107 Simulated Performance of Windcatchers in an Urban Environment

Tomas Elizalde [1,2], Dejan Mumovic [1]

[1] UCL, London, UK

tes@phaconsult.com
[2] PHA Consult, London, UK

Abstract

There is an increasing interest in passive design of buildings, and natural ventilation has proved to be the most efficient low-energy cooling technique. However, the complex relationship between the building and its urban environment is not understood well, and this contributes to underperformance of state of the art ventilation systems in naturally ventilated buildings. This paper aims to improve our understanding of the effect of the urban canyons on simulated performance of windcatchers. The analysis has been carried out using a two step CFD modelling approach, computing urban canyon airflow driven by the combined forces of wind and thermal buoyancy and its subsequent effect on a set of enclosures set within two buildings surrounding this space.

It has been shown that the steady state ventilation of the studied system changes dramatically, both in terms of the thermal stratification and air-flow rate, when placed within various confines simulating spaces within two buildings in an urban canyon. Furthermore, it is found that at high wind speeds, the performance of the windcatchers is better in top storey spaces, where flue length is minimised. High façade pressures emerge as a result of urban canyon airflow, and give rise to induced higher air change rates for the top storey windward spaces whilst observing a reduction in thermal stratification and air stagnation.

Keywords: Natural Ventilation

1. Introduction

The aim of the study is to assess the effect of canyon flow on the performance of Windcatchers with regard to the ventilation pattern and temperature structure inside a set of enclosures serviced by this technology. Subsequently, determining the suitability of windcatchers as a means of providing good indoor quality and thermal comfort levels to spaces in an urban environment. In this simulation, natural ventilation is aided by the Monodraught Ltd. windcatcher system, and its performance is assessed under various configurations.

This is achieved by analysing the ventilation rate, ventilation pattern, and temperature structure displayed in a series of models simulated using computer fluid dynamics. As a result, this study offers particular insight into the efficiency of natural ventilation systems such as Monodraught's windcatcher to improve air quality, by taking a closer look at air dispersion and mixing quality, determinants of air freshness; and heat exhaustion, by analysing the temperature structure in the internal space.

The novelty of the work lies in the depth of analysis featured in this study, regarding the temperature structure and especially the ventilation pattern, taking into account, that such are directly affected by the airflow occurring in a comparatively larger external space, induced by the conditions defined by urban canyon flow. A two step simulation allows the two spaces to be associated, and additionally, allows for a more precise analysis of each. This is a common method in research led computational fluent dynamics. However, the research possibilities within the area of urban canyon flow and its effect on the ventilation of small enclosures serviced by innovative natural ventilation systems such as Monodraught's windcatcher, are yet to be exploited. Although there are studies that link natural ventilation potential and urban canyon flow, they do not assess the specific performance of windcatchers within this setting, and the opportunities for natural ventilation they present as a result.

2. Method

The performance of windcatchers and natural ventilation modes imposed on various scenarios is investigated under a variety of conditions. These scenarios are a simulation of typically large rooms, such as office spaces, situated in buildings within an urban canyon. The scenarios are situated at different storey heights within these two buildings forming the canyon. Two windcatchers per scenario will be connected to the rooms via a flue, of varying length as a result of storey height. Furthermore, these rooms undergo two tests: under the effects of infiltration as a result of air leakage through windows; and under the effects of the opening of these windows.

The investigation requires two models. An external scenario with natural boundary conditions such as a natural temperature gradient and an urban wind speed profile includes two masses forming an urban canyon within.

The second set of models are set within the buildings in this canyon and are composed of one room, it's facade, windcatcher and flue. These models simulate Top, Middle, and Ground floor Upstream and Downstream cases.

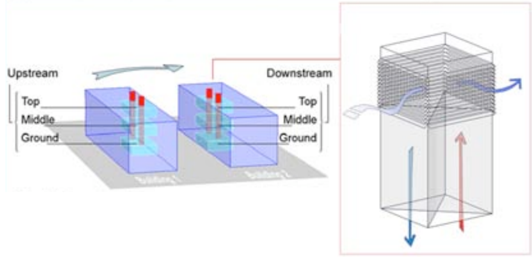

Fig 1. Model Construction and Windcatcher

The results obtained from the external urban canyon model form the boundary conditions of the internal models situated within the former. This association works by recording air pressure, wind speed, and direction, acting on the facades and windcatcher of the external urban canyon model. These are then applied to the conditions and surfaces of each individual internal model.

2.1 Calibration

To validate the results, both models are calibrated. Verification of adequate flow within the internal model is measured through analysis of the post-processing data as shown in Figure 2. This is compared to the data in the validation database which is composed of results obtained by the BRE in a life-size experiment of an enclosure of identical properties[1].

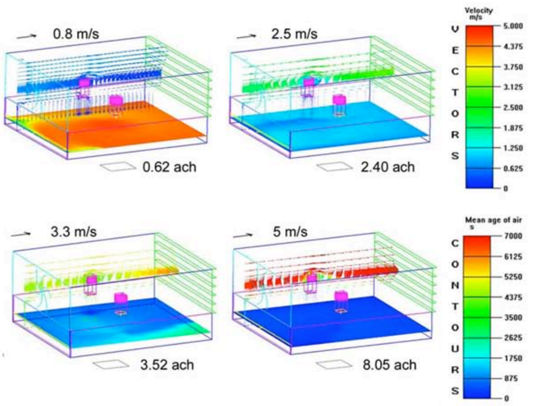

Fig 2. Calibration of the internal space

The external model is adjusted to emulate urban canyon flow at the three different analysis conditions (1, 3, and 6 m/s winds) in line with the results obtained by similar studies[2,3].

3. Results

Results in Figure 3 show ACH per scenario per condition (infiltration or open windows) for different wind speeds. The higher the wind speed, the higher the façade pressures and during infiltration conditions, top storey spaces show higher ACH. When windows are opened inlet air volumes increase and the buoyancy effect results in higher ACH for the ground scenarios, using the windcatcher flues as exhaust.

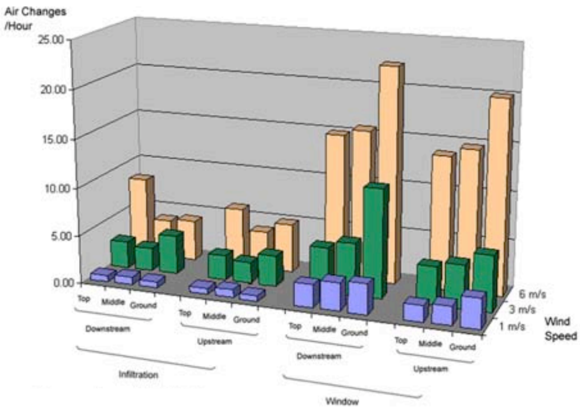

Fig 3. Resultant ACH achieved by each scenario

The quality of mixing and thermal stratification are judged of equal importance. Therefore natural ventilation performance is assessed according to a score measuring air changes per hour and the mean age of the oldest air pockets in the room. Scenarios with high ACH combined with smaller pockets of aged air (or low stagnation) score highest.

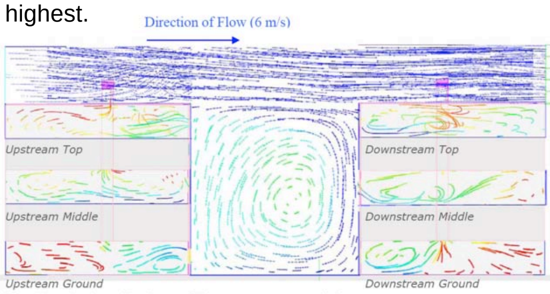

Fig 4. Combined Visualisation of the two-step models

4. Conclusion

The results show that higher ACH do not necessarily lead to better mixing quality. It follows that spaces that achieve high ACH such as ground floor scenarios under open window conditions, suffer considerably as a result of the poor mixing that ensues due to large pockets of stale air forming towards the end of the room. In contrast, top scenarios display a more efficient use of the inner workings of the windcatcher and combined with high facade pressures score higher with regard to overall natural ventilation performance.

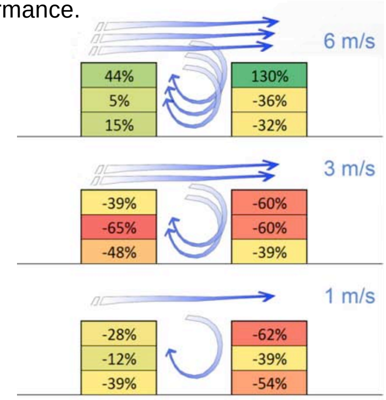

Fig 5. Combined "Open Window" and "Infiltration" mode conditions scoring for each scenario (% improvement over basecase)

5. Acknowledgements

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6. References

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