CONTROLLED VENTILATION AS A COOLING AGENT IN SCHOOL DESIGN FOR ARID TROPICAL AREAS

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ABSTRACT. This paper studies the utilization of natural ventilation in school buildings for hot arid regions. It attempts to provide natural ventilation by the controlled movement of cool air. This is to be assisted by special use of stack effect system in buildings. To achieve such goals, two typical problems have to be resolved; firstly, external temperatures should be reduced to the minimum; secondly, pressure differences between inside and outside should be increased to the maximum. The outcome of this study indicated that, typical layouts (central hall, double banked corridors, etc...), should be avoided. The solution should incorporate functional and what it may call climatical layouts. The conventional methods of applying the stack effect system are not effective in these circumstances. An original method has been developed to utilise the stack effect system to use convection currents to draw cool air through the building.

1. CONCEPT

This paper describes an experimental and innovative design for school building in Jeddah, Saudi Arabia. It is based on the functional requirements for educational provision in that country, which proscribes particular planning form and layout. Beyond that functional aspect there were conceptual aspects which were as follows:

1. The design would respect the cultural tradition of the region.
2. That where possible mechanical air-conditioning would be avoided, and in particular class rooms and teaching areas would be cooled by natural means.

A great deal of investigation and experimental work was undertaken by Dr. Khafaji. This lead to the following principles being adopted for the prototype design.

1. That natural air movement, mainly convectional, which had been used traditionally in houses at Jeddah, could be used in school design. In particular, the use of cross ventilation during early morning and night to cool the building fabric. (Fig. 1)
2. The use of suitable construction and materials to restrict internal radiation to those periods when the building was not normally in use.
3. The recognition that in Jeddah, sun angles are such that careful consideration must be given to the formation of self shading buildings by suitable planning and appropriate planting as well as functional shading devices.
4. The development of shaded areas to form cool air 'pools' which could be utilised for cooling purposes.
5. To utilise the propriety of heated air to rise and create convection currents throughout the building.
6. The need for flexibility in the building operation to take advantage of the diurnal rhythm and changing thermal conditions.

Design using these principles is often described as 'passive' to reflect the lack of mechanical aids. The authors would instead regard this as 'active' solar design as thermal gain is used in solar 'chimneys' to create air movements which can then be directed for cooling and/or provision of comfortable conditions.

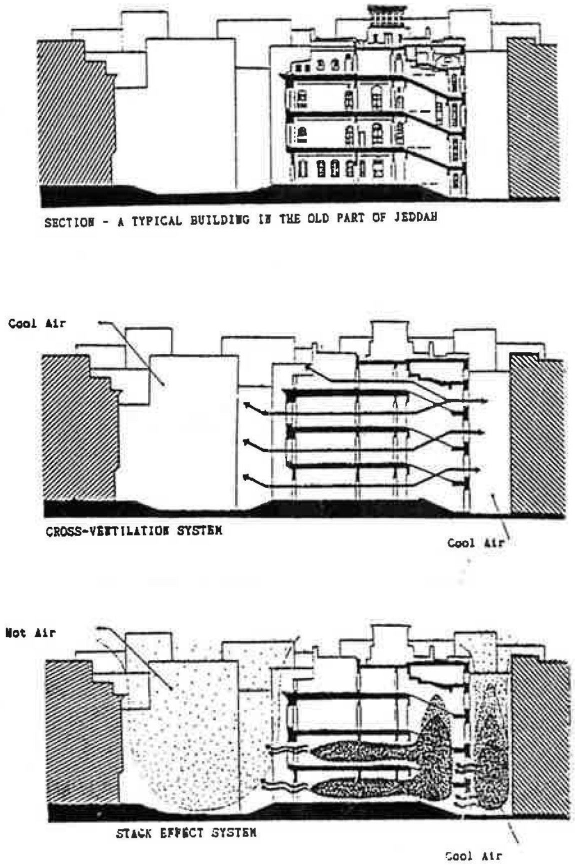


Fig. 1

2. DESIGN POLICIES AND PROPOSALS

The starting point for the environmental part of the work was an analysis of traditional buildings in Jeddah. This showed that the self shading principle was soundly based and led to the rejection of some standard layouts for school buildings which were popular in other climatic zones. A clear example was the finger plan layout orientated east/west which is often adopted in tropical areas.

Thι double banking of teaching spaces around a central circulation route, so economical in temperate zones was also rejected. A surprising high number of such layouts were found in the survey of existing educational buildings in the area. Fig. 2 represents this quite usual situation showing three temperature zones. The creation of cluster groups has been devised to improve this situation. These form 'climatical' layouts which enable the strategy of control of air movement, seen as the driving force for natural cooling to take place. Fig. 3 shows how the three temperature zones have been increased to five, giving greater flexibility and a hierarchy of temperature related areas.

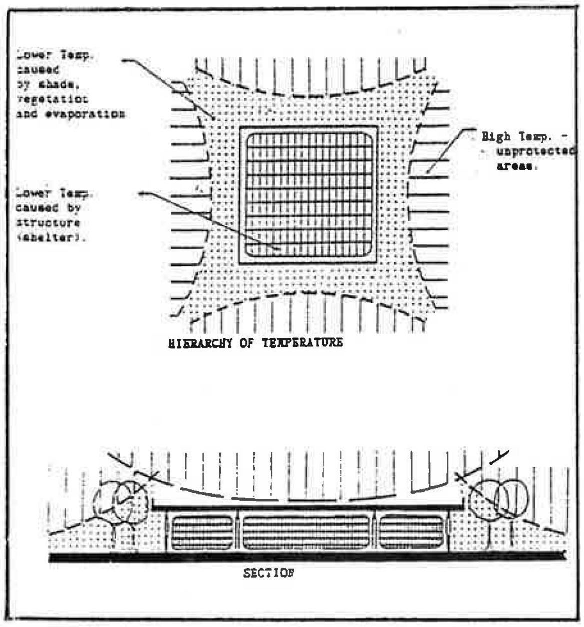
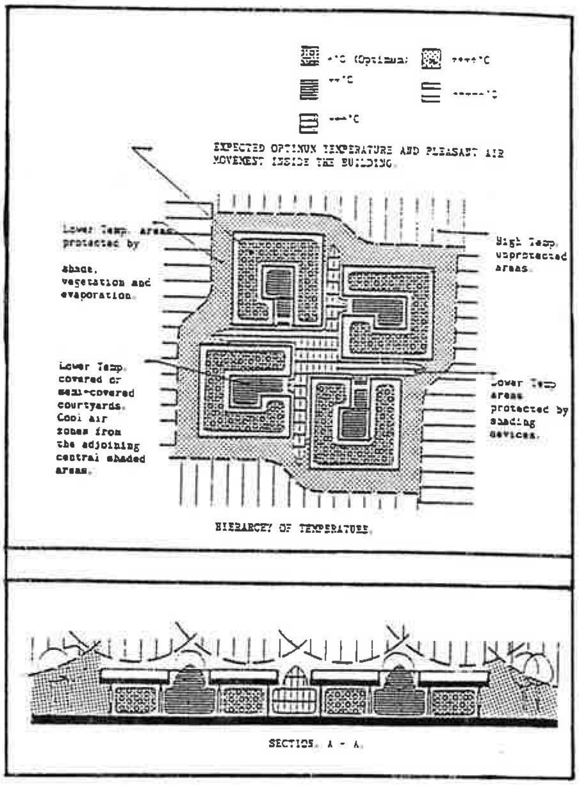


Fig. 2

This technique, based on traditional forms, is to create areas which have a significant difference between external air temperature and that of the shaded areas. The resultant pressure differences being used to create air movement which will be directed across body levels.

The theoretical stance adapted was that air passing into the teaching areas would pass through four zones (the last one being the teaching space itself), the boundaries between the zones acting as filters, and the travel paths deliberately elongated by the planning process, assist the cooling process. Where conditions are suitable, cross ventilation can be used.



Figs. 3

The first zone, the shaded courtyard would employ water, either in the form of removable pools or other evaporative devices, to reduce air temperature. Normally, ventilation in arid tropical buildings is reliant upon cross winds and natural convection. An innovative design for forcing the flow of air to body levels in the teaching areas is by placing solar 'chimneys' on the exterior and drawing air from the inner zone by convection. The flues having a suitable cross section to give some control by use of dampers or louvres. The higher part of the 'chimney' is of glass and steel to increase temperature to a high level. The principle is illustrated in the sections. (Fig. 4) The stack is expected to be of use in the later part of the day as well as when the cross ventilation system is closed down in mid-morning.

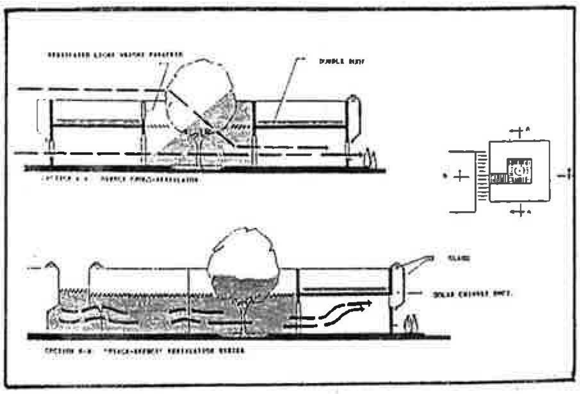


Fig. 4

The detail of the 'chimney' is shown in Fig. 5 while Fig. 6 shows the model made for wind tunnel testing. Fig. 7 shows the wind tunnel test in operation.

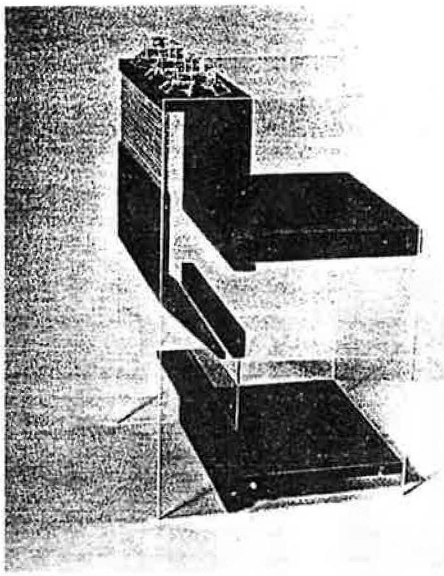
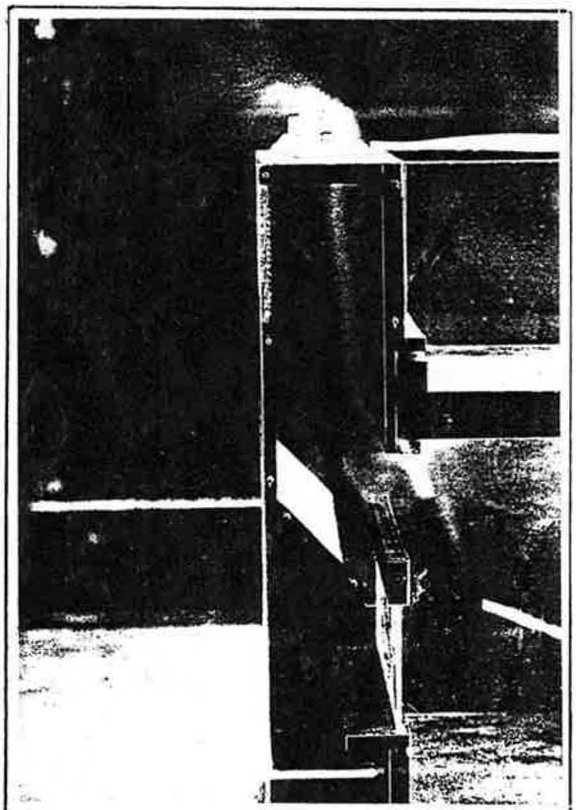


Fig. 6



A model of the chimney duct has been made to examine the air flow by using the wind tunnel. This picture shows the flow of the smoke in and out of the chimney.

Fig. 7

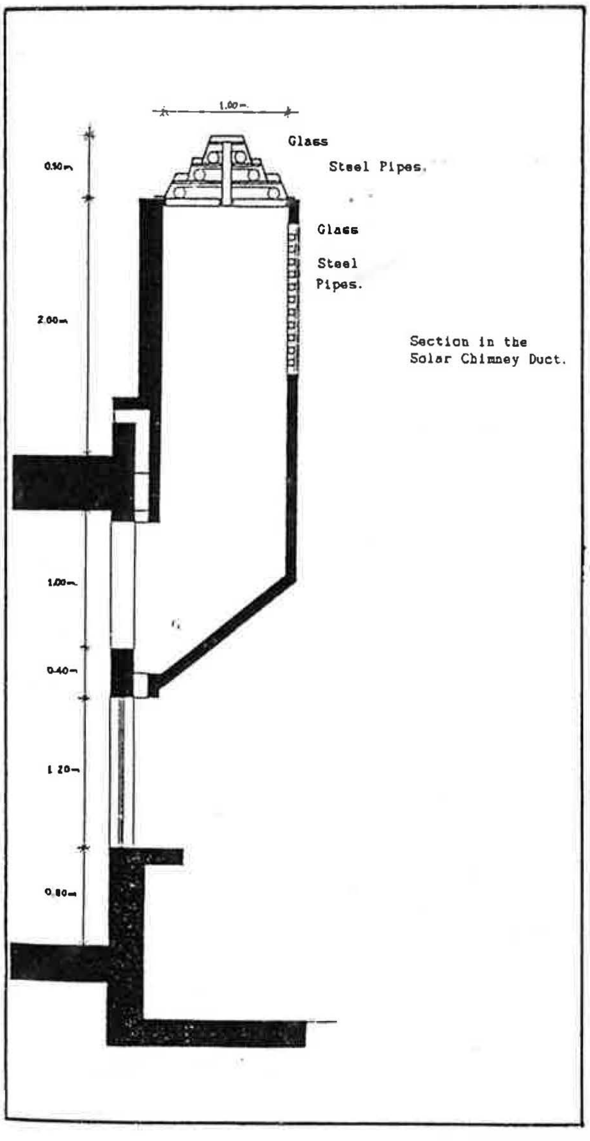


Fig. 5

3. CONCLUSIONS

The testing and theoretical studies indicate that a combination of cross ventilation, and active cooling from the technique described could provide architectural solutions within the original conceptual framework. It also became clear that the design of buildings in hot arid climates demanded attention and selection to materials which provide a thermal time lag so that radiation from internal surfaces took place after school hours. In addition, the design of roofs needed spatial attention to prevent radiation occurring quickly in teaching areas and thus distorting the convectional flow. There is still detailed work to be done. Lighting levels, which if provided by using natural daylight, means heat has to be carefully thought out. Again, the plan allows for carefully shaded openings and the use of light from courtyards etc. Dust penetration is a hazard which has to be prevented by filters at appropriate places before the ventilation air reaches sensitive areas.

There are, of course, may other factors to be considered in school design. The plans, Figs. 8, 9 and 10 show the application of the climatic cluster technique to two functional areas with a variety of teaching functions, thus demonstrating realistic and practical application of the system in a positive manner.

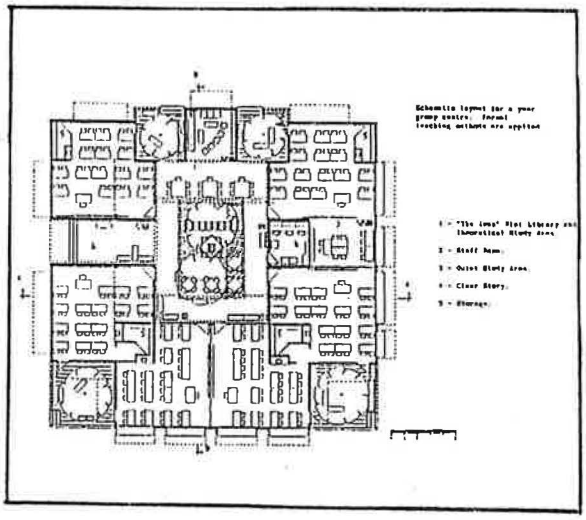


Fig. 8

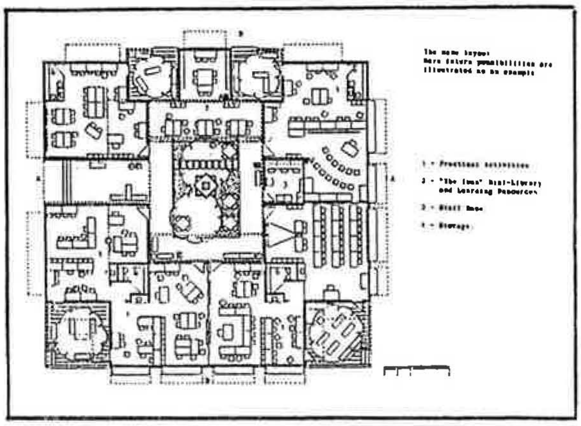


Fig. 9

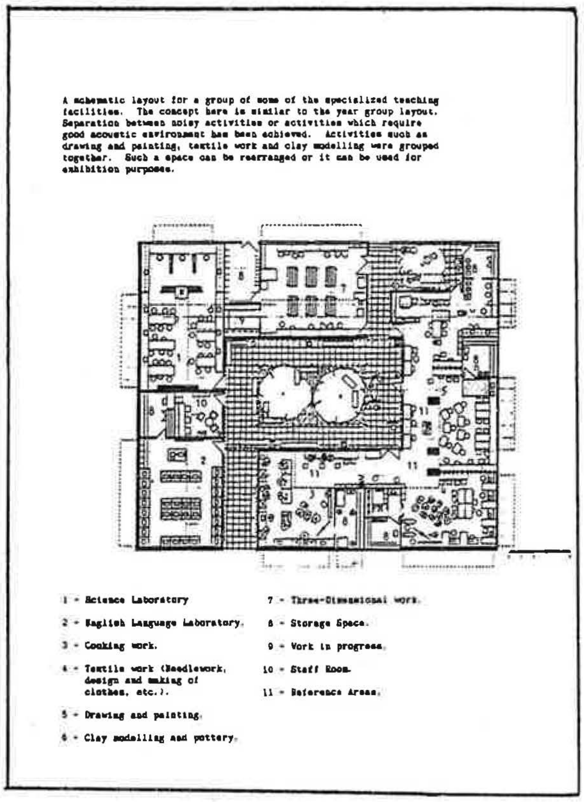


Fig. 10