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INSIDE THE LIVING SPACE OF FABRIC STRUCTURES

1. INTRODUCTION

The factors which determine comfort or amenity provided in fabric roofed buildings or enclosures are no different from any other building and are :

1.1. Dry bulb air temperature.

1.2. Mean radiant temperature of the surface surrounding the person.

1.3. Wet bulb temperature.

1.4. Air movement - draughts.

The feeling of comfort can, however, be modified by the colour of the surroundings, the layout, lighting and general ambience.

The analysis leading to the design of the thermal environmental systems has to take account of 1.1 to 1.4 above. Experience has shown that if this is done, then normally accepted standards of comfort are achieved, i.e. 70% to 80% if the occupants are satisfied.

The difference between buildings with fabric roofs and those with conventional roofs is that the separation between the internal environment and the external environment is by a thin skin which allows rapid flow of heat. However, the distance of separating the roof and floor in buildings with fabric roofs is generally considerably greater than conventional buildings.

Although the heat may enter or leave through the fabric its effect on the occupants is either not felt or delayed.

The rate of change of equilibrium conditions in the building is dependent upon many factors, one of the most important of which is the thermal storage of the building fabric.

2. PROJECTS

2.1. General

Since 1982 I have been associated with a number of projects, the first being the Atrium of Canberra International Motor Inn. The roof is over an area surrounded by bedrooms so the roof is the sole external influence on internal conditions. The difference between this and Atriums with glass or other transparent material is the shape and size together with the thermal properties of the fabric employed.

The design approach was to introduce the air at a low level, the majority of the air not being directly supplied but relieved from the rooms and public areas. This air is vented through the top of the roof thus providing a "throw away blanket" which is cooled or heated before leaving the building. To overcome the radiant loss to the roof part the floor was heated. The area under the fabric includes a Foyer, garden and restaurant.

Shortly after this a medical centre was constructed, again with an internal Atrium in which the waiting areas were situated. People are therefore seated for perhaps quite long periods, sometimes being in an anxious state. A similar approach to the Hotel was adopted. The Atrium is far smaller than the Hotel but nevertheless, subject to the same thermal factors.

Both buildings have a fairly heavy weight construction thus possessing thermal storage to release or absorb heat during periods of change of external conditions, both solar radiation and air dry bulb temperature of the outside air.

A number of other buildings of similar construction have showed, with installed systems based on similar design assumptions, that comfort conditions are maintained. Unfortunately there has never been the opportunity to determine exactly how "safe" the designs are under normal design external conditions.

2.2. Lightweight Structures

Lightweight structures have a far higher rate of response to changes of external conditions. Where there are considerable areas of glass, particularly facing north, the air conditioning system must be capable of fast response. If the system provides supply air at the occupied zone but allows stratification in the upper regions of the enclosure, the system refrigeration capacity can be reduced.

Even in temperate areas the space can become uncomfortably hot unless cooling is provided. In Autumn the system will need to be able to change from heating in early morning to cooling by midday. If this space is partitioned then zoning is essential. This can present considerable problems. Attempts to maintain conditions with outside air without refrigerated cooling may be successful if the outside air temperatures are low enough, but careful analysis of the heat flows and allowances for thermal capacity should be carried out.

2.3. Tropical Conditions

The fabric roofs will result in air temperature under it several degrees above the outside dry bulb temperature. These conditions can be more than uncomfortable and result in heat stress. Cooling is essential if the space beneath the fabric is enclosed. In summer the difference between maximum day and minimum night temperatures is small so the thermal capacity of the building has little effect and hence there is a rapid response of the space air temperature to heat gains from solar transfer through the fabric roof. The air flow rates of outside for ventilation to be effective without refrigerated cooling are very high. Ventilation by outside air of course can never reduce the space below the outside air temperature. If the roof is at a high level the effective use of temperature stratification in vertical layers and relief from the highest point are helpful but alone are not effective enough in general to maintain satisfactory conditions.

2.4. Arid Conditions

I have no direct experience but as with tropical conditions the air in the space must be above the ambient air temperature unless some form of cooling is provided. Unlike the tropics evaporative cooling could provide relief from heat stress but not comfort, as it is normally defined. Dry bulb temperature outside are higher but humidity is lower than the region classified as tropical.

Fabric roofs have been provided as sun shades in which case natural ventilation is provided through the open sides.

2.5. Cold Conditions

Obviously there is greater heat loss requiring greater heat input. A major factor is the lowering mean radiant temperature of the surrounding area due to the expanse of cold fabric over the occupants thus increasing the rate of heat transfer from them, causing a sensation of cool or cold. Down draughts will result unless offset by appropriate supply of air and/or by the provision of radiant surfaces. Radiant surfaces both increase the mean radiant temperature of the surroundings and counter down draughts. Electric cables or heating pipes embedded in the floor slabs can be provided.

In high spaces if the supply air temperature greatly exceeds the bulk air temperature in the space buoyant forces will result in rapid movement of the supply air upwards with inadequate mixing or entrainment with the occupied space air. This problem is not of course isolated to spaces with fabric roofs.

In Europe and U.S.A. double thickness fabrics have been used, some to act as solar collectors.

The control of the rate of flow of relief air from the top of the fabric roof is important. The "chimney effect" will cause the entrained areas to the building to be cold. Windlocks or revolving doors are essential.

3. MECHANICAL SERVICES REQUIREMENTS

As with most buildings, heating, cooling and ventilation are required. Heating may not be required in warmer regions and cooling not provided in colder areas. As with most buildings with transparent or semi-transparent roofs, refrigerated cooling is required in Summer and perhaps in Autumn, to maintain satisfactory conditions.

The calculation of heat gain to the space involves the same basic understanding and application of heat gain transfer as for more conventional buildings. The design and arrangement of the system can minimise the capacity and energy consumption of the system.

The geometry of the fabric in particular makes the prediction of radiant transfer complex. The patterns of air movement induced by natural convection from the under surface of the fabric to the air in space is not fully described, although there have been attempts to do so. This, of course, is modified by the air movement caused by the flow of supply air into the space.

If the control of the environmental conditions is not initially adequate, the cost to augment or change the system is very considerable. If cooling is omitted and then must be installed later, the cost of doing so may be several times greater than had it been originally provided.

4. ENERGY CONSUMPTION

Predictions have been made for the energy consumed for projects. It is, however, difficult to isolate the energy consumed in the fabric covered area from the overall consumption of the building.

Where the hours of sunshine are high in winter, the energy consumption during the day is considerably less than conventional roofs.

The predictions made have not been verified by the metering of consumed energy in that portion of the building.

5. LIGHTING

During daylight hours artificial lighting, other than effects and special purpose, is not required. At night the major component is reflected light from the surfaces, the source of light being either incandescent or high efficiency discharge lamp such as mercury vapour, metal halide or similar. The intensity can be varied by switching in arrays. Other possible effects can be created by projection of images, patterns or colours.

The natural lighting of the interior of the space is one of the major reasons for providing use of the fabric.

I have not encountered difficulties in providing adequate and acceptable lighting.

6. CONCLUSIONS

The experience gained has highlighted the following:

6.1. The importance of providing cooling, particularly for lightweight structures which have solar gains other than that through the roof.

6.2. Mechanical ventilation alone cannot maintain acceptable conditions in summer in other than very cool climates.

6.3. Allowing stratification of the upper levels of the air in the space reduces the refrigeration load in the air conditioning plant.

6.4. Careful analysis of the heat flows for the particular project is essential to avoid costly amendments or additions to the building services after the project is completed.

6.5. There is scope for more rigorous monitoring of the energy consumption and performance of systems so that the system design can be refined.