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## **Urban pollution and indoor air quality, an undisputed relationship: CFD modelling of single-sided pollutant ingress**

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### **Abstract**

This study simulates near-field pollutant dispersion and subsequent ingress into building envelopes within urban street canyons via computational fluid dynamics (CFD). Qualitative pollutant dispersal experiments conducted in wind tunnels are compared against numerical simulation.

Two street-canyon aspect ratios were investigated (Height/Width=0.5 & 1). Roof angles were investigated (flat and 26.6°). An open window was located on the on the leeward side connecting to an interior room. ANSYS Fluent 15 was used to model airflow and employed a k-omega turbulence model. CO<sub>2</sub> tracer was released between the buildings and concentrations were measured inside the open window.

Increasing canyon width reduced the residence time of pollutant and reduces ingress. Flat roofs for both ratios drew CO<sub>2</sub> to the leeward side of the building due to negative pressures. However pitched roofs created more complex systems that reduced contaminant in the canyon due to unsteady vortices. This may indicate a decrease in vertical exchange due to intermittent turbulent structures which maintain overall mass transfer with the air above.

### **INTRODUCTION**

The importance of urban airflow on indoor ventilation is an area of crucial but challenging research. Current building design, driven by carbon reduction policies, strives to maintain equilibrium conditions indoors regardless of the changing urban microclimate outside. This energy-centric approach however may lead to short term sustainability gains but occupants opening a window “just to get some air” due to poor indoor air environments may lead to long term health and energy costs (Sundell et al., 2011). Understanding how pollutants ingress into buildings through single sided natural ventilation is important in getting a handle on indoor environment quality.

### **METHODOLOGY**

CFD package ANSYS Fluent 15 was used to investigate CO<sub>2</sub> dispersion in and around 3D street-canyons (Fig 1). Four cases similar to Barlow et al. (Barlow & Leidl, 2007) were studied in a domain of 120mx24mx30m: Aspect ratios (Height/Width=0.5 and 1) and two roof angles (flat and 26.6°) were chosen. Building height was 5m from ground to eaves in both cases. An open window (1mx0.5m) was positioned on the leeward façade of the second row of buildings. The atmospheric boundary layer profile was modelled with a reference velocity of 6m/s at eave height. Pressure-Outlet conditions were 0Pa. CO<sub>2</sub> was released continuously from a volume source at ground level in the second street canyon and relative concentration was measured inside the building. Mesh cell count was 3.5 million approximately after mesh sensitivity analysis. The k-omega SST turbulence closure with standard wall-functions was solved via the SIMPLE algorithm with second order accuracy for all variables under steady state. Three vortex generators (1m high) were introduced upwind of the canyons. Results were considered converged when continuity residuals reached 1E-6 for 100 iterations.

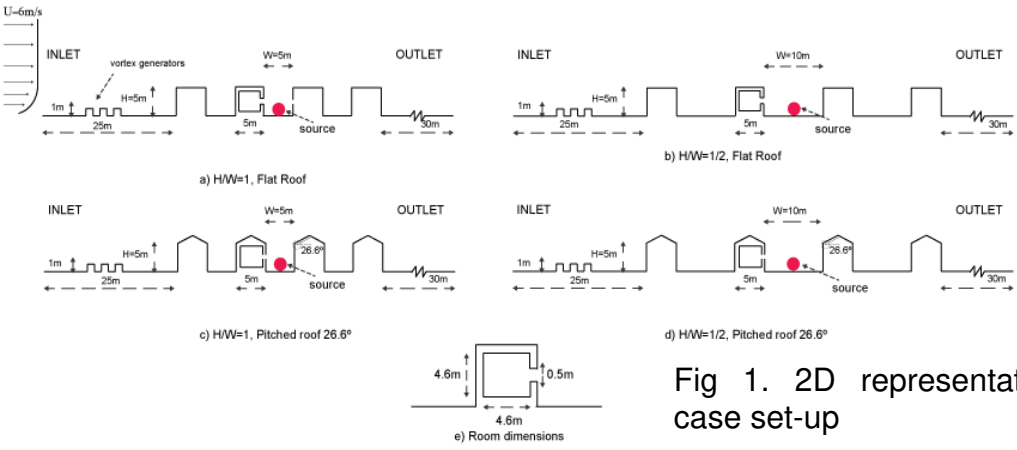


Fig 1. 2D representation of case set-up

**RESULTS AND DISCUSSION**

Figures 2 & 3 show contour plots of relative contaminant concentration in the four cases throughout the central vertical plane of the second canyon. Experimental images are from Barlow and Leidl (2007).

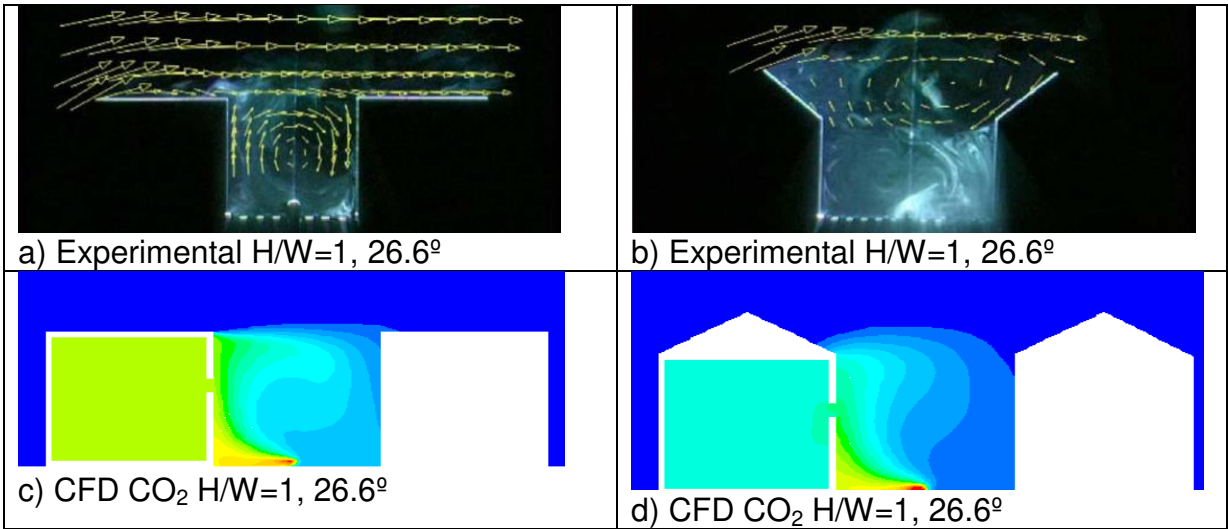


Fig 2. Relative concentration of contaminant

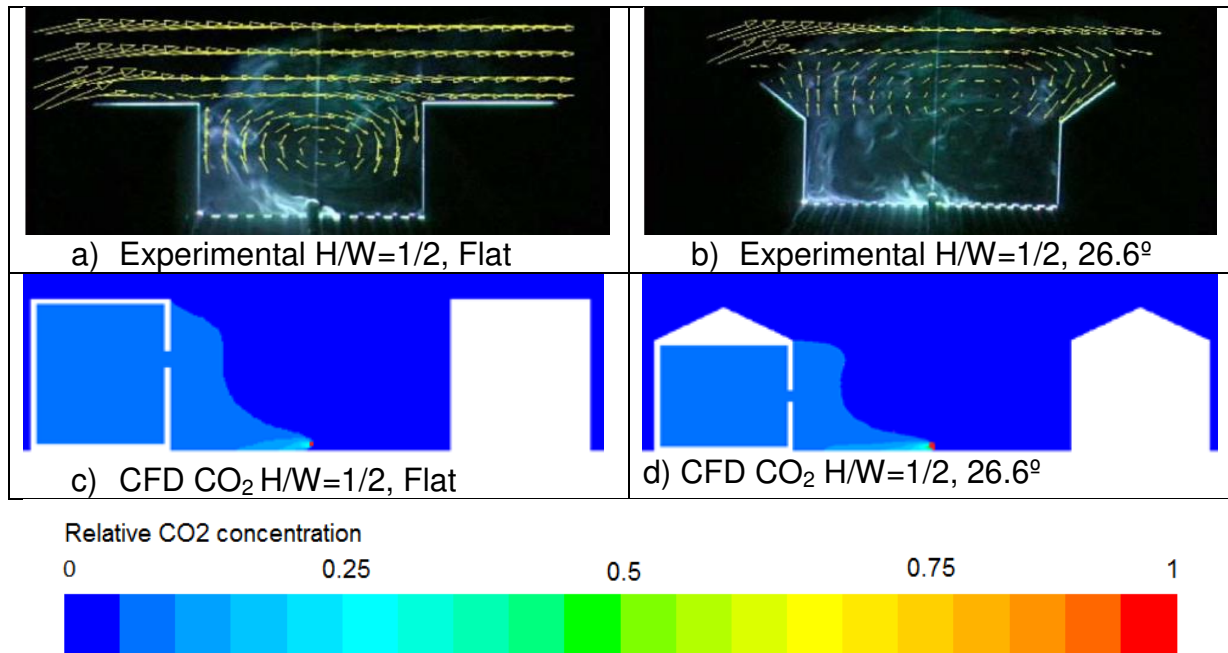


Fig 3 Experimental and CFD relative contaminant concentrations

Table 1 presents the average relative CO<sub>2</sub> concentration inside the space behind the open window compared to the average in the space between the buildings from CFD.

Building height (H)/canyon width (W)	H/W=1		H/W=1/2	
	Flat	26.6°	Flat	26.6°
Relative CO <sub>2</sub> conc. %	54%	37%	34%	28%

Table 1 Relative CO<sub>2</sub> concentrations for different configurations

Increasing canyon width reduced the residence time of pollutant and decreases ingress. Flat roofs for both ratios drew CO<sub>2</sub> to the leeward side of the building due to negative pressures. However pitched roofs created more complex systems that reduced contaminant in the canyon due to unsteady vortices. This may indicate a decrease in vertical exchange due to intermittent turbulent structures which maintain overall mass transfer with the air above.

## CONCLUSION

Pollution is found to be entrained by the turbulent eddies close to the leeward side of the buildings in all cases but predominantly within narrower canyons. Pitched roofs with wide canyons improve pollutant dispersal due to turbulent detachment at the apex. This has a result of increasing the height of the recirculation zones and decreasing ingress into the building envelope.

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