

## Building physics design

There is considerable largely anecdotal evidence to suggest that archive material survived better prior to the advent of central heating and air conditioning. This may be arguable, but by observation of historical building types (Buchmann, 1993; Cassar and Clarke, 1993; Stehkämper, 1988) and by comparing the actual performance of mechanical systems against the calculated predictions, it is evident that the building itself can exert a significant moisture as well as a thermal inertia effect.

A building's fabric, and contents, have an ability to absorb moisture and heat during periods of excess and re-emit them during periods of deficiency. The result of this phenomenon is the smoothing of both room temperature and humidity fluctuations. Along with the recent development of advanced computer-based analytical techniques for predicting the thermal dynamic performance of building materials has come the potential to develop similar techniques for predicting moisture performance. However, until now there have been no generally available moisture analytical techniques suitable for use during the design process. It is only when these techniques are available that the scale of moisture effect can be explored and its potential established. In this way, buildings can be designed to fully exploit this phenomenon as an alternative to environmental control solutions based on mechanical equipment.

In the case of the Jersey Archive, the proposal to make maximum use of passive environmental control received active support from the client. The main proviso was that repository conditions should aim to achieve the recommendations of the then current British Standard 5454:1989 (British Standards Institution) namely,  $60 \pm 5\%$  relative humidity and  $15.5^\circ\text{C}$ . To allow the combined passive environmental effects to be better understood and to establish how far they could provide total control, an integrated moisture and thermal dynamic building simulation computer tool was developed. This tool allowed quantitative analysis of building design options and hence a design tailored to maximize the passive effects – a technique that was unavailable to the designers of previous examples of non-air-conditioned archive repositories.

As with most passive environmental control projects, the real benefits are yielded where this approach allows a significant change in the design solution. Simply reducing the size of mechanical plant generally provides only marginal benefit particularly with regard to capital cost. So this project set out to establish the feasibility of eliminating entire systems and, in particular, mechanical cooling and ventilation.

Figure 18 is based on one of the initial concept sketches used to illustrate that with standard U.K. weather data, a building with sufficient moisture and thermal inertia to respond to monthly average weather conditions could stay within the critical top limit of BS5454. If this could be achieved it would offer the client considerable benefits, including:

- significant reduction in building services capital costs
- reduction in plant room space and hence further reduced building cost

- reduced site infrastructure costs (e.g. in this case the avoidance of an electrical substation)
- less complex services systems
- reduced risk of plant failure jeopardizing archive conditions
- low energy consumption and running cost
- low long-term operating and maintenance commitments
- reduced pollution emissions and environmental impact.

### Identifying and developing the most suitable method

Approaches to modelling moisture movement through porous fabric over the last thirty years can be classified into two categories. One category applies the physical characteristic to representative analytical nodes (Jones, 1993; Stevens and Fordham, 1996) and the other considers the variation of moisture flux (or flow) within the thickness of the fabric. Where the movement of moisture within the fabric is to be considered, the latter more rigorous method is required.

Three variations of this latter method were considered. Each approached the problem in a different way, though each was based, fundamentally, on the same theory. The variation adopted offered the best basis for an accurate model because it was versatile in all three dimensions, it was well documented and it was the only one that had undergone any sort of experimental validation. Figure 19 describes the principles of the moisture algorithm written for this method. The main modelling assumptions are:

- All moisture movement takes place in the vapour phase and is due to gradients in vapour pressure or air-borne convection. Thus all moisture must first be evaporated from the liquid phase with the latent heat considered in the thermal modelling
- The fabric is divided into finite elements, the size of which depends on the extent to which moisture is expected to vary at a particular point
- The vapour resistance of air/fabric interfaces is regarded as small in comparison with the vapour resistance of fabric
- All fabrics are considered to be rigid, homogeneous and isotropic
- Detailed hydrodynamics are not considered and the air nodes are considered to be well mixed
- Thermal transmission values are not temperature dependent and thermodynamic equilibrium exists in all places at all times
- Hysteresis (or the rate of change over time) of the sorption isotherm (analogous to thermal capacity in heat terms) and any temperature dependence of this isotherm is ignored.

### Application of moisture algorithm

Having developed the moisture algorithm, it was added to Oasys Ltd's ROOM dynamic thermal software (Holmes and Conner, 1991) to allow simultaneous room temperature and humidity modelling. A computer model of a repository room was assembled and building component combinations tested to establish their relative thermal and moisture performance. Sorption isotherms of the form shown