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Testing away the problem

The bay window design for the new offices at Bracken House posed a major problem for the design of a perimeter air distribution system. Mike Holmes explains how laboratory testing resulted in an optimal design solution.

The air distribution in Bracken House is by means of a floor-mounted system, where conditioned air is supplied to internal zones by means of swirl diffusers. One Arup and Partners has a great deal of confidence in the application of this type of diffuser, and so the design of means of handling the air quantities necessary to offset either a heat loss or solar gains.

For these reasons it was decided necessary to employ underfloor fan coils to discharge air vertically over the window.

This would not normally have caused concern, and the grilles would have been selected using a standard procedure. However, in this case there was a number of complications, the most significant of which was the presence of a downstand (Figure 1).

The obvious concern here is that air discharged up the window may flow along the ceiling and then be directed into the room with a subsequent undesirable effect on the comfort of the occupants. There is little general design guidance available to handle such situations.

Other concerns were associated with the connection between the fan coil unit and the supply diffuser, the location of the exhausts in the floor on either side of the bay, and whether or not the blind would raise as air is blown covered.

The most important of these was the airflow, as the performance of a diffuser is related to the momentum flow it creates, which in turn is dependent on the velocity profile at the diffuser. Furthermore, the effect of a distorted velocity profile could be to bend the jet, either throwing it onto the blinds or away from the window and into the space, again with consequent implications for the comfort of the occupants.

These issues made it essential that some form of modelling should be done. There were two obvious approaches - applying computational fluid dynamics modelling, or building a test rig.

CFD modelling was thought unsuitable as it would be difficult to represent the inlet conditions caused by the bend and expansion following the fan coil unit. In addition, the open blind would interfere with the boundary conditions, and blind rattling could only really be confirmed visually.

For these reasons a test rig was built at ARUP's laboratories in Sweden, which allowed Arup's to take full advantage of the most important feature of physical models - the instant feedback on the general effect of any modifications.

Figure 2 shows the main features of the mockup and instrumentation that was used. The effect of solar gain on the temperature of the glazing is simulated by using heated panels instead of glass. The impact of direct gain on the space is represented by electrical heating tape on the floor in the region of the bay.

Other heat sources are lights, occupants and equipment. Lighting is properly modelled using realistic fittings, whilst the grey tubes (each containing a 100 W lamp) represent the occupants. Office equipment is modelled in a similar way.

Air velocities and temperatures were measured by an array of instruments connected to a data logger which was used to produce a plot of space conditions.
greater importance in assessing the performance of the system was the availability of smoke for flow visualisation. It is important not only that velocities in the space are within acceptable comfort bounds (for example no greater than 0.25 m/s), but that a stable air flow pattern is established. The latter can only be properly checked by using some form of flow visualisation.

So what happened and what did we find out?

Testing results
The first test carried out was to work out a flow rate of 280 litres/s corresponding to an air change rate of 14 ac/h and a heat load of 1.9 kW. The air flow pattern was totally unacceptable, with the blinds rattling and flow separation from the ceiling at the downstand. Measurement of the velocity profile at the slot showed that the flow was being directed towards the blinds, again due to tono-uniformities.

On investigation, it was found that, due to a misunderstanding, nothing specific was done to control the flow in the transition piece between the fan coil and the supply grille. The concentrated space available made this a complex piece of ductwork, involving a right angle bend, followed by an expansion (see figure 3).

The advantage of being present at the tests was now apparent in that we were able to discuss and experiment to find the best way to ensure a uniform air stream at the diffuser without causing damage.

This was done in several stages. First, a vertical perforated plate was introduced just before the bend and expansion (figure 3). A quick check indicated that the supply air was moving sideways, somewhat following the line of the diffuser, and probably short-circuiting directly into the two extract ducts at either side of the bay (see figure 4). The addition of vertical blanking plates at the top of the transition piece rectified this. The resulting airflow pattern was as required, that is to say, up the window, around the downstand and down the rear wall. However, the blinds were moving.

Further investigation of the airflow pattern at the diffuser showed that the flow was being directed towards the blinds, again due to tono-uniformities.

The introduction of a horizontal perforated plate (also shown in figure 4) rectified the situation, and a satisfactory air flow pattern was achieved with stationary blinds, but high velocities in the space. We now had to find a way to reduce the velocities in the room.

After some discussions and deciding on our course of action, the staff concluded that the heat gains used in the original test set-up were too high (a boost condition had been set) and so the air flow rate could be reduced, but even so it was likely that the grille should be changed. This was done, and after a little experimentation we were able to specify a grille on the basis of maximum discharge velocity.

The tests had confirmed that the design would work, and relieved our worries that the jet might detach at the downstand (figure 5).

The value of attending such tests and participating in the experimental work was demonstrated further when we decided to see what happened if we altered the blind angle (something not in the specification). At a certain angle the jet's upward travel was halted. We decided that we would need something to prevent this happening, a mechanical stop was specified.

With the unit designed, a prototype was built and tested to find the best way to ensure a uniform air stream at the diffuser without causing damage. A prototype unit was built and tested both for sound and thermal. Performance testing was carried out by the Building Services Research and Information Association (BSRIA), with acoustic tests being undertaken by Harman Whittle.

BSRIA used the 85 84 test rig for the performance testing, which demonstrated that the airflow was comfortably achievable and that the unit was achieving the required performance.

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