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**Poster 30**

**Air Flow In A Cavity Wall**

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## ABSTRACT

The external facade of a nine storey office building has been reclad with a ventilated cavity structure with a length to height ratio greater than forty. As there is little published information regarding the likely air flows within such cavities a research programme has been set-up to investigate the ventilation and energy performance of this structure. This paper will address the cavity air flows through both theoretical and full scale measurements.

Theoretical predictions were calculated using the COMIS infiltration simulation programme utilising different pressure profiles from around the building. A detailed wind tunnel study [1] was carried out prior to this in order to obtain accurate wind pressure distribution profiles for the building.

The experimental measurements were carried out on the cavity wall structure on the second (west facing) floor of the building. Using a $N_2O$ tracer gas detector system, the flow velocity and the air flow volume were deduced from the measurements and compared with the theoretical prediction. The comparison of the two sets of results show good agreement, considering the varying wind and temperature conditions which are difficult to simulate. The maximum difference between the calculated and the predicted airflows, for the tests carried out is in the range of 30 %.

Air flow pattern and mixing of the tracer gas were demonstrated using a 2.44 metre long segment of the wall structure under laboratory conditions.

## INTRODUCTION

As part of the updating policy of the University of Sheffield the external facade of a nine storey office building has been reclad with a ventilated cavity wall structure. This recladding was to prevent deterioration of the building due to moisture penetration through the original glass curtain wall cladding. The cavity on each floor on the west and the east facades measures 1.2 metre in height and extends 46 metres along the length of the building. The new cavity wall structure consists of a brick layer, an air cavity of 10 cm followed by 5 cm of cavity insulation and the original concrete structure with plaster on the inside wall of the building. To prevent moisture built-up and condensation problems, 98 weep hole devices were installed along the wall to ventilate the cavity. As little can be found in the literature on the performance of these weep hole devices a pressurisation test to determine the "crack" flow characteristics of the weep hole device was carried out. The coefficients were calculated from a standard statistical package using the measured data and found to be $k1=0.00015329$ and $k2=0.4105174$. Using this data the occurring airflows in the cavity due to wind pressure difference in and around the wall structure were investigated using COMIS.

The pressure profiles used as input data to the model were obtained from a detailed wind tunnel study of the building within its surroundings [1].

## THEORETICAL PREDICTIONS

To calculate the air flow in the ventilated cavity the infiltration simulation programme COMIS was used. The infiltration modelling programme COMIS was developed as a multizone model on a modular base. COMIS can be used as a stand alone infiltration model with input and output features or as an infiltration module for thermal building simulation programmes[2,3]. The two parts of the COMIS programme used for this work were the COMIN and COMVEN programme routines. The input file was created using the COMIN programme entering all the available data of the wall structure necessary to perform the simulation. These specific input data are described in table 1 below:

Table 1: COMIS input values

| Description | Input values |
|---|---|
| Wind speed | 3,7,10,15 [m/s] |
| Cavity volume per zone | 0.2326 [m^3] |
| Weep hole devices zone 1,25 | bottom 1 per zone |
| Weep hole devices zone 2-24 | bottom 2 per zone |
| Weep hole devices zone 1-25 | top 2 per zone |
| Cavity temperature | 20 deg C |
| Crack temperature | 20 deg C |
| Outside temperature | -10 and 20 deg C |
| Cp-values | from wind tunnel study [1] |
| Crack flow characteristics | from de-pressurisation test<br>k1=0.00015329<br>k2=0.4105174 |

The wind pressure coefficients chosen from the wind tunnel study characterise wind from the north-west. Calculations using the COMVEN programme were only carried out for the 2$^{nd}$ floor on the west facing facade. The overall air flow from zone to zone and the contribution of each weep hole device to that air flow was calculated.
The results for the 4 different wind speeds are presented in figures 1.

Theoretical Airflow

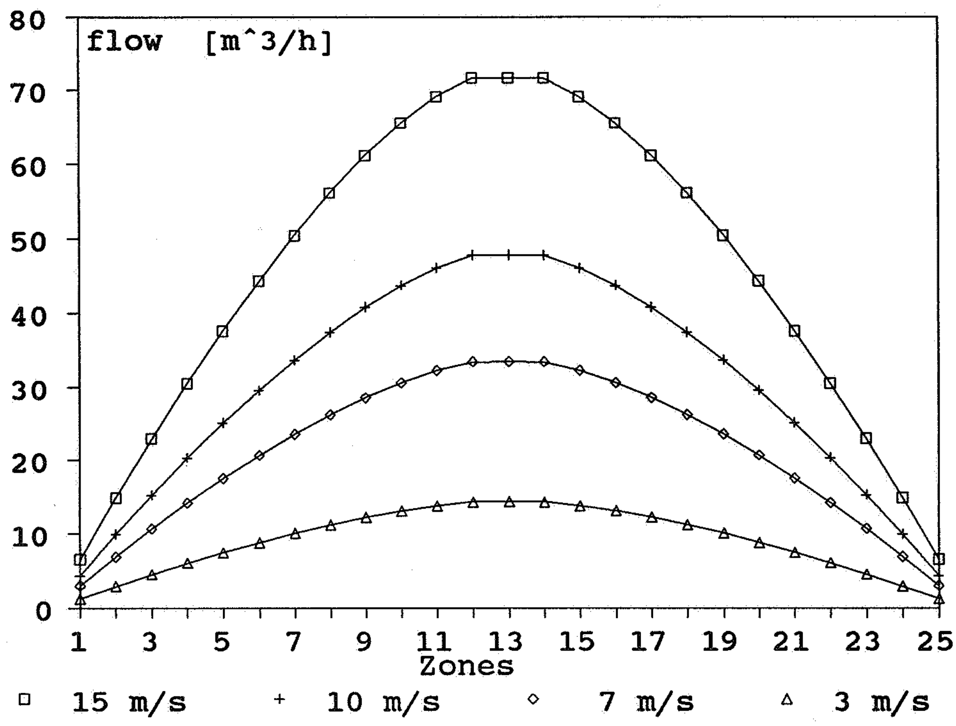


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Figure 1: Theoretical predictions of air flow at various wind speeds

## LABORATORY TESTS

To be able to control the ambient conditions during the experiments, a segment of the wall, 2.44 metre in length, was built in the laboratory. The wall segment has four built-in weep hole devices, of which two were covered with flow hoods connected to a pressurisation system used to simulate the in-going air flow. The air flow was measured with a standard 40 mm orifice plate. For the experiments carried out, the tracer gas was injected at a constant flow rate either into the top or the bottom flow hood. Eighteen sampling points were used to trace the flow occurring in the cavity due to the imposed flow. Where using tracer gases to determine the flow between zones, it is essential to reach a homogeneous mixture of the gases with the air anywhere in the zone, otherwise significant errors may arise [4]. The following experiments were conducted to show that reasonable mixing occurs in the cavity. For the first test the gas was injected into the top weep hole device. The injected gas concentration was first measured directly behind the inlet. After 10 minutes, allowing for the flow patterns to stabilise, the 18 sample points were connected, one after the other, to the gas analyser. The sampling time at each point was two minutes and 30 seconds. Between the two tests the cavity was flushed with fresh air to eliminate gas pockets that might have accumulated in corners of the laboratory set-up during the previous test. The imposed air flow and the $N_2O$ gas flow were kept at a constant rate of 94 L/min and 0.5 L/min respectively. The procedure for

the second test was similar, however the gas was injected in the bottom weep hole flow hood.
The results of the two tests performed show that the top and the bottom weep hole devices in this wall configuration create slightly different flow patterns. Due to the constant supply of tracer gas stable flow patterns should build-up at the 18 sampling points (figure 2) giving information of these two flow patterns.

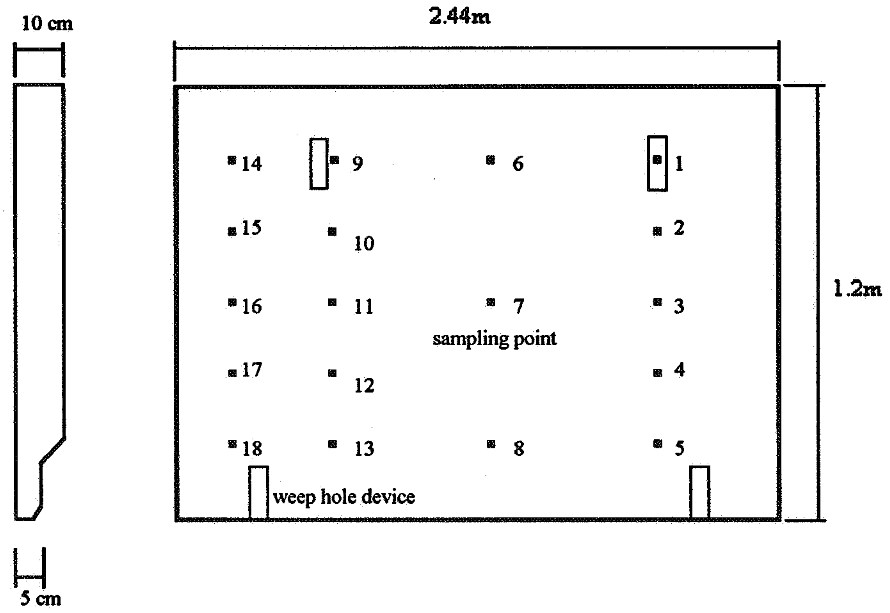

Figure 2: Sampling points in the laboratory wall segment

For the first test (figure 3), with the tracer gas being injected in the top flow hood the tracer gas concentration decreases in the vertical plane from sample point 1 to 5 and 6 to 8. In the horizontal plane the tracer gas concentration decreases from the initial inlet concentration by 25 % at point 6 and stabilises at this value for the remaining sampling points 9 to 18. This result shows that good vertical and horizontal mixing occurs approximately 1 metre from the injection point.
The gas concentrations measured during the second test (figure 4), with the tracer gas being injected in the bottom flow hood, show that only very little of the injected gas flows to the top part of the cavity, represented by sampling points 1,2,6,9,10,14 and 15. However, in the centre of the cavity the gas concentration stabilises at 30 % below the gas concentration measured at the inlet weep hole. This phenomenon can be explained by the different area configuration at the bottom of the cavity wall, where the width of the cavity is only half (figure 2).
Further tests simulating the real situation were carried out on the laboratory set-up to determine the flows. A known constant airflow of 96.95 L/min was imposed on the cavity via the two flow hoods. After the initial waiting period of ten minutes, allowing for the flow pattern to stabilise the tracer gas was injected at a constant rate of 0.5 L/min into the top weep hole device. The aim of this was to measure the travelling time. It took the tracer gas 98.5 sec to travel the distance a 1.25 metre to the second top weep hole

where the sampling tube, connected to the gas analyser was fixed. This corresponds to an average velocity of 0.01269 m/s, resulting in an airflow of 91.4 L/min. This test was carried out several times to show reproducibility and the differences between the imposed flows and the deduced flows were in the range of less than (+-)7% which indicates good agreement.

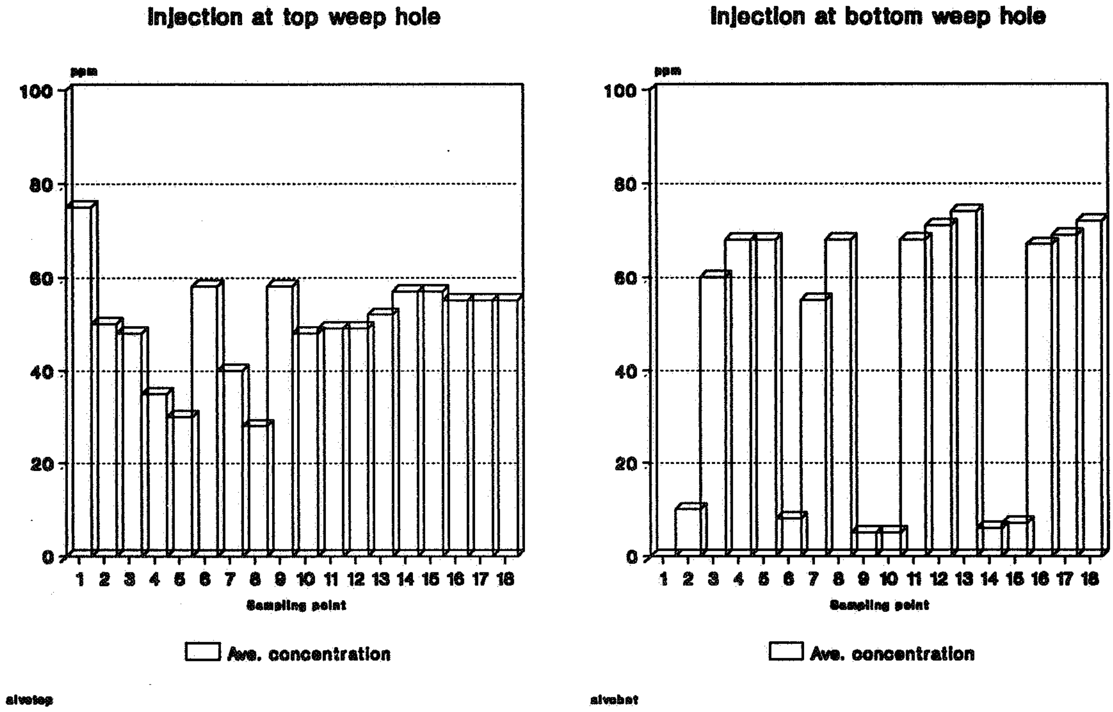


Figure 3 and 4: Average gas concentration measured at the 18 sampling points

## HICKS BUILDING EXPERIMENTS

The procedure for the experiments carried out on the 2nd floor of the building were more complex. First, the wind direction and the wind speed had to be determined in order to predict the flow direction in the cavity according to the wind pressure profiles obtained from the wind tunnel study [1]. The tracer gas was then injected into the top weep hole nearest to the centre, whereas the sampling tube was inserted into the second weep hole into the cavity opposite the centreline of the building. The distance between these two points measured 2.89 m. The aim was to measure the time necessary for the injected tracer gas to travel to the sampling point. Due to the known area configuration of the cavity, the amount of air flow can then be determined.

Several tests with different wind direction and wind velocities to check the technique were carried out. For a calm day with an average wind velocity of 1 m/s the first record of the tracer gas were detected after 3.5 minutes. Five minutes after the start of the tracer gas injection a more reliable record of the gas was detected. The travelling time i.e. the travelling speed of the tracer gas and the known area of the cavity allowed the air flow volume at this point in the cavity to be calculated. The first record of the tracer gas

Building were in good agreement for the cases considered. The maximum difference between the calculated and the measured airflows was up to 30 % which may be explained by the varying wind and temperature conditions during the full scale measurements.
These results show that as the wind speed increases there is better agreement between the measurements and the simulations. This indicates that at low wind speeds convective currents within the cavity may be dominant.

## FUTURE WORK

This paper reported the first step of a research project aimed at investigating the overall thermal and ventilation performance of a ventilated cavity wall structure. Future steps will include the calculation and measurement of the ventilation efficiency, the heat flux through the wall and the moisture behaviour of the wall.
The effect of the airflow on the thermal and moisture behaviour will be investigated in the second part of this project.


## ACKNOWLEDGEMENTS

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would indicate a flow velocity of 0.01376 m/s, the more reliable record, after five minutes results in 0.00963 m/s. These velocities correspond to a deducted air flow of 0.0016512 $m^3/s$ and 0.001156 $m^3/s$ respectively.
Measurements in the cavity, with a wind velocity of 1.5 m/s from the Southwest resulted in an air flow rate of 0.00211 $m^3/s$. With a wind velocity of 4 m/s from the SSW the air flow rate was 0.0029 $m^3/s$.
The highest air flow measured for West wind with a wind velocity of 3.5 m/s and 5 m/s in gusts was 0.0048 $m^3/s$.

## COMPARISON OF THE RESULTS

Considering that the computer simulations were carried out using constant "set" temperatures for the cavity air, the outside air and the crack temperature, as well as the wind direction and wind speed the results from the simulation with the COMIS programme and the measurements on the cavity structure in the Hicks Building compare reasonably well. Table 2 shows the results of the simulations and measurements carried out.

| Table 2: Calculated and measured results | | | | |
|---|---|---|---|---|
| | wind direction | wind velocity | COMIS | measured |
| 1 | calm | < 1 m/s | 0.001645 [$m^3/s$] | 0.00165; 0.00156 [$m^3/s$] |
| 2 | SSW | 4 m/s | 0.00262 [$m^3/s$] | 0.0029 [$m^3/s$] |
| 3 | West | 5 m/s | 0.00473 [$m^3/s$] | 0.0048 [$m^3/s$] |

At a wind speed of 1 m/s using the appropriate wind pressure coefficients the result of the simulation at the centre line of the cavity give an air flow of 0.001645 $m^3/s$. The measurement with the same, but averaged wind velocity give an air flow between 0.0016512 $m^3/s$ and 0.001156 $m^3/s$. The first record of the tracer gas is in good agreement with the prediction. However, the more reliable second record of the tracer gas indicates an airflow being 30 % below the predicted.
The simulation results for the wind direction SSW were calculated for 4 m/s. The resulting airflow in the centre of the building is 0.002622$m^3/s$, which is 10 % less than the deducted airflow from the measurements.
The simulation results for the last test for West wind with a velocity of 4 m/s is 0.00379$m^3/s$ which under predicts. However, the simulation results for a wind velocity of 5 m/s were 0.004738 $m^3/s$ and were in good agreement with the measurement which was 0.0048$m^3/s$.

## CONCLUSION

The results of the laboratory tests show that mixing occurs in this wall configuration suggesting that the tracer gas method adopted to deduct the airflow from the travelling time of the tracer gas in the cavity can be applied on the wall structure.
The comparison of the numerical prediction calculated with COMIS and the tracer gas measurements carried out on the cavity wall structure on the second floor of the Hicks