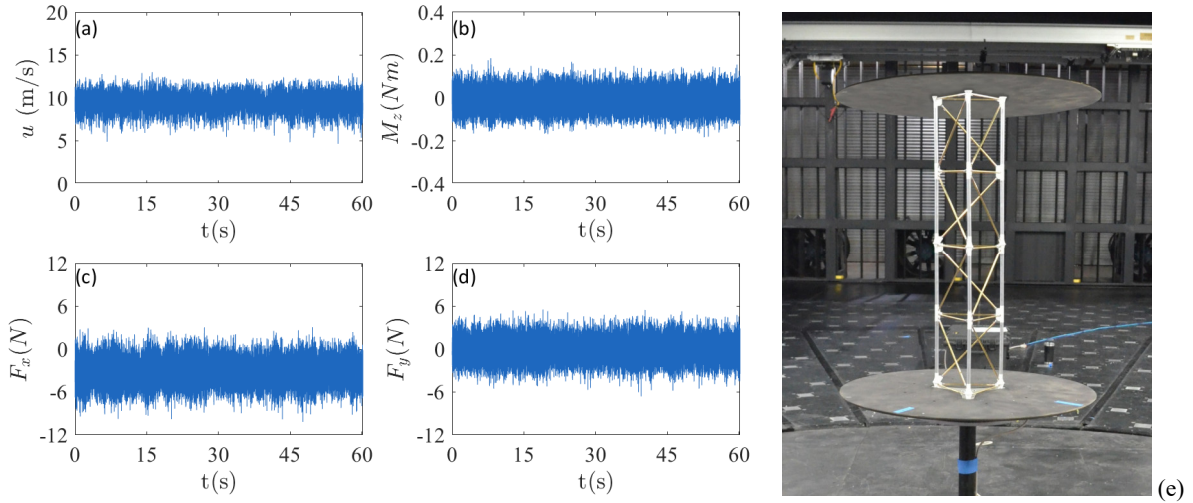


Figure 4: Data records for MC 1 ($\theta = 0^\circ$): (a) wind speed, (b) moment M_z , (c) force component F_x , (d) force component F_y and (e) MC2 model.

Coşoiu et al. (2025) conducted a CFD study for the MC2 configuration. The simulations were performed using a steady-state, pressure-based coupled solver with second-order discretization schemes. The $k-\omega$ SST turbulence model was selected to capture flow separation in the wake of the lattice structure. The computational domain (Fig. 5a) consisted of a box with dimensions $3.5H \times 2H \times 1H$, where $H = 1$ m is the model height. A grid sensitivity analysis was conducted on three meshes: Grid 1 (20.7 million cells), Grid 2 (18.0 million cells), and Grid 3 (16.5 million cells). All grids were hybrid poly-hex, with refined boundary layers. Near-wall resolution achieved $y^+ < 2$ for more than 95% of the wall nodes on the two finer meshes. Results showed very small variations across the grids ($< 2\%$), confirming mesh convergence.

The numerical simulations reproduced the same inflow conditions as those measured in the wind tunnel and were performed for angles of attack (θ) ranging from 0° to 60° in 10° increments, consistent with the experimental setup. Good agreement between numerical and experimental drag coefficients was observed for all angles of attack and inflow velocities as seen in Figure 5b.

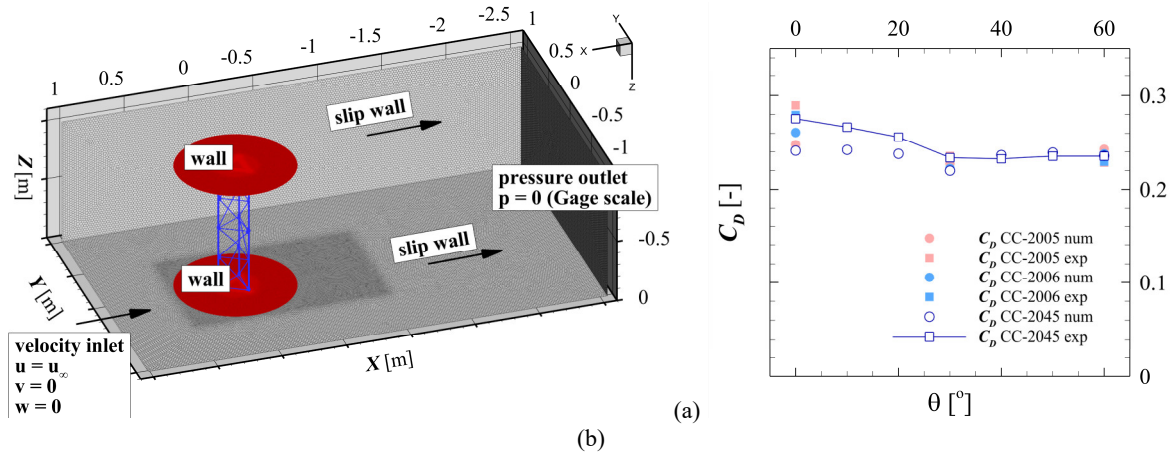


Figure 5: (a) CFD simulation domain and boundary conditions for MC2 test case ($\theta = 60^\circ$) and (b) variation of drag coefficient C_D with angle of attack θ .

5. CONCLUSIONS

This paper presents the database of wind tunnel test measurements acquired in the WindEEE Dome within the ERIES-BOLT project. It includes winds field characterization, aeroelastic tests on the models of two lattice towers of 90 m and 50 m heights and aerodynamic tests on the sectional model of the 50 m lattice tower. The database represents a critical benchmark for the experimental characterization of thunderstorm wind effects on lattice towers and serves as a valuable resource for validating computational models. The database also represents an ideal training set for emerging data-driven and artificial intelligence methodologies in wind engineering.

ACKNOWLEDGEMENTS

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