Active reduction of air pollutant concentrations at an urban square
Introduction – urban squares

Urban squares
- Important functions in urban life
- Often high car traffic in neighbouring streets
- Influence of vegetation not negligible

József Nádor Square, Budapest
Schlick Square, Vienna
Havlíček Square, Prague
Fitzwilliam Square, Dublin
unnamed squares, „Michel-Stadt”
• high traffic density on the northern side (36 000 veh./day)
• NO$_x$, NO$_2$, PM$_{10}$ concentrations exceed limits by 50-100%
• underground car park planned (for 500 cars)
• How to avoid further growth of pollutant concentrations?
Part I
- CFD simulation of the actual square geometry
- Comparison to on-site measurement data

Part II
- CFD simulation of the simplified square geometry
- Comparison to wind tunnel data

Part III
- Concept to reduce local air pollution using the powerful ventilation system of the car park
Part I: actual square geometry

- Emission calculations based on HBEFA 2.1 and Hungarian vehicle fleet data (2006 and 2010)
- Background concentrations from background stations and ADMS-Urban results (2006)
- MISKAM 5.01 microscale flow and dispersion model:
  - RANS with modified K-ε, staggered grid, Eulerian dispersion (Eichhorn et al.)
- Vegetation modelled as porosity, modified eqs. for momentum and turbulence
- Simulations for 8 wind directions
- Annual mean NO\textsubscript{x} concentration predictions (2006 and 2010)
Part I: CFD results

NO\textsubscript{x} annual mean 2006
(limit: 70 \(\mu\text{g/m}^3\))
Part I : CFD results

NO$_x$ annual mean 2010 (limit : 70 $\mu$g/m$^3$)

- Improvement due to car fleet renewal
Part I: comparison to on-site data

Possible error sources of the simulation

- No traffic induced turbulence – overest. at 0 deg
- Wind measurements 2 km away – peak shift at 270 deg
Part I: comparison to on-site data
Part II: simplified square model

- Test in 0.5 x 0.5m test section wind tunnel
- Simplified block model H = 30 m
- 1:650 scale

\[ \frac{W}{B} = 0.3 \]
\[ \frac{H}{W} = 2 \]
Identified flow features at North wind
(based on LDV measurement and CFD)

Separation zones

– over the first building row,
– near the side buildings
– behind the upwind center building
Identified flow features at North wind (based on LDV measurement and CFD)

- Horse shoe vortex around the downstream center building block
- Outflow in the perpendicular side streets due to the horse shoe vortex
Part II: simplified square model

Normalized concentrations at ground level

- Wake of upwind building decreases concentrations
- Simulation underpredicts concentrations near the source
Original traffic situation at the square
Situation with new underground car park:

- Car entry and exit through ramps | ventilation capacity: 100,000 m³/h
- Concept 1: Inlet and exhaust of air at ground level

⇒ further increase of local concentrations, concept not acceptable
Situation with new underground car park:

- Concept 2:
  - Air inlet through exit ramps
  - Release above rooftop level (za. 30m)
Part III: ventilation concept of the car park

- Car entry and exit through ramps | ventilation capacity: 100,000 m$^3$/h
- Concept 1: Inlet and exhaust of air at ground level
- Concept 2:
  - Air inlet through exit ramps
  - Release above rooftop level (za. 30m)
Part III: ventilation concept

Flow field at the garage ramps

Flow and concentration field at the stack

Ventilation stack realization
Reduction of pollutant concentrations
Reduction of pollutant concentrations

2010 | without car park

2010 | with car park
Reduction of pollutant concentrations

Average annual mean concentration decrease in 10 selected locations on the square: 3-4 % on average.
Remarks

• This concentration reduction method only works because of:
  – available ventilation capacity of the car park
  – closed environment of the square

To do:
• check the effect of polluted air removal in wind tunnel
• Generalize findings for urban squares
Thank you for your attention!