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A testing time for natural ventilation

The School of the Built Environment at De Montfort University represents the first in a new breed of naturally ventilated buildings. *Bart Stevens* reveals the findings of recent heat-load tests carried out to establish the effectiveness of the building's passive engineering.

The Queens building at De Montfort University, Leicester[1,2] plays host to two auditoria, drawing studios, laboratories and classrooms in one of the largest naturally ventilated structures in Europe.

In order to achieve its aim of being a low energy construction the building incorporates – among other features – high levels of daylighting, a chp unit, a condensing boiler and high efficiency lighting.

However, the main energy saving feature is undoubtedly the extensive use of natural ventilation for cooling purposes.

The natural ventilation strategy is coupled with the high thermal mass of the building and, by naturally ventilating at night, the structure can be cooled down, thus helping to combat heat gains the following day.

Areas of high internal heat gains are connected to chimneys which draw up hot air, creating a stack effect and increasing the natural ventilation air flow through the space.

The building was completed in August 1993, and as part of the construction and commissioning process heat-load tests were carried out in the auditoria to assess the performance of the thermal mass of the building, the natural ventilation system and the controls.

Due to the lack of warm weather immediately following the building's completion – as well as the requirement to first prove the controls, at least to some extent – the heat-load tests were not carried out until June 1994.

The correct functioning of the automatic controls is essential to maximise the performance of the building, and in particular the night-time cooling. In winter the lphw heating will come on to heat up the auditoria to the set-point of 19°C.

During summer days, fresh air inlets and stack top dampers open to allow air in to cool the room down to 22°C (provided that it is cooler outside than inside). In summer at night-time, and at weekends, the ventilation dampers will open to pre-cool the building structure.

The problem with pre-cooling is in making sure that the heating does not switch on to re-heat the building at the start of the next day, while ensuring that the occupants are not too cold if a cool day follows a hot day. This is overcome by ensuring pre-cooling is only allowed to a minimum building structure temperature of 17°C.

There are also CO_2 detectors which open the fresh air inlets to keep the CO_2 level within the space below a set level, whatever the internal and external temperatures.

Heat-load testing

The heat-load test ran for eight hours and consisted of installing 16 kW of electric radiant and convector heaters distributed around the auditorium.

This simulated the room being full with 160 students for the whole day, representing the worst case scenario for the rooms. In rough terms the external temperature reached 30°C and the internal temperature 23°C (figure 1).

The performance of the building will be significantly better on the first few days of a heatwave because the structure of the building will not have had a chance to heat up. The external temperature during the four days prior to the heat tests peaked at between 22°C and 31°C, so the structure of the building would have been reasonably warm.

After the heat-load testing the heating valve to the space was opened to heat the room up quickly and measure how well the controls were operating.

As soon as internal temperatures rose above external ambient, all the dampers opened fully to cool the room down.

Before the dampers opened it was reported that conditions were rather stuffy in the auditoria. This shows the need for injections of small amounts of fresh air in to the room at all times that it is occupied during the summer.

The first test was carried out mainly to examine the performance of the building's thermal mass. The test started at about 10.30 am. As it was warmer outside than inside the fresh air dampers remained closed throughout the test.

In normal operation the CO_2 detector would have opened the fresh air inlet (probably to about 25%) to prevent the room getting too stuffy. This would have introduced warmer external air, thereby heating the room up.

During the second day the dampers in this auditorium were fully opened to try to gauge the effect of introducing warmer external air (figure 2).

The results show that the

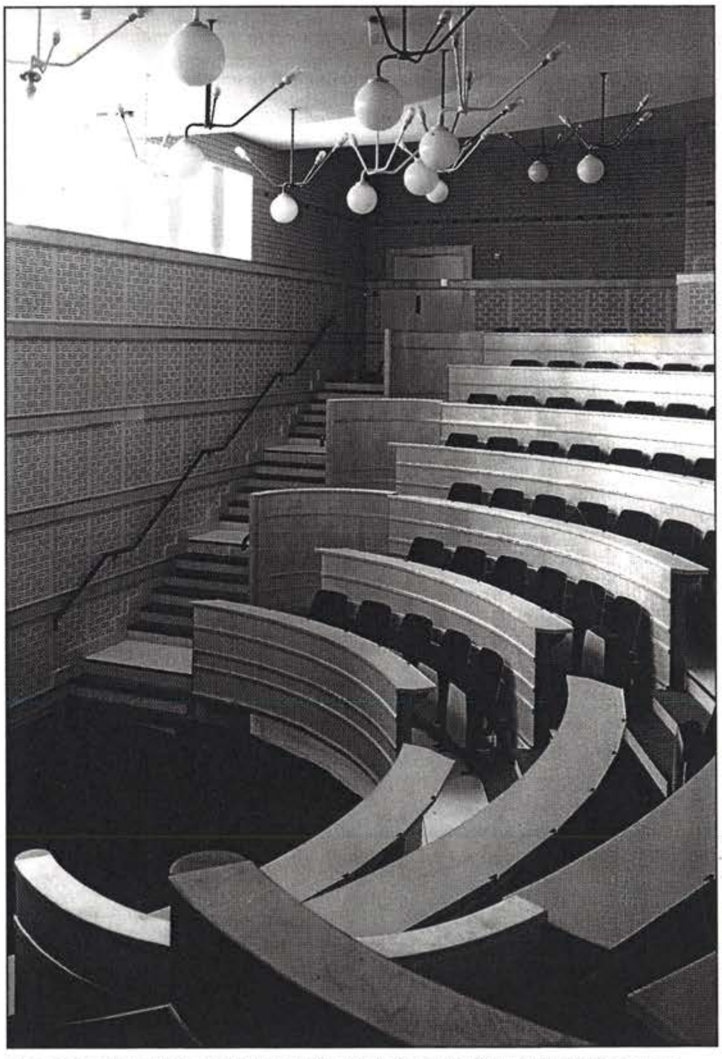

Photo: Peter Cooke

The auditorium at De Montfort University's School of the Built Environment.

room was heated up by less than 1°C in three hours, leading to the conclusion that 25% fresh air for a duration of eight hours (in normal operation) would raise the temperature in the auditorium to 24°C at an external temperature of 30°C.

These internal temperatures were agreeably rather lower than we had initially predicted.

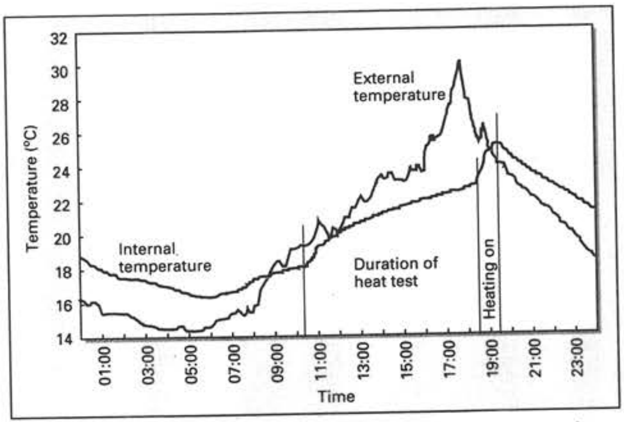

Figure 1: The first test was carried out to examine the building's thermal mass performance. The fresh air dampers remained closed.

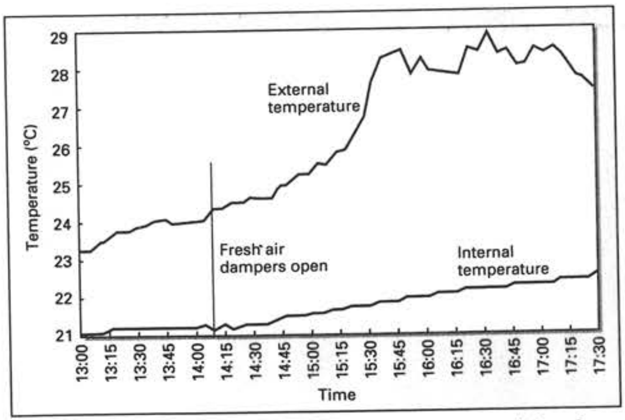

Figure 2: Once the dampers were opened on the second day of testing the room was heated up by less than 1°C in three hours.

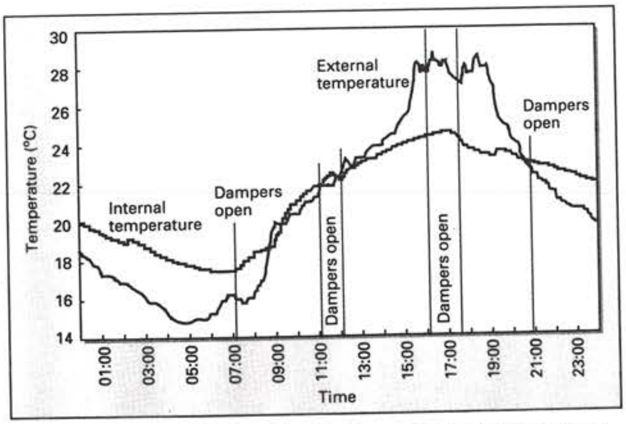

Figure 3: Results of the heat-load testing carried out in the second auditorium at De Montfort University.

The second test was carried out in the neighbouring auditorium in a very similar fashion to the first. The test started at about 9.00 am, and one result of this earlier start was that as the room heated it became warmer inside than outside (figure 3).

At that point the control dampers started to open to cool the space (the room feeling very fresh and cool inside at this time). As soon as it became hotter outside all dampers closed again.

At the end of the day the dampers were opened manually to try to gauge their effect on the internal temperature. The external temperature peaked at 29°C and the internal temperature rose to nearly 25°C.

The probable reason why the results in the second auditorium were not quite as good as the first is that the controls were not working correctly in the second auditorium, and the night-time cooling strategy was not functioning properly until two nights before the test.

Therefore the structure was not cooled as much as it otherwise might have been. This is shown by the fact that the ceiling slab temperature on the morning of the test was about 19°C in the first auditorium, and about 21°C in the second auditorium.

Teething troubles

Some teething troubles have been encountered in the auditoria over the past year, many of which have now been solved.

There were downdraughts from the stacks at times during the winter. These occurred when the fresh air inlets and the rooflights opened to cool the room down slightly and combat rising temperatures at time of high occupancy.

Due to the large area of the stack it was possible for hot air to go up one side and cold air to come down the other. This problem has been solved by closing the rooflights if an air temperature below 12°C is sensed in the stack.

There have also been complaints that the auditoria are too cold in summer. If this were a major problem the daytime set-point, or the night-time cooling set-point, could be adjusted.

At times there is a 2-3°C temperature gradient from the bottom of the room to the top seating position in the room. This is very difficult to eliminate without installing mechanical systems.

This temperature gradient is more marked in winter when there is relatively little outdoor air admitted to the space.

There was an occurrence of snow entering the auditoria through the open rooflights. This happened because there was a fire alarm test which caused the rooflights to open in order to vent the smoke.

Unfortunately, due to a bug in the software the bms computer forgot that it had opened the rooflights, and so they remained open for the entire day, although this problem has now been rectified.

Conclusions

The results from the heat-load test were neither conclusive nor exhaustive because there were only two tests carried out, and there are so many variables that could be considered.

However, the tests do indicate that the night-time cooling of the heavyweight structure of the building, coupled with the natural ventilation, appears to be working very well.

Over the course of the next year the results of a more detailed research investigation into the performance of the auditoria ventilation will be carried out by Professor Andrew Howarth of De Montfort University and Richard Walker of the Building Research Establishment.

This research should provide greater insight into the dynamic behaviour of these passive spaces.

Bart Stevens CEng MCIBSE is a partner of building services consulting engineers Max Fordham Associates.

Further reading
[1] Bunn R, "Learning curve", *Building Services*, October 1993, p20.
[2] "Will natural ventilation work?", *Building Services*, October 1993, p41.