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CFD of cross-flow ventilation of a full-scale cubical building using a time-dependent k- ω SST SAS turbulence model

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SUMMARY

Experimentally measured ventilation rates in the Silsoe cube under cross-flow ventilation configurations are compared with computational fluid dynamics (CFD) simulations conducted in ANSYS Fluent using a hybrid RANS-LES k-ω SST SAS turbulence model. Eight wind directions are studied with the cube in a) isolation and in b) a new staggered nine cube array format. Relationships between air change rate and wind angle were much weaker in the array cases. Turbulent structures close to windows improve mixing in the array case.

KEYWORDS

CFD; Silsoe; benchmark; cross-flow ventilation; indoor air quality

1 INTRODUCTION

The importance of airflow on indoor ventilation is an area of crucial but challenging research. The Silsoe cube is a 6x6x6m hollow metallic cube, located in open countryside and is a well-known example of an idealised experimental scenario which has been used for wind engineering research since the early 1990s (Hoxey and Richards, 1993). Simulating natural ventilated buildings though CFD has been notoriously difficult. This research compares CFD simulations of a new configuration of Silsoe cubes (isolated and in an array configuration) under cross-flow ventilation and eight wind angles (see Figure 1).

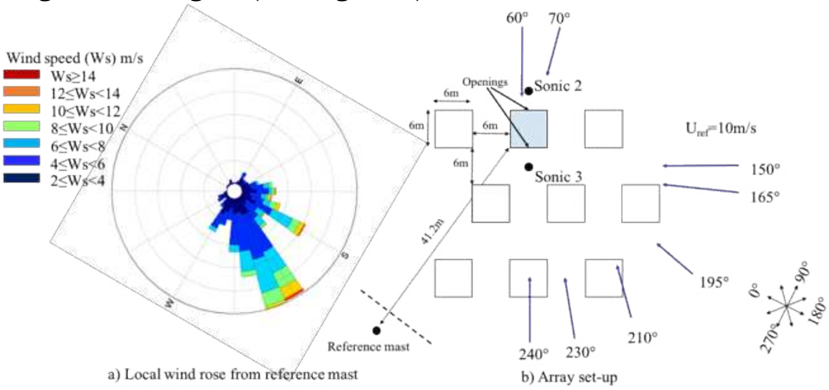

Figure 1 Schematic of Silsoe cube layout

2 METHODS

New experiments have been carried out to investigate the effect of cross-flow ventilation on façade pressures and indoor air ventilation rates at different wind angles. This was configured to include two 0.4m wide by 1m high removable windows half way up opposite sides. Ventilation rates were calculated through pressure differences between the external and internal cube face, measured by thirty external and two internal pressure taps.

CFD simulations using ANSYS Fluent were carried out for two full-scale geometries: Case a) isolated cube and Case b) nine cube array. In both cases a scale adaptive simulation (SAS) k-ω

SST turbulence closure was solved via the PISO algorithm with bounded second order accuracy for all variables. The inlet atmospheric boundary layer profile was modelled logarithmically as in Richards and Hoxey with a reference velocity (U_{ref}) of 10m/s at eve height. Outlet conditions were 0Pa pressure in both cases. Domain size was 3building heights (H)x10Hx3H. Meshes were created of entirely hexahedral cells with clustering of cells around the cubes and windows. Cell count for Case a) and Case b) was in the region of 1.5 million and 18 million cells respectively. Convergence was considered achieved when mean pressure at two façade centre surface points on the cube front stabilized.

3 RESULTS

For all configurations tested, two distinct indoor flow regimes were found: quasi-impinging jet and recirculation. Figure 2 shows the normalised ventilation rate for both configurations.

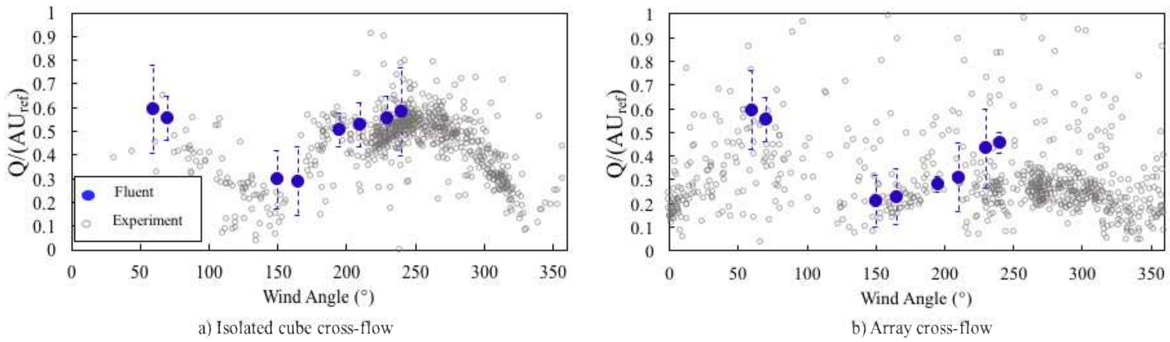

Figure 2 Normalised ventilation rate through the Silsoe cube

4 DISCUSSION

The k-ω SST SAS turbulence model performs well in these circumstances. Good comparison is found for isolated cases with a clear peak in experimental normalized ventilation rates appearing where windows are facing the wind (240°). Similar trends are not quite so obvious in an array configuration meaning that upwind cubes may complicate ventilation predictions. A relationship between wind angle and ventilation rate can be seen for the isolated case for both window configurations but is less clear in the array. A possible explanation may be due to the vortex shedding of downwind cubes causing airflow to be more of a pulsatile nature, whereby averaged ventilation rates may not reflect this. As a result, future simulations must take this into considerations and a different ventilation metric may need to be developed.

5 CONCLUSIONS

The k-ω SAS model shows to be a suitable approach to simulating flow features present within building arrays and enabling external-internal flow coupling.

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6 REFERENCES

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