A REVIEW OF ACOUCTIC PROBLEMS IN PASSIVE SOLAR DESIGN

Mike Wilson

Low Energy Architectural Research Unit Polytechnic of North London Holloway Road London N7 8DB

INTRODUCTION

The future of the planet may well depend on us changing our attitudes to the design of buildings. We can no longer afford the building equivalent of the 'gas guzzler'.
Passive Solar Design uses renewable energy to limit fossil fuel consumption.
This paper examines the impact of such design decisions on the acoustic environment.

PASSIVE SOLAR DESIGN

With approximately 50% of the annual primary energy consumption within the UK being used by buildings it is not surprising that growing concern about the greenhouse effect has given an impetus to energy efficient design. Commercial buildings account for about 30% of this building energy consumption. While a decade ago the emphasis on reducing energy was focused on domestic buildings, commercial buildings have recently been attracting more attention. The principles of passive solar design can be applied to both domestic and commercial buildings though the potential energy savings come in different forms.

In housing, after adequately insulating, siting, differential sizing of windows according to orientation, high performance glazing and the use of pre-heat ventilation from sun spaces (conservatories) have been used in passive solar design. For commercial buildings it appears that the greatest savings will come from daylight substitution for electric lighting and the use of natural ventilation. Atria have the potential to contribute to energy savings but often do the opposite.

The problems of natural ventilation and summer overheating, especially in offices, are those that are most likely to lead to acoustic problems.

Passive solar housing schemes have so far generally been developed on green-field sites without much traffic noise problem and large natural ventilation rates can consequently be achieved by simply opening windows. If some sound attenuation is required moderate ventilation rates (2-5a.c.h.)

may be achieved by staggered opening of secondary glazing systems and others described later. An angled transparent sound reflector at present under development may allow even higher ventilation rates. While dwellings can overheat, often these can be solved by the much greater control and freedom of movement that exists for the individual in such spaces as opposed to non-domestic buildings.

CRITERIA

In commercial buildings the situation becomes far more complicated. Comfort conditions, thermal, acoustic and lighting, are fairly rigidly laid down for an office. A naturally ventilated space is unlikely to satisfy these criteria all the time. Overheating may occur on some days, noise levels may be high and lighting may be more variable. It is going to be necessary to establish what variability is allowable. There is strong evidence to suggest that people feel better in naturally ventilated buildings. In an early study of building sickness syndrome[1] comparing workers in almost identical air-conditioned and naturally ventilated offices identifiable medical symptoms were much more common in the air-conditioned offices.
Later in a similar study it was reported[2] that an important contributing factor to building sickness was the reduced level of control that individuals have over the environmental conditions when buildings are sealed which heightens the perceptions of discomfort. Griffiths[3] found that the greater variability in temperature in passive solar buildings did not appear to affect thermal comfort and that people did not find such changes unpleasant.

The acoustic environment is one contribution to the total environmental comfort in a space. Its relative importance in relation to thermal and visual comfort will depend on the nature of the space. The acoustic criteria for offices are laid down for the modern air-conditioning office, with the air conditioning playing an important role in acoustic privacy and the sealed glazing keeping out noise. These are $L_{Aeq} = 40-45dB$ or $L_{Aeq} 45-50dB$[5] (NR35 or NR40[4]) depending on the type of office and are as much minimum as maximum. While road traffic noise may be intrusive it has already been suggested that people will tolerate higher levels of low frequency sound so that laminated glass can be used in fast track construction. To what extent these levels can be increased to allow natural ventilation where intrusive road traffic noise exists is a matter for the total comfort sensation of the office as a

whole. But are there limits?
Maximum intrusive noise levels to allow normal speech conversation are $L_{Aeq}=51dB$ at 2m and $L_{Aeq}=57dB$ at 1m.[5]
Telephone conversations are satisfactory at 58dBA or NR50, slightly difficult at 68dBA or NR60.[4] Perhaps an absolute maximum could be set at $L_{Aeq}=55-60dB$?
These may describe the upper limits for noise within the office but there is still a need for a minimum. Sound masking systems fulfil this function adequately at the moment but it is sometimes difficult to persuade a client demanding a 'green' 'healthy' building that electronically created noise is necessary.

SOUND ABSORPTION AND THERMAL MASS

Without air-conditioning the passive solar building loses the need for a ceiling void behind acoustic tiles with the minimal services supplied in a small raised floor. Acoustic control is still needed but application of acoustic treatments in the form of a suspended ceiling or by direct attachment to the ceiling creates thermal insulation between the air and the ceiling. Mass is an important element in the design of naturally ventilated buildings as it helps to prevent overheating. Access to the floor slab is prevented with a raised floor and/or carpets so the ceiling needs to be exposed.

It has been reported[6] that an exposed ceiling will reduce the room temperature on a warm day by 1-2°C or that the internal heat load can be increased by 5-10W/m^2. This can be maintained over a long period by night-time ventilation.
The effect is almost maintained if a suspended ceiling is in place with 11% of the tiles removed in strips. The consequences on reverberation time of the room is marginal but there will be increased problems of room to room transmission. Physical barriers above partitions may be the only solution as acoustic treatment of the underside of the floor slab will act against providing thermal mass. These barriers are not easy to implement if the void carries services[7,8].

The role of the convection currents set up in the void is obviously very important and a similar thermal performance could not be expected from the use of directly attached tiles or from a shallow void designed to satisfy the lighting requirements. No data is available although suggestions are being made (though not in print!) that for directly attached tiles about 80% of the ceiling area needs to be exposed. There

must be doubts about this area of tiles being acoustically satisfactory. At the moment a voidless ceiling is only likely to be aesthetically compatible with an uplighting system. These systems use high pressure sodium and metal halide discharge lamps which are not yet compatible with daylight substitution electric light controls and therefore not suited to daylit buildings.
Open grid ceilings will fulfil the requirement for access to thermal mass but the incorporation of the acoustic absorber needs careful consideration. Vertical acoustic elements (akin to the functional absorbers used in factories and sports halls) may be fixed above the open grid but in such a manner that convection currents are encouraged to expose the thermal mass to the mixed room air.

It is worth noting that the elimination or reduction of the void can have positive energy benefits by increasing window height or immediate economic benefits during construction by reduction of floor to floor heights.

NATURAL VENTILATION SYSTEMS

It was argued earlier that acoustic criteria will have to be interpreted with more flexibility and that insulating against road traffic noise and in some cases aircraft noise is likely to cause most problems for naturally ventilated buildings. High ventilation rates required to avoid summer overheating in commercial buildings are not compatible with good sound insulation. However it has been mentioned that certain systems can give some sound insulation in conjunction with moderate air change rates (2-5a.c.h.). Secondary glazed systems allowing a staggered 100mm open gap on each pane have been shown to give a sound insulation of 27dBA-30dBA depending on the type of noise.[9,10]

Recent work at the BRE[11] has looked at trickle ventilators and passive stack ventilators applicable to domestic buildings. Trickle ventilators are holes or slots. Holes generally provide better attenuation than equivalent slots and the actual transmission naturally depended on size. In general those tested provided no worse attenuation than closed single glazing below 630 Hz and below 315 Hz with secondary glazing. At the higher frequencies the performance was no worse than opening the windows. Passive stack ventilators performed similarly though better attenuation would be provided against traffic noise than aircraft noise because of the change in angle of incidence of the noise. The type of duct was important in the performance above 630 Hz. Rather interestingly a larger 155mm duct gave better attenuation than a 100mm duct. The nature of the termination and type of duct affected both the acoustic performance and ventilation rate generally in opposite directions. Attenuators may be necessary but they can become very large in commercial buildings. Solar chimneys have similar problems as they are designed to move the air quicker, thereby helping reduce overheating. Essentially a part glazed vertical duct exposed to the sun, the air is warmed and the stack effect increased. They are not common in the UK but a study centre for the Centre for Alternative Technology, Machynlleth, Wales[12], proposes to use them to provide summer time ventilation for bedrooms located behind a glazed buffer space. Duct areas are large but in this case the problem is potentially cross-talk and can easily be solved by designing a separate chimney for each bedroom. In other cases where a chimney , solar wall or double skin type system may have to serve several vertically arranged spaces the solution is not so simple.

While the stack ventilator or solar chimney itself may cause problems the air inlet needs to be considered. The proposed Energy faculty Building at Leicester Polytechnic[13] uses passive stack ventilation chimneys to ventilate a lecture theatre, the air being drawn through grilles under the seats from the outside via the plenum created by the builders work. The problem is obtaining sufficient sound attenuation with minimal flow resistance. Traffic noise is around 70 dBA in the street outside and very large attenuators have been provided. In addition the chimneys have been lined with acoustic absorber

ATRIA

Another concern in passive solar design is atria. Atria have the potential for improving the energy efficiency of a building if unheated or minimally heated. Mostly designed with hard finishes the reverberation times are often high and sometimes boasted about. The problems arising will depend on use of the surrounding spaces, the use of the atria and the size of the atria. Despite a long reverberation time the reverberant sound level in large spaces is low and it is likely to be the smaller atria where problems could arise. In some cases the acoustics of small atria such as the Cambridge Consultants building in Cambridge Science Park have benefited from acoustic treatment of the surface.
In a recent International Energy Agency Task Group XI report on Passive Solar and Hybrid Commercial Buildings,[14] three social surveys give an insight into the occupants' reaction to

noise in atria. These were either retrofit atria or extensions to existing buildings and in two cases before and after studies could be done. The first dealt with was that of the Tegut Company, Fulda, Germany. Additional office space was created and then glazed over. The glazed area was heavily planted. With office workers moving from the air-conditioned spaces to the atrium pavilions there was a slight reduction in the perceived noisiness although they remained on the noisy side of neutral. The air-conditioning in the original offices had been causing noise problems.

In another development at the Norwegian Institute of Technology, the extension to the Department of Electrical Engineering and Computer Science, several new office and laboratory buildings were linked to each other and existing buildings by glazed spaces. The occupants found the building slightly noisy but a concluding remark was 'noise levels in the atria and noise disturbance from the atria to office spaces also gave rise to some complaints.' This apparently arose because groups of students congregate in the atria to drink coffee and make conversation.

Finally a development in Wasa City, Gaule, Sweden, involved glazing over an area linking dwellings, shops and offices. The social survey was designed for the residents, many of whom had lived in the dwellings before retrofit. Traffic noise in the area was very high but the report comments: 'Rooms badly affected by noise lie to the same extent facing the courtyard as facing the street. During the summer the ventilation shutters in the roof cause noise. In winter, snow on the roof makes noise as it slides down the glass in great chunks. Also the wooden duckboards in the open spaces in the atrium were mentioned as a source of noise. Noise is intensified in the atrium'.

While it would be unwise to draw any general conclusion from the surveys, they do tend to confirm current opinion. Noise problems created in offices by atria are less likely in large than small atria. Problems can arise if activities occur in the atria which create noise, Eg the congregation of a fairly large number of students at a coffee bar in the atrium or if a small orchestra or band is employed to play. The type of space surrounding the atrium is important. Dwellings and possibly teaching spaces are likely to be much more sensitive than offices.

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