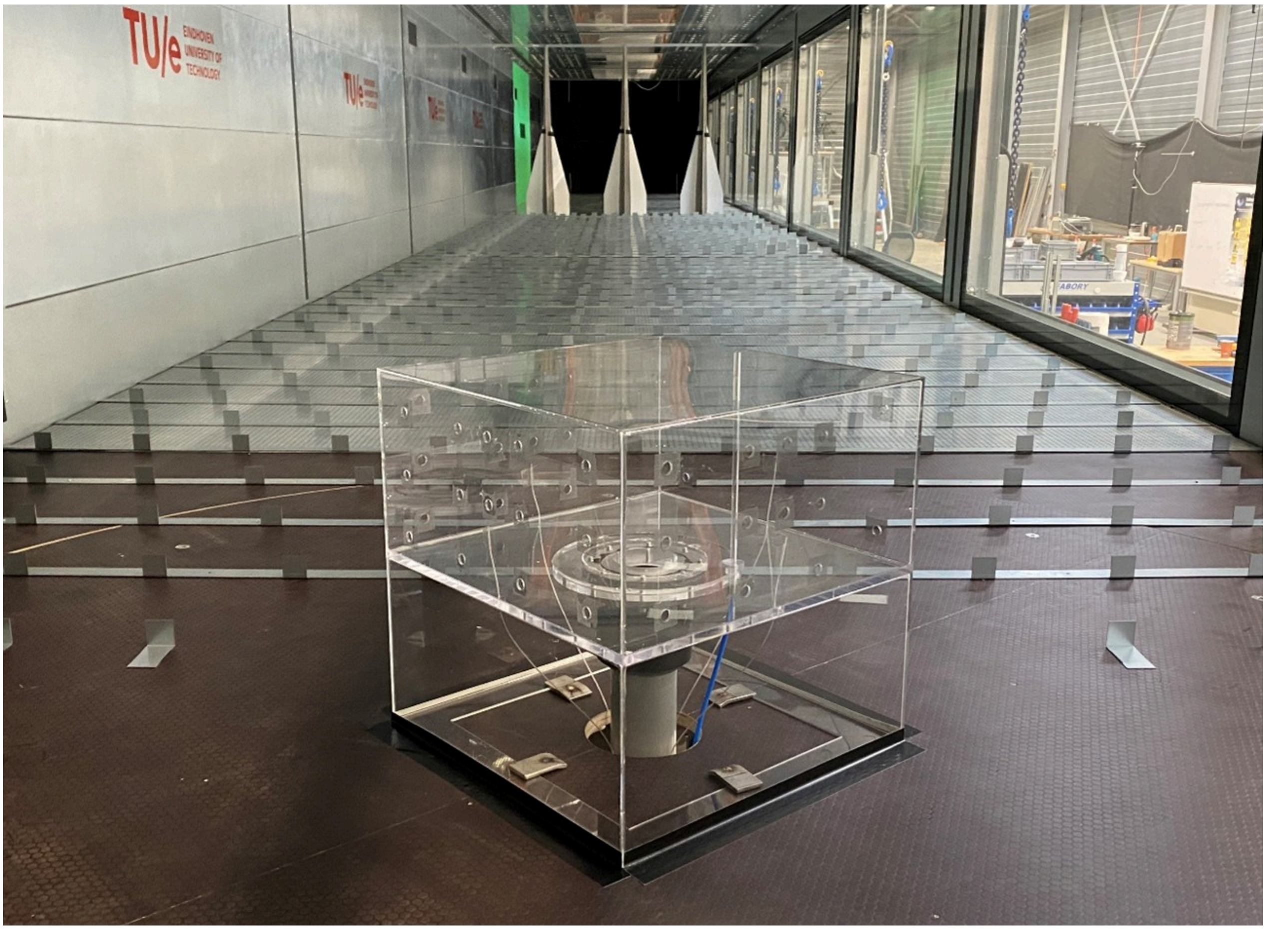
Metadata Report



Project Name

Pollutant Reintroduction Investigation for Occupational Risk Reduction - a Benchmark

Period

2024-2025

Dataset Description

A series of experiments was conducted in the closed-circuit Atmospheric Boundary Layer Wind Tunnel at Eindhoven University of Technology, involving a building model at a reduced geometric scale of 1:40. The building model includes a working single-flow mechanical ventilation system and a pollutant source above the roof. The aim of this test was to provide an experimental benchmark to quantify pollutant re-introduction due to both building ventilation and atmospheric wind effects. The steady-state normalized pollutant concentration at the exhaust ventilation fan was measured for 13 reference wind directions (0°, 15°, 30°, 45°, 50°, 60°, 75°, 90°, 135°, 180°, 225°, 270° and 315°) and 3 reference wind speeds (6.4 m/s, 9.0 m/s and 11.1 m/s), leading to 39 wind conditions. For the two most critical scenarios, an internal mapping of the normalized pollutant concentration was conducted on a 3x3x3 grid inside the building. For one wind condition, the normalized pollutant concentration was measured at each of the 40 ventilation air inlets of the building model. In the framework of occupational risk control, these data can be used first to better understand the dynamics of pollutant dispersion around and into a ventilated building, then to assess corresponding numerical simulations.

Project Domain

Wind

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Focus Area(s)

Pollutant dispersion, Ventilation, Idealized model, Isolated model

Keywords

Pollutant re-introduction, Mechanical ventilation, Fan, Tracer gas, Occupational Safety and Health, Wind tunnel experiment

GEM taxonomy

Specimens

Specimen 1. Idealized building equipped with mechanical ventilation system

The closed-circuit Atmospheric Boundary Layer Wind Tunnel (ABLWT) at Eindhoven University of Technology with a cross-section of 3 m width and 2 m height was used to conduct a series of experiments on a building model. The wind tunnel allowed to reproduce wind flow characteristics with a geometric scale of 1:40 and a velocity scale of 1:0.707. This scaling was applied to an isolated cubical building model including a stack for pollutant release. This led to a building side length of 0.45 m, a stack length of 0.025 m and a stack inner diameter of 0.006 m. The stack centre was located on the roof in a corner at 0.15 m from cube edges. The building was mounted at the centre of a turn table, which allowed to test various wind incidence angles. The maximum blockage ratio of the building in the wind tunnel

was 4.8 %. The building was divided so that the internal ventilated volume was 0.046 m3. The ventilation was composed of 40 passive ventilation air inlets (0.012 m in diameter), 16 leakage holes (0.003 m in diameter) and one mechanical ventilation exhaust (flow rate of 100 m3/h) using a fan connected to the building ventilated volume with a 1.7-m long pipe (0.1 m in diameter). Details about the design of the reduced-scale ventilation system can also be found here:
http://dx.doi.org/10.1016/j.jenvman.2024.122698

The pollutant release was simulated by using a tracer gas being a mixture of ethylene and nitrogen with a density similar to the one of ambient air. It was released at the stack outlet with an average volume flow rate of 0.65 m3/h, corresponding to an exhaust velocity of 6.4 m/s.

Experiment 1. ABL flow characterisation

Three reference wind speeds of 6.4 m/s, 9.0 m/s and 11.1 m/s were applied. The reference height for wind speed is the building height. For those measurements, the building model was not present. The spires located upwind in the test section of the wind tunnel and the roughness elements in the test section were positioned to achieve the target average velocity and turbulence vertical profiles at the planned building location. These profiles correspond to an Atmospheric Boundary Layer (ABL) flow with a slightly rough terrain and the Reynolds number based on the building size ranges from 1.9x105 to 3.3x105.

Details about the ABL flow characterization can also be found here:
http://dx.doi.org/10.1016/j.jweia.2023.105442

Instrumentation

A pitot tube located in the free stream above the wind tunnel ground to measure the reference wind velocity. A Series 100 Cobra probe (a four-hole pressure probe) from Turbulent Flow Instrumentation Pty Ltd (TFI) was mounted to a three-axis traverse system installed inside the wind tunnel to measure streamwise approach flow velocities, turbulence intensities and turbulence length scales at 1000 Hz for 120 seconds.

Experiment 2. Internal pressure characterization

To verify ventilation airflow rates prior to testing in the wind tunnel, the indoor-outdoor pressure difference was measured at the centre of each building facade. For those measurements, the building model was outside the wind tunnel. The indoor pressure was calibrated at -40 Pa compared to outdoor and the extracted flow rate was set at 100 m3/h to achieve the design total ventilation airflow rate.

Instrumentation

The Scanivalve MPS4264 pressure scanner was used to measure pressure. Internal pressure readings were taken at the centre of each facade of the building model. The pressure transducer was connected to the façade using 1.37 mm internal diameter urethane tubing of 1 m length.

Experiment 3. Pollution re-introduction measurement: effect of wind direction and wind speed

This experiment aims at analysing the effect of wind conditions on the re-introduced pollutant concentration. Results are expressed as the percentage of pollutant concentration measured in the pipe upwind the exhaust fan normalized by the pollutant concentration released at the stack. The pollutant release flow rate at the stack is controlled by mass flow controllers and a calibration procedure was carried out before each experiment to verify the accuracy of the tracer gas measurement by means of a known ethylene source. The background pollutant concentration in the approach flow was measured simultaneously to be subtracted from the measurements in the pipe upwind the exhaust fan. After reaching the quasi-steady state, the concentrations were averaged over 180 s. The air temperature and the absolute atmospheric pressure were also tracked in order to compute the real air density. This experiment was conducted for each of the 13 reference wind directions and each of the 3 reference wind speeds. A non-dimensional velocity (M) was introduced as the ratio between the release velocity at the stack and the reference wind velocity, leading to M values ranging from 1.0 to 1.7. Four measurements have been replicated 3 times to estimate the reproducibility error.

Instrumentation

A pitot tube located in the free stream above the wind tunnel ground to measure the reference wind velocity. A 2-channel Cambustion HFR 400 Fast Flame Ionization Detector (FFID) was used to measure both the background ethylene concentration and the ethylene concentration in the exhaust fan pipe. The capillaries had an inner diameter of 0.25 mm and a length of 405 mm (background probe) or 315 mm (exhaust probe), with respective frequencies of 78 Hz and 100 Hz.

Experiment 4. Pollution re-introduction measurement: internal mapping of the pollutant concentration

Based on Experiment 3 data, the two most critical scenarios were chosen for detailed measurements of the internal pollutant concentration, namely for wind directions of 0° and 45° at M=1.7. Measurements were conducted on a uniform 3x3x3 grid, with an averaging of 180 s after reaching the quasi-steady state. The background pollutant concentration measurement was maintained and the internal mapping of the pollutant concentration was realized by means of a probe mounted to a three-axis traverse system installed inside the wind tunnel. The air temperature and the absolute atmospheric pressure were also tracked in order to compute the real air density.

Instrumentation

Identical to the instrumentation described under Experiment 3, except capillary probe positions. The capillary probe with a length of 405 mm was used for the internal measurement and the capillary probe with a length of 315 mm was used for the background measurement.

Experiment 5. Measurement of pollutant concentration re-introduced through each air inlet

Based on Experiment 3 data, the most critical scenario was chosen for detailed measurements of the pollutant concentration at ventilation inlets, namely for the 45° wind direction at M=1.7. Measurements were conducted at the centre of each of the 40 air inlets, with an averaging of 180 s after reaching the quasi-steady state. The background pollutant concentration measurement was maintained and the pollutant concentration measurement was realized at each air inlet by means of a probe mounted to a three-axis traverse system installed inside the wind tunnel. The air temperature and the absolute atmospheric pressure were also tracked in order to compute the real air density.

Instrumentation

Identical to the instrumentation described under Experiment 3, except capillary probe positions. The capillary probe with a length of 405 mm was used for the air inlet measurement and the capillary probe with a length of 315 mm was used for the background measurement.