# Chapter 33
# Validation of Cross-Ventilation Flow in a Realistic Building Geometry

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**Abstract** Wind tunnel (WT) measurements for the validation of computational fluid dynamics (CFD) are essential to enable an accurate numerical assessment of complex indoor airflows in naturally-ventilated buildings. However, there is a lack of WT studies that employ realistic building geometries. The objective of this study is the validation of 3D steady Reynolds-averaged Navier–Stokes (RANS) simulations and scale-adaptive simulation (SAS) of cross-ventilation in a realistic building geometry using WT experiments. Therefore, velocities were measured in and around a cross-ventilated realistic building model with internal partitions by means of laser Doppler anemometry (LDA). The steady RANS simulations were conducted with the RLZ $k$-$\varepsilon$ and SST $k$-$\omega$ turbulence models, whereas SAS was performed with the SST $k$-$\omega$ model. This study showed that the SAS significantly outperforms the steady RANS simulations.

**Keywords** Cross-ventilation · Realistic building model · Wind tunnel measurements · CFD · SAS

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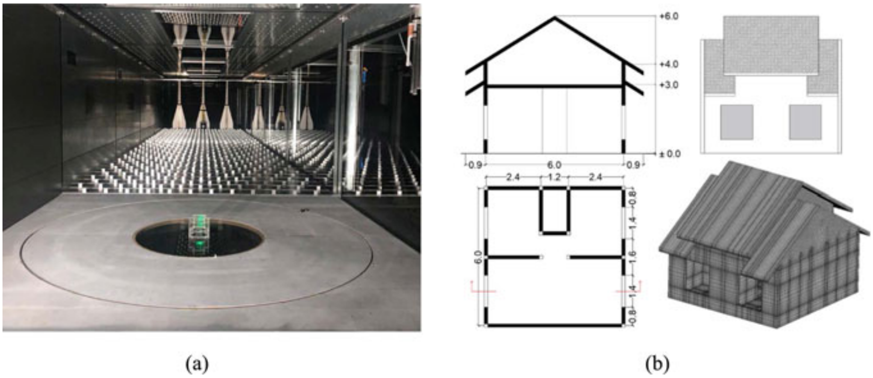


**Fig. 33.1** **a** Experimental setup in WT. **b** Building geometry in full-scale, dimensions in m; and computational grid on the building

## 33.1 Introduction

Cross-ventilation is an important passive method for improving indoor air quality and thermal comfort and for saving energy in buildings (Liddament 1996). As wind is turbulent in nature, the flow field inside a building with cross-ventilation and internal partition is very complex. In residential buildings, internal partitions are used to separate building internal spaces for utility purposes. Cross-ventilation could be significantly affected by the presence and layout of the internal partition. To enable an accurate numerical assessment of complex indoor airflows in cross-ventilated buildings, CFD simulations have been used in many studies (Blocken 2014). Last decades, a range of CFD validation studies were conducted for cross ventilation using WT data of airflow in simplified (nearly) cubical enclosures. However, there is a lack of WT studies focused on realistic buildings with inclusion of critical geometrical features such as pitched roof, internal partition, doors, ceiling to validate the CFD simulations. This study presents a validation study of 3D steady RANS and SAS simulations (e.g. (Egorov et al. 2010)) of cross-ventilation in a realistic building geometry with partition using WT data (Fig. 33.1). The building model represents a typical single-story residential building.

## 33.2 Methods

WT experiments were performed in the closed-circuit atmospheric boundary layer (ABL) WT facility at Eindhoven University of Technology, employing a geometrical scale of 1:40 for building model and ABL approach flow conditions. The wind tunnel setup is shown in Fig. 1a. Horizontal velocity components *u*-*v* (*x*–*y*) in and around the building model were measured with LDA. The approach flow reference wind velocity ($U_{ref}$) was measured at the height of the center of the window. The CFD simulations were performed on a grid resulting from a grid-sensitivity analysis. It has a total of 2,684,888 hexahedral cells. Figure 1b shows the full-scale building geometry and the computational grid on the building. The same grid was used for both the RANS and SAS simulations. The RANS simulations were conducted with the realizable $k$-$\varepsilon$ (RLZ) and SST $k$-$\omega$ turbulence models. The SIMPLE algorithm was used for pressure–velocity coupling, pressure interpolation with second-order discretization schemes. The SAS was performed with the SST $k$-$\omega$ model. Pressure–velocity coupling with PISO and time discretization with a bounded second-order scheme. The time step ($\Delta t$) was calculated based on a maximum CFL number of 1 and was equal to $\Delta t = 0.0001$ s.

## 33.3 Results and Discussion

A comparison of dimensionless mean streamwise-velocities ($U/U_{ref}$) obtained from the WT experiment and CFD simulations (SST $k$-$\omega$, RLZ $k$-$\varepsilon$ and SAS) along two horizontal lines is shown in Fig. 33.2. The comparison along these two lines shows in general a good agreement between the experimental data and the results from the CFD simulations. The mean velocity is more accurately reproduced by SAS than by RANS. The results for the majority of the measurement locations fall within a deviation of 40% for the RANS simulations, whereas for SAS most of the points fall within a deviation of 30% from the experimental results. Note that the largest relative deviations occur in the low-velocity regions and that the deviation at many locations is thus smaller than the aforementioned values. The validation metrics (FAC1.5, NMSE) shown in Table 33.1 indicate that SAS shows indeed the best performance for the two lines considered in Fig. 33.2.

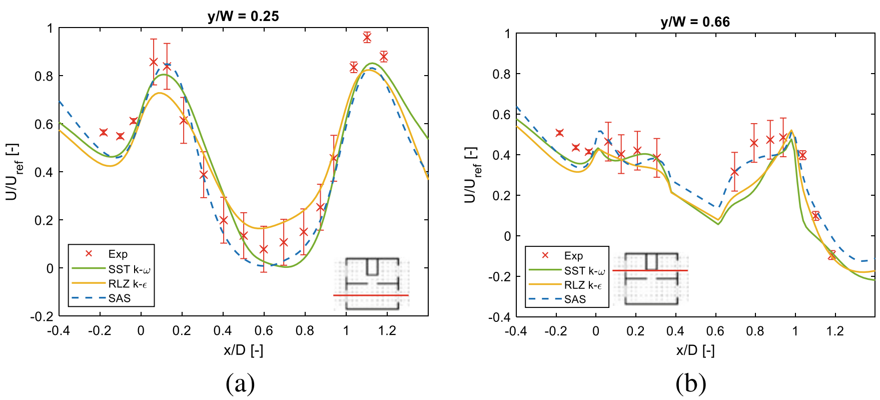


**Fig. 33.2** **a** Building geometry in full-scale, dimensions in meter. **b** $U/U_{ref}$ from experiment and CFD

**Table 33.1** Validation metrics for dimensionless mean streamwise-velocity ($U/U_{\mathrm{ref}}$)

| Turbulence models | FAC1.5 | NMSE |
|---|---|---|
| SST | 0.7097 | 0.0725 |
| RLZ | 0.7742 | 0.0582 |
| *SAS* | *0.8387* | *0.0362* |
| Ideal value | **1** | **0** |

## 33.4 Conclusions

The comparison of mean velocities obtained from the WT experiment and CFD simulations shows that the SAS simulations significantly outperform the steady RANS results.

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