CODASC: A DATABASE FOR THE VALIDATION OF STREET CANYON DISPERSION MODELS

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Abstract: CODASC stands for Concentration Data of Street Canyons (CODASC 2008, www.codasc.de). It is a database which provides traffic pollutant concentrations in urban street canyons obtained from wind-tunnel dispersion experiments. CODASC comprises concentration data of street canyons with different aspect ratios subjected to various wind directions and also for street canyons with tree-avenues. The database includes concentration data of tree-avenue configurations of different tree arrangement, tree stand density and crow porosity. In total, CODASC offers a comprehensive dataset of pollutant concentrations of 28 street-canyon/tree-avenue configurations. The main purpose of CODASC is to provide wind-tunnel dispersion data for validation in urban air quality modelling. Since it comprises a large number of street-canyon/tree-avenue configurations, the CODASC database allows for a profound assessment and validation of numerical urban dispersion models of different complexity.

Key words: *Street Canyon, Pollutant Dispersion, Air Quality, Avenues, Trees, Database, Validation*

INTRODUCTION

Traffic emissions are frequently the main source for air pollution in the urban environment. Critical situations occur in densely built-up city areas which are formed by street canyons suffering from limited ambient air exchange and high pollutant concentrations. Tree-avenues inside street canyons even complicate the situation, since they decrease the street-level-wind speeds and lead to reduced dispersion and enhanced traffic pollutant concentrations. However, despite the large number of urban air quality studies, in particular street-canyon-dispersion studies, trees or tree-avenues have, with very few exceptions, been ignored in such investigations.

In order to investigate and quantify the effects of tree-avenues on the dispersion of traffic pollutants, wind-tunnel experiments with an urban street-canyon model and tree models have been performed at the Institute for Hydromechanics IfH at the Karlsruhe Institute of Technology KIT in the years from 2004 to 2008. During that time, a large number of street-canyon/tree-avenue configurations with systematic variations of the approaching wind direction α, the street-canyon aspect ratio W/H (street width W and building height H), the tree stand density ρ_{ts} and the tree crown porosity P_{Vol} have been investigated. The experiments have shown that tree-avenues in urban street canyons result in large increase in traffic pollutant concentrations. In comparison to tree-free street canyons, increases of up to 146% in average pollutant concentrations at the canyon walls and local increases of up to 305% have been found. The most critical situations have been observed in street canyons with tree-avenues for oblique wind directions. The results underline the necessity to include tree-avenues in urban street canyon and neighbourhood scale dispersion studies. They also indicate that contrary to common practice in air quality studies wind directions other than perpendicular have to be accounted for. Finally, in 2008, from the measurement data of those experiments, the CODASC database (CODASC 2008) has been established.

STREET-CANYON MODEL AND TREE MODEL

The urban street-canyon model was formed by two parallel aligned blocks made of acrylic glass with length to height ratio L/H = 10 and placed on a wind-tunnel turntable (Figure 1). The setup was subjected to a simulated urban atmospheric boundary-layer of model scale M = 1:150. Detailed information on the simulated flow can be found in Gromke and Ruck (2005), Gromke (2008) and CODASC (2008). Traffic emissions were simulated by tracer gas (sulphur hexafluoride SF_6) emitting line sources that were embedded in the street. Measurement taps at the leeward and windward canyon walls (hereafter referred to as wall A and wall B, respectively) sampled the near-façade canyon air which was than brought to an Electron Capture Detection (ECD) device for the concentration analysis. The tree-avenue models were realized by line-like lattice cages which were divided by equally sized cells and filled with a filamentary synthetic wadding material (Figure 1). Different crown porosities P_{Vol} were modelled by varying the amount of the wadding material filled into the cells; different tree stand densities ρ_{ts} were realized by filling every n^{th} cell (n = 1, 2, …) of the lattice cages. It has to be noted that the tree trunks were not modelled as they are fairly small compared to the crowns and their influence on the flow past trees is negligible. For a more detailed description of the street-canyon model and the tree-avenue modelling the reader is referred to Gromke (2008), Gromke and Ruck (2009b), Gromke (2011) or Gromke and Ruck (2012).

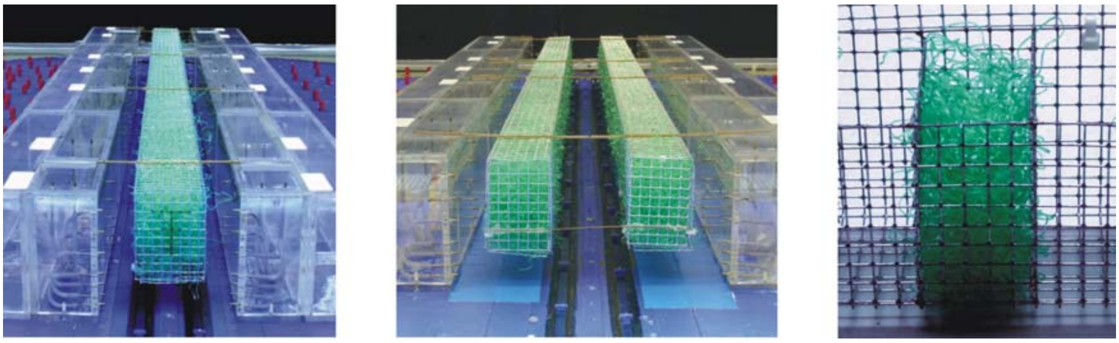


Figure 1. Street-canyon model with tree-avenue models: W/H = 1 (left) and W/H = 2 (middle), and a cell of the lattice cage filled with wadding material (right).

THE CODASC DATABASE

The database is designed to provide modellers with the information required for developing and setting up a numerical model. The information can be accessed by the hyperlinks on the left part of the CODASC main page (Figure 2). In particular, CODASC provides information on the

- wind-tunnel layout and wind-tunnel boundary-layer flow characteristics (hyperlink: *Wind Tunnel*)
- street-canyon geometries including the positions of the tracer gas emitting line sources and the tree-avenues (hyperlink: *Photo Gallery*)
- tree-avenue modelling concept (hyperlink: *Tree Modeling*)

In the core of the CODASC database is the wind-tunnel concentration data. The concentration data is accessible on the CODASC main page in the table indicated at the bottom part of the image shown in Figure 2. It has to be noted that the concentration data is provided in normalized form according to

$$c^+ = \frac{c\, u_H H}{Q_l} \qquad (1)$$

where c^+ is the normalized concentration, c is the measured concentration, H is the building height, u_H is the flow speed of the undisturbed boundary-layer at height H and Q_l is the tracer gas emission line source strength.

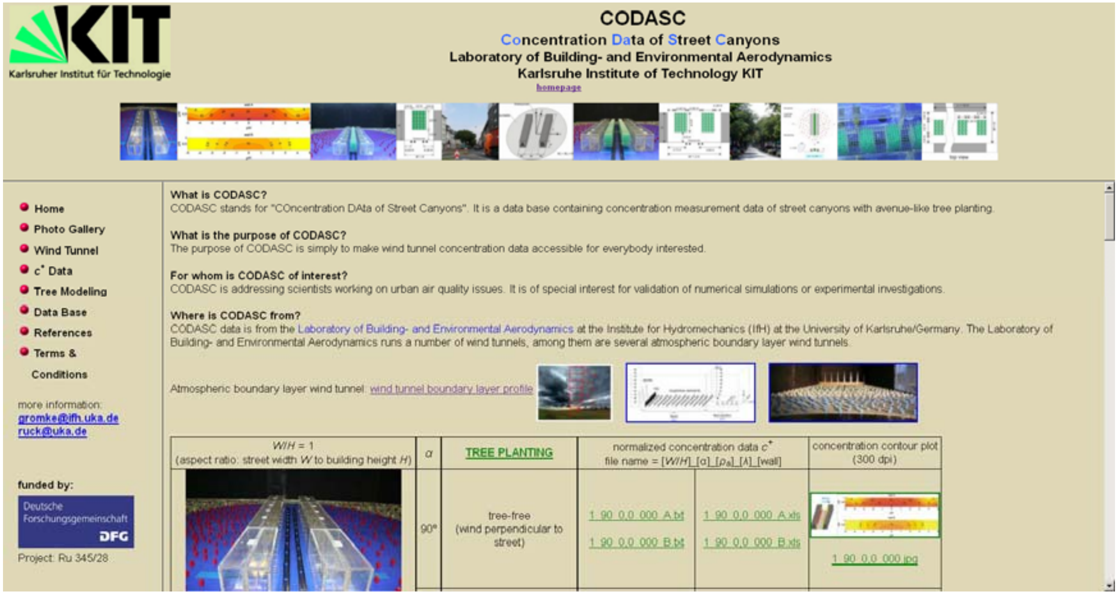


Figure 2. CODASC main page (www.codasc.de). The concentration data files can be accessed by the hyperlinks in the table at the bottom part of the CODASC main page.

The nomenclature of the concentration data files is as follows:

[W/H]_[α]_[ρ_{ts}]_[λ]_[wall]

where

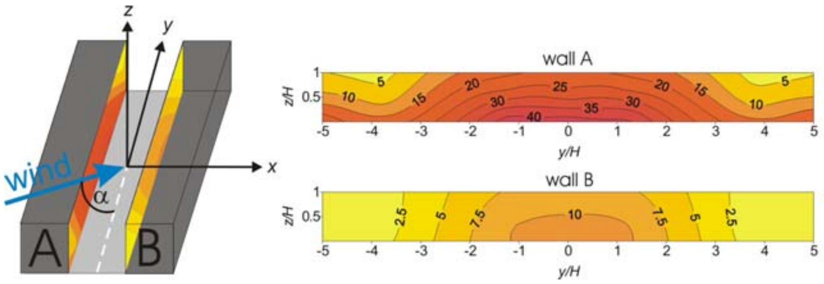
- W/H is the aspect ratio (street width to building height); W/H is either 1 or 2
- α is the angle of approaching wind; α is either 90° or 45° or 0° (perpendicular, oblique, parallel to the street axis, see Figure 3)
- ρ_{ts} is the tree stand density; ρ_{ts} is either 0.0 or 0.5 or 1.0 (tree-free, every 2nd lattice cage cell filled, every cell filled with wadding material, see Figure 1 (right)
- λ is the pressure loss coefficient of the tree crown; λ is either 80 Pa/(Pa m) or 200 80 Pa/(Pa m) corresponding to P_{Vol} = 97.5% or P_{Vol} = 96.0% (Gromke 2011, Gromke and Ruck 2012)
- wall is the name of the wall; wall is either A or B

An overview of the included street-canyon/tree-avenue configurations is given in Table 1.

Table 1. Street-canyon/tree-avenue configurations contained in CODASC

	α [°]	**0**		**45**		**90**	
	W/H [m m^{-1}]	**1**	**2**	**1**	**2**	**1**	**2**
tree-free		x	x	x	x	x	x
ρ_{ts} = 0.5 [-]	λ = 80 (P_{Vol} = 97.5%)	x	-	x	x	x	x
	λ = 200 (P_{Vol} = 96.0%)	x	x	x	x	x	x
ρ_{ts} = 1.0 [-]	λ = 80 (P_{Vol} = 97.5%)	x	-	x	x	x	x
	λ = 200 (P_{Vol} = 96.0%)	x	x	x	x	x	x

Each concentration data file contains the concentration data on a regular grid consisting of 700 nodes. The data is in ASCII format (*.txt) and in spreadsheet format (*.xls) available. Each file consists of 3 columns, see Figure 3 (right). The first column contains the normalized along street-axis coordinate (y/H), the second the normalized vertical coordinate (z/H) and the normalized concentration c^+ (Eq. 1) in the third column. In addition, concentration contour plots (Figure 3, middle) are provided for each street-canyon/tree-avenue configuration.



y/H	z/H	c+
-5.00	0.00	27.09
-4.90	0.00	26.60
-4.80	0.00	25.96
-4.70	0.00	25.23
-4.60	0.00	24.48
-4.49	0.00	23.73
-4.39	0.00	23.01
-4.29	0.00	22.33
...	...	...
...	...	...

Figure 3. Location of the coordinate system with the angle of approaching wind α (left), sample-contour plot of normalized concentrations c^+ (middle), and structure of the concentration data files (right).

PAST AND PRESENT UTILIZATION OF CODASC

Since its establishment in 2008, the CODASC database has been served in several CFD studies of pollutant dispersion in urban street canyons (tree-free or with tree-avenues) for the purpose of model validation and assessment. A list of those studies is given below:

- Gromke et al. (2008): FLUENT, steady-state RANS (k-ε + RSM), α = 90°, W/H = 1, tree-free + one row of tree-avenue, (RANS: Reynolds-averaged Navier Stokes, RSM: Reynolds Stress Model)
- Balczó et al. (2009): MISCAM, steady-state RANS (k-ε), α = 90°, W/H = 1, tree-free + one row of tree-avenue
- Buccolieri et al. (2009): FLUENT, steady-state RANS (RSM), α = 90°, W/H = 2, tree-free + two rows tree-avenues
- Salim et al. (2011a): FLUENT, steady-state RANS (k-ε + RSM) + LES, α = 90°, W/H = 1, tree-free
- Salim et al. (2011b): FLUENT, steady-state RANS (k-ε + RSM) + LES, α = 90°, W/H = 1, one row of tree-avenue
- Buccolieri et al. (2011): FLUENT, steady-state RANS (RSM), α = 45°, W/H = 2, tree-free + two rows of tree-avenues
- Moonen et al. (2011): FLUENT, LES, α = 90°, W/H = 1, tree-free + one row of tree-avenue
- Baik et al. (2012): unsteady RANS (RNG k-ε), α = 90°, W/H = 1, assess effects of air cooling by roof greening on flow and pollutant dispersion in street canyon

CONCLUSION

The CODASC database (CODASC 2008) provides wind-tunnel dispersion data for validation purposes for urban air quality modelling. CODASC differs from other dispersion studies in that it also provides concentration data for street canyons with tree-avenues and for various wind directions. The inclusion of tree-avenues and the careful investigation of different wind directions are indispensable for reliable urban air quality investigations since pollutant concentrations can be considerably higher than in the standard case, i.e. in the tree-free street canyon subjected to a perpendicular approaching wind.

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