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The first floor office overheating problem suggests that provision for natural ventilation was insufficient despite being increased from the original scheme. In view of the general increase of the use of electronic office equipment in this type of building, consideration should be given to maximising the opening window area at the design stage. This will ensure that the potential of natural ventilation is maximised and reduce the necessity for air conditioning.

The office heating system performed satisfactorily and the occupier had no criticisms to make. The design of the system and controls was suitable for the application, and operation was correct except for the absence of weekend set-back. In addition, the control temperature may be considered a little high, but is within the normal range of temperatures generally used in office areas.

The production area heating system, in conjunction with the destratification fans and roof extract fans, provides a comfortable working environment. These cater effectively for the wide range of heat loads and ventilation demands imposed by the activity. The printing presses incorporate a number of heaters, the total heat output of which may vary by 400%, depending on the type of printing taking place. The control of the heaters and fans is simple with individual thermostats for each heater and manual switches for fans, but appeared to be well matched to the process, allowing operators to control the environment to suit the activity.

Side view

Domestic hot water was fed from electric storage water heaters, locally mounted, and this represents an efficient use of energy by eliminating transport losses and minimising standing losses. The storage loss from these units is small, particularly in comparison with a system utilising the main heating boiler.

The building demonstrates that a good quality building, both in terms of design and construction, can be developed at reasonable cost, requiring only simple management to achieve good energy efficiency.

ACKNOWLEDGEMENTS

The case study has been prepared by W S Atkins Consultants Limited. The assistance of the building owner and developer is gratefully acknowledged.

PASSIVE COOLING

Ventilation using earth tubes

A new theatre at Bedales school, designed by Hampshire County Architects, includes on its green agenda a cooling system made from underground concrete pipes, through which cold air is driven

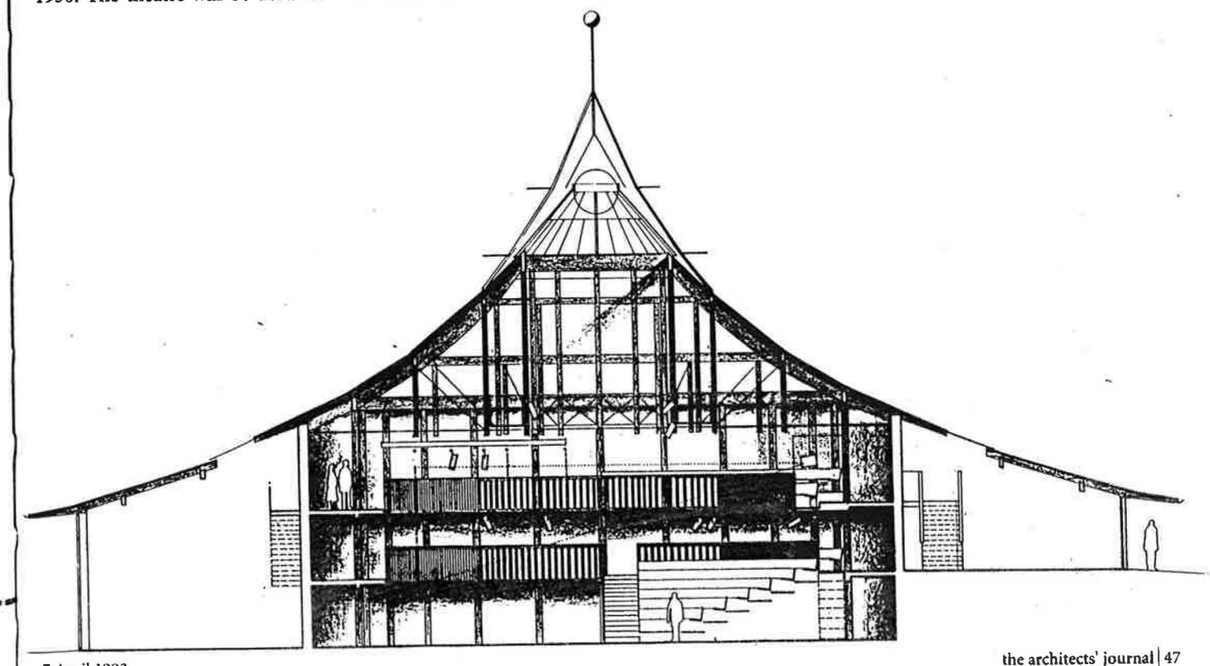
BY BARRIE EVANS

To mark its 1993 centenary, Bedales school has commissioned a new classroom and study block, and a dormitory, all will soon be completed. There are also plans – though fund-raising is taking longer than expected – for a theatre. All three buildings are designed by Hampshire County Council, led by Colin Stansfield-Smith, an arrangement made possible because the private school is a charity, one of the few out-of-house client types that local authority architects are permitted to serve.

The Olivier Theatre, as it will be called, will be used for a variety of activities. Much of the time, it will be used as a teaching space for drama, music, dance, scenery- and costume-making. It will also house the wardrobe, a historical and theatrical costume collection started in 1930. The theatre will be used for school performances, and may be hired out to other organisations out of term time.

The job architect, Ian Templeton, describes briefing and sketch-design development as unusual. The specific brief simply listed the range of functions that were to be accommodated, indicating a need for flexibility, an awareness of green issues and stating that the building should be 'magical'.

Below: job architect Ian Templeton's drawing of the auditorium of the Olivier Theatre, with its galleries and timber roof structure



Cooling the auditorium

One challenge of the green brief, and of the cost equation of a building likely to be used only infrequently for performances, is to provide cooling when the auditorium is full yet without using air-conditioning. One precedent is the high-ceilinged Victorian schoolroom with its capacity to collect stale, warm air above head level and which is flushed out several times a day. Tadley school, also designed by the Hampshire architects, has a similarly upsweeping roof which provides an air-collection space akin to that in a Victorian schoolroom, but also uses roof-top venting to allow the stack effect to help drive natural ventilation.

At Bedales, ventilation will be similar to that at Tadley during teaching times. But during summer-time performances, there will need to be extra fresh air and cooling capacity. The plan is to lay concrete pipes in the ground and drive cool air through them, which will, in turn, cool the surrounding earth. When auditorium cooling is required for performances, ventilation air will be drawn in through the earth tubes and thus cooled, and distributed at low level in the auditorium. The controls have not yet been designed, but, in principle, they should be simple. However, dealing with the natural variability of earth and air will make them more complex and will require careful commissioning.

Modelling of the tubes and auditorium continues. The latest tube configuration is of four concrete pipes 50-75mm thick, 80m long and 900mm in diameter to be laid two metres deep and two metres apart. The air velocity modelled is

2m/s. This looks near optimal thermally, but cost studies have not yet been produced. The large-diameter pipes provide a lot of surface contact area for heat transfer and are big enough to crawl through for maintenance. Some aspects, such as the slope of the pipes for drainage and concerns over legionella, have yet to be resolved.

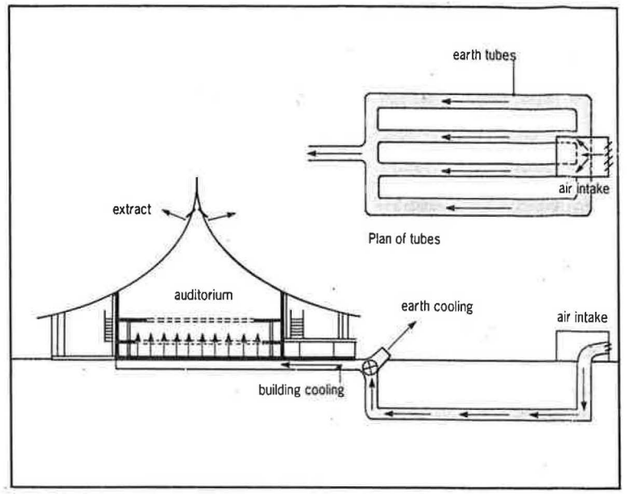
Ideally, the ground would be dense – without insulating air pockets. Waterlogging, or even water movement, could help, since water is a relatively good conductor. On this site, the ground is dry down to 3.5m in the trial pits cut in November and the earth mostly sandy clay – not ideal, but acceptable.

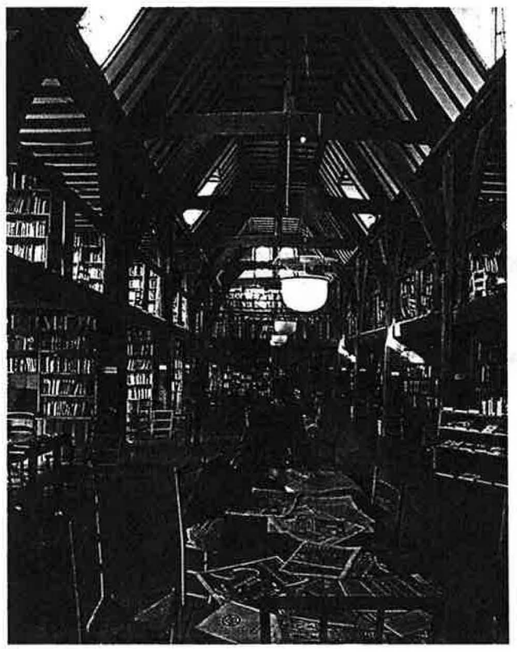
The cooling capacity for a modelled worst case – a 20°C inlet air temperature to the tubes maintaining a supply air temperature of 14°C – is 50kW. This about matches the predicted heat loads of 32kW from people (400 @ 80W) and 25kW from lights in an evening performance. One side-effect of the high lighting load being located at the apex of the roof is that it may help drive the stack ventilation. But it wouldn't cope with a further 50kW peak daytime solar gain through the structure as well.

In pursuing a green agenda, the school has to decide whether it is prepared to accept the looser control over air conditions generally than would be achieved with mechanical air-conditioning. There will have to be a restriction on daytime performances during hot weather, unless some mechanical assistance – such as putting a fan in the occulus (not compatible with the current architecture) and putting a chiller unit in the air inlet – is provided.

It is characteristic of a passive system that its performance reflects the inherent variability of the natural forces it taps into. It is easy enough to say that controlling temperatures to, for instance, ± 1°C, as with air-conditioning, is unnecessarily restrictive and that specifications could be looser. But how much looser, we do not yet know. The standard laboratory comfort trials are not necessarily a predictor of what comfort tolerance is acceptable in buildings that occupants know are green. What would we prefer or accept? We need to know soon if we intend to expand the stock of buildings with passive-energy systems.

Right: schematic section and plan of the earth-cooling systems. Below: the Gimson library, a built confirmation of its Arts and Crafts traditions. Opposite page: model (below and bottom) showing dominance of the roof and how the auditorium is surrounded by teaching space. Far right: because of the sloping site, the ground-floor level is only a part plan. The main entrance is at first-floor level





Theatre structure

Another untypical stipulation of the brief stated that the auditorium should be hexagonal, a democratic shape though not traditionally one which lends itself to proscenium performances. This led the architects initially to a plan for a 12-sided building. Following discussion between the designers and clients, it was decided that the auditorium should be made square and the design for the building eight-sided.

The architects also liaised with the school's heads of English and music, though the school's democratic approach sometimes made it difficult to discern who was making the final decisions.

The tone of the design is set by the school's spread-out set of buildings in a woodland setting and its Arts and Crafts traditions. The timber-framed Gimson library is a focal point of the school.

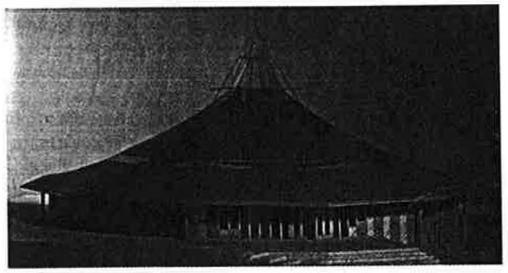
The Arts and Crafts influence can also be sensed in the fact that the brief called for a green approach to the theatre. This is an area the county architects – best known for mid-tech, low-energy schools on open sites – are experienced in, both as masterplanners and designers.

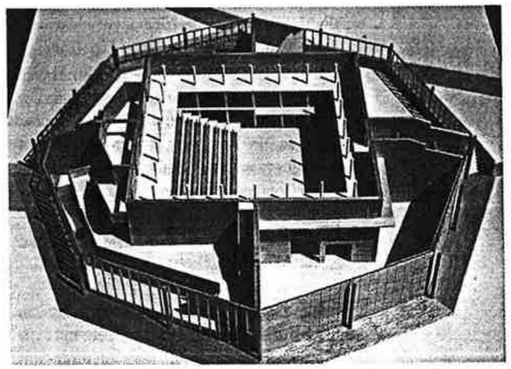
The octagonal theatre building has a 1000m² footprint and is dominated by its roof, which comes to a central point in a glazed occulus incorporating big circular windowvents. There is metal framing at the top for strengthening and to provide a platform for maintenance work. The roof framing will be formed from timbers and tension cables. The lower roof slopes will be copper-clad, the upper ones tiled, some areas patterned, perhaps with tiles that the students design and fire themselves. Widely overhanging eaves will provide considerable protected outdoor space. External walling will be pole columns with coloured boarding between. Inside, the servant spaces wrap round the masonry box of the auditorium, the roof floating above it. The main entrance is at first-floor level due to the slope of the site. On the ground floor, there is retractable raked seating. On the first and second floors, there are galleries around all four sides capable of taking two or three rows of seating: total capacity will be about 400. The galleries give a sense of an Elizabethan theatre such as the Globe, though this was not a part of the main design intention.

'Drama has lived from hand to mouth and in holes and corners, rehearsing in classrooms before breakfast.' This early extract from the *Bedales Record* shows that the school has long been committed to the performing arts. Now it will be well provided with facilities as well. □

ESTIMATED BUILDING COSTS

Building element	Cost, including fees and VAT (£)
Foundations	176,000
Upper floors, frame	155,000
Roof	356,000
Stairs	9,000
External walls, windows, 101,000 doors	
Internal walls, doors	88,000
Wall finishes	43,000
Floor finishes	44,000
Ceiling finishes	88,000
Fittings and furnishings	121,000
Services	742,000
External works	38,000
Total	*1,961,000*





CREDITS

OLIVIER THEATRE AND GIMSON LIBRARY, BEDALES SCHOOL

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