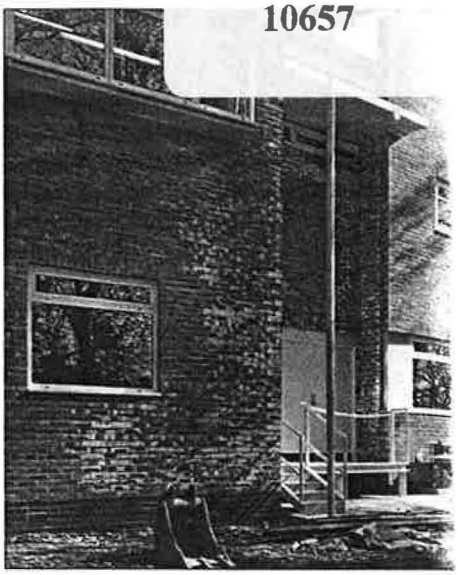
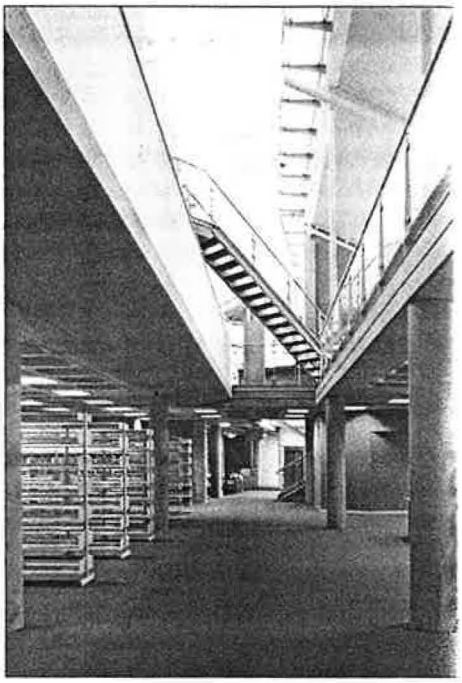


From the early stages of the concept, the Learning Resource Centre at Selly Oak Colleges was designed to use the building fabric as the primary environment modifier. Glen Irwin and his team at Ove Arup, Birmingham carried out detailed thermal modelling to predict internal comfort conditions

A learning experience



THE THERMAL ANALYSES carried out sought to quantify the comfort levels expected within the spaces during times of high heat gain and elevated ambient temperatures.

In order to quantify the effect of each variable such as: window area, thermal insulation, solar shading etc. a series of computer runs was carried out and the results considered to identify practical ways to optimise thermal comfort.

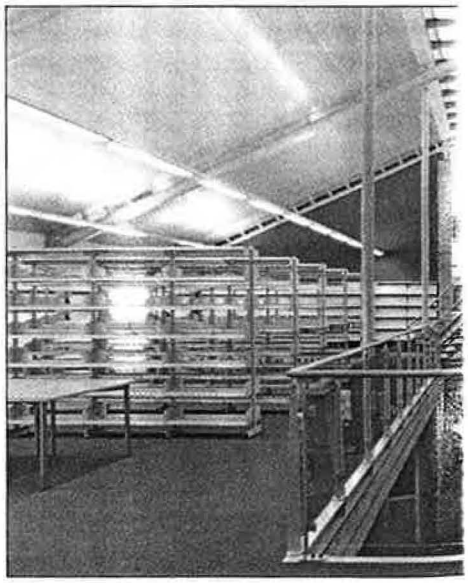
These calculations were used, primarily, to model the environment within the open-plan library areas of the building. Large, communal areas, such as these, present the greatest challenge in terms of thermal design. This is due to the height of the space, the fact that it will be automatically controlled, and the variation in occupancy. Other areas such as: cellular offices, staff rooms etc., are mostly single-storey, and are able to offer full manual override of heating and window openings. Therefore, provided the thermal environment within the library areas is found to be acceptable, then the other naturally ventilated spaces will be as comfortable, if not more comfortable.

The majority of occupants would actually prefer the building to be naturally ventilated rather than air-conditioned - particularly when the view out is of a natural, leafy environment. Occupants tend to be less critical of a naturally ventilated space because they have greater control over their local environment by opening windows. Provided reasonably comfortable conditions can be maintained throughout the year, including the peak summer conditions, a naturally ventilated building can offer a pleasant, 'airy' space, which is energy efficient, with the added bonus of being simpler and cheaper to maintain.

In summer, occupants are comfortable in air temperatures in the range 20°C to 27°C, with internal air speeds in the range of 0.1m/s to 0.6m/s and depending on their level of clothing. If the radiant temperatures of cool internal surfaces are taken into account and dry resultant temperatures are used, then the upper limit of comfort can be extended up to approximately 27.5°C.

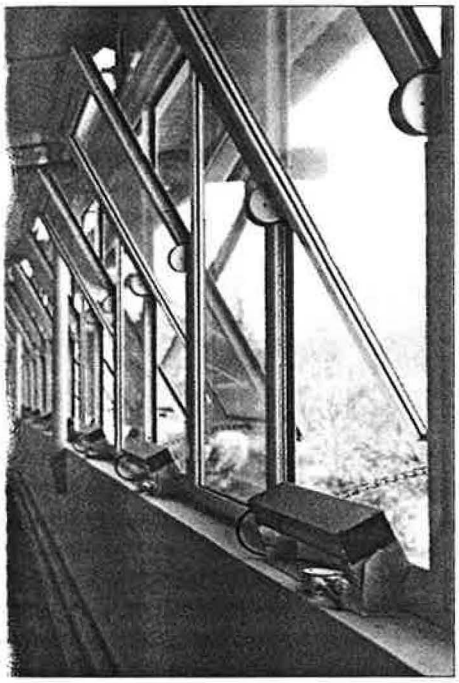
To reduce surface temperatures within the space during the summer, the design for Selly Oak provided a substantial 'thermal mass' by incorporating exposed coffered slabs at first and mezzanine floor levels. Also, by incorporating higher than normal levels of insulation within the roof, the heat transfer through the fabric has been reduced, thereby reducing the internal surface temperature in the summer. Both of these fabric elements have a significant impact on the internal environment.

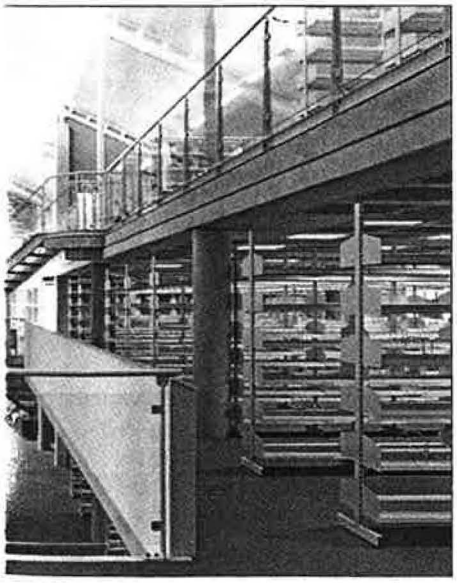
Although humidity also plays a part in comfort, with low occupancy levels in a large naturally ventilated space of this type, humidity would not be expected to be an issue. Provided the trickle vents are used by occupants, then, outside of the heating season, the internal humidity levels will, in general, follow the external ambient levels. During the heating season internal humidity will usually be lower than ambient, but, as for the remainder of the year, this would not normally present a problem in a building of this type.



Ventilation

■ Stack-effect ventilation is driven by the difference in buoyancy between warmer internal air and the cooler external air. The more buoyant heated air rises through the space and is released at the high level openings, this air being replaced by cooler outside air entering through the lower level openings. The greater the temperature difference and the greater the height difference between air inlet and outlet, the greater the pressure differential developed to create the





air flow. The pressures involved are relatively small and therefore minimising resistance to air flow is crucial. Selly Oak LRC has been designed to maximise the height difference between high and low level window openings and to make these as large as practical when in the open position.

Cross ventilation is driven by the much greater differential air pressures produced by the wind. Outside air passes through the building via openings, driven by the pressure differential across the faces of the building. Because of the low pressure differentials developed with stack-effect, even very low wind speeds will override stack-effect ventilation.

As the pressures involved in cross ventilation can be quite high on windy days, it is important to provide trickle vents for ventilation at these times. Trickle vents offer a much higher resistance to air flow than by simply cracking-open windows, they therefore offer better manual control of air flow through the building and so allow minimum background ventilation without creating draughts.

Fresh air

■ Although 8 l/s per person would be ideal, a more reasonable design target would be to provide a minimum background fresh air supply rate of around 5 l/s per person. This would achieve a compromise between air freshness and energy conservation during the heating season. The Building Regulations: Section F - table 2 stipulates that for buildings with openable windows, a minimum free area of openings is required for background ventilation in the form of trickle vents. These vents need to be manually operated by the occupants: the Building Regulations suggests 'hit and miss vents' which are commonly used for domestic ventilation in conjunction with air bricks.

Still-air conditions have also been used as the basis of summertime 'design day' calculations because it is at these times when the area of openings needs to be sized to ensure adequate stack-effect ventilation. When the windows are opened on anything other than calm, still-air days, the openings will provide plenty of air movement. This air movement will help keep occupants cool when internal air temperatures are above external temperatures. For most of the year however, the trickle vents will form the main method by which the occupants manually control the fresh air input to their local internal environment.

The main source of ventilation is via the opening fanlight windows, 50% of which are motored-open automatically by electric actuators, the remainder being manually openable. These windows are bottom hung, inwards opening, an arrangement which was seen as the most secure and one which directs the cooler outside air up to the coffered slab where it is required. It is vital that all actuated windows have the facility to be opened during the night to allow night time precooling.

The actuated fanlight windows will be opened/closed to either a minimum or maximum position dependant upon the dictates of the control system. To give occupants some degree of local control, a manual override facility is provided.

Roof level window openings are not expected to experience the same security risks as those at the lower levels, and so here horizontal, central pivoting openings are proposed. They are also closed/opened automatically by electric actuators together with a manual override facility.

In addition to the fanlight windows, there are also conventional large pane manual opening windows at certain corners of the library areas which open onto secure courtyards. These windows will provide additional ventilation local to the openings. As it cannot be guaranteed when the manual windows will be open, none of these openings have been considered in the thermal analysis, although it should be borne in mind that they will offer potential for improved comfort in these areas.

Solar shading to the glazed area will be achieved primarily by building overhangs. The effectiveness of the overhangs depends on the 'solar altitude' i.e. the angle of the sun to the ground.

During the middle of a June day the solar altitude will be around 60° to the ground, whereas, at the same time in February the solar altitude will be much lower at around 30°. The overhangs will shade most of the glass when it is needed: in mind summer, but allows sun and thus daylight penetration during the winter.

The existing trees, and ultimately some of the new trees, when they are mature, will offer good shading to the building in certain areas, especially during early and late summer when solar altitudes are lower. The trees will, in fact, cool the surrounding air due to the evaporation of moisture from the surface of the leaves. In addition to this is the significant psychological affect on occupants: if the view is of leafy, shaded areas this makes them feel cooler than if the view is of highly reflective, hard, concrete surfaces.

Sunlight

■ As shading to the building cannot be guaranteed at all times it is likely that some form of blinds may need to be employed in certain areas to cut-down glare from direct sunlight.

At ground floor the trickle vents are positioned immediately below windows, and above the heat source i.e. radiators. These vents are ducted to air bricks in the external leaf of the wall. At first floor, on the south facing windows, the vents are fitted in either the window units or the window cills. On the north facing windows,

> "The main source of ventilation is the opening fanlight windows"

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at first floor, the vents are either fitted in the windows themselves or in the raised floor with ducting to outside. All vents need to be highly visible, quick and easy to use. These vents will provide background ventilation local to where occupants are seated and so will be fitted evenly along the facades to spread the fresh air input.

By mounting the vents adjacent to the heating source i.e. radiators or convector heaters, the incoming fresh air is tempered before mixing with the internal air. This will help to reduce draughts from the incoming air.

The insulation installed in the roof, 120mm mineral fibre, is above the minimum required under the Building Regulations to satisfy the maximum allowed heat loss in winter ('U' values). This extra insulation will reduce heat transfer through the roof fabric and thus reduce the internal surface temperatures during the summer as well as reducing heat loss during the winter.

The coffered slab construction is an effective way of providing a substantial thermal mass with a high surface area, which will help to absorb heat gains to the space in summer. Conventional cast concrete used in the slabs has a high thermal capacity. If this concrete can be used to store a substantial amount of 'coolth' by cooling the slab at night, when external air temperatures are lower than during the day, then this will offset the heat gains received during the following day.

As mentioned previously, comfort depends to a great extent on the combined effect of the air and radiant temperatures within a space. At all times of the year, the ideal comfort condition is achieved when occupants have 'a cool head and warm feet'. The soffit seen from most of the ground floor and part of the first floor, is the coffered slab. If these slabs are cooler than the air temperature, then useful 'radiant cooling' will be received by the upper parts of the body, thereby creating this 'cool head' situation. The raised floor above the slabs will provide insulation to the feet from the relatively cool surface of the slab, thereby creating the 'warm feet' situation.

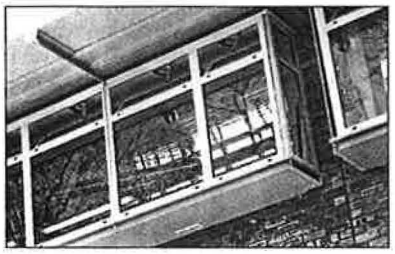
Design Conditions

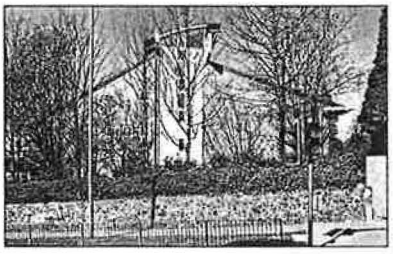
■ The computer program used in the thermal analysis simulated the effect of various climatic conditions on the internal environment. In particular, the analysis sought to predict the internal comfort conditions within the main library area of the building during the peak conditions of an average summer. Computer runs were also undertaken to establish the likely internal conditions if a series of extreme summer days were to occur.

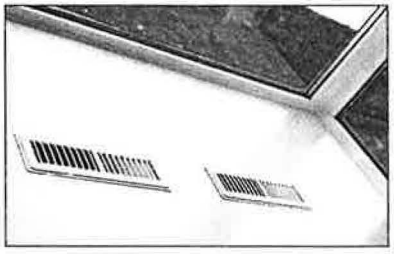
The external climate has a major influence on internal comfort, so the weather files used in the calculations must be selected carefully. To establish a summer 'design day', it has been assumed that still-air conditions are coincident with high solar irradiances and moderately high ambient air temperatures. These design conditions can be considered a reasonable representation of peak summer conditions. During these conditions Stack-Effect ventilation will prevail; providing the driving force to remove heat gains from the space. The results of the analyses enabled us to assess the appropriate free areas of the openings and the ventilation rates which would be achieved through them under these conditions.

The weather files used in the analysis are published in CIBSE Design Guide A2.

Checks were carried out using a peak ambient temperature of 28.7°C (which is a temperature recorded for several consecutive days last summer) coinciding with still air conditions. This was carried out to ensure that, if this situation were to occur, then the space would still be habitable. Surveys undertaken at other buildings of this type have shown that, during periods of very high ambient temperatures, if people can be encouraged to keep the windows closed during the peak hours of the day, then the internal temperature will be significantly lower as a result.







"Coffered slabs for large thermal mass with high surface area"

The results show that conditions are likely to correlate with the original theory: that peak internal temperatures will not exceed ambient temperatures by more than 3°C. In fact, provided occupants can be encouraged to keep the manual opening windows closed during the peak hours of the day, room temperatures in most of the library areas would be expected to be 1-2°C below ambient.

The predicted dry resultant temperatures are, in most areas, lower than the air temperatures. This demonstrates the extent to which thermal mass and high levels of insulation will help to reduce internal surface temperatures, and thus improve comfort.

Stratification

■ At mezzanine level, temperatures are above those at ground level. There are two reasons for this: firstly, due to the design of the structure, it was not possible to incorporate a coffered slab overhead, as elsewhere; secondly, due to the difference in height between ground and mezzanine floors stratification will occur. In real terms, a difference of 2.4°C, although perceptible, would not make a major difference to the comfort at the higher level.

The ventilation rates predicted for the design case still-air conditions should offer acceptable levels of freshness and air movement. During low to medium wind speeds, which occur quite frequently, moderate to high ventilation rates will allow additional cooling for occupants local to openings.

The computer runs using extreme ambient temperatures peaking at 28.7°C predicted internal dry resultant temperatures of 26.2°C at ground floor and 28.7°C at the mezzanine level. The temperature for mezzanine level is above the normally accepted maximum of 27°C, but this should not prevent the area being habitable for these periods. The frequency of these periods might, in an average year, only be 7 hours of each of the months June to September e.g. the peak 2 to 3 hours of 2 or 3 days of each of these months.

In general, the computer analysis indicated quite acceptable internal conditions, during ambient conditions which are not exceeded for 97_% of the summer months. Also, the space will remain habitable even in extreme ambient conditions, which in an average year would only occur for around 1% of the summer months. ■

Glen Irwin won the 1997 H&V News Award for Building Services Engineer of the Year, sponsored by Toshiba, as a result of this project