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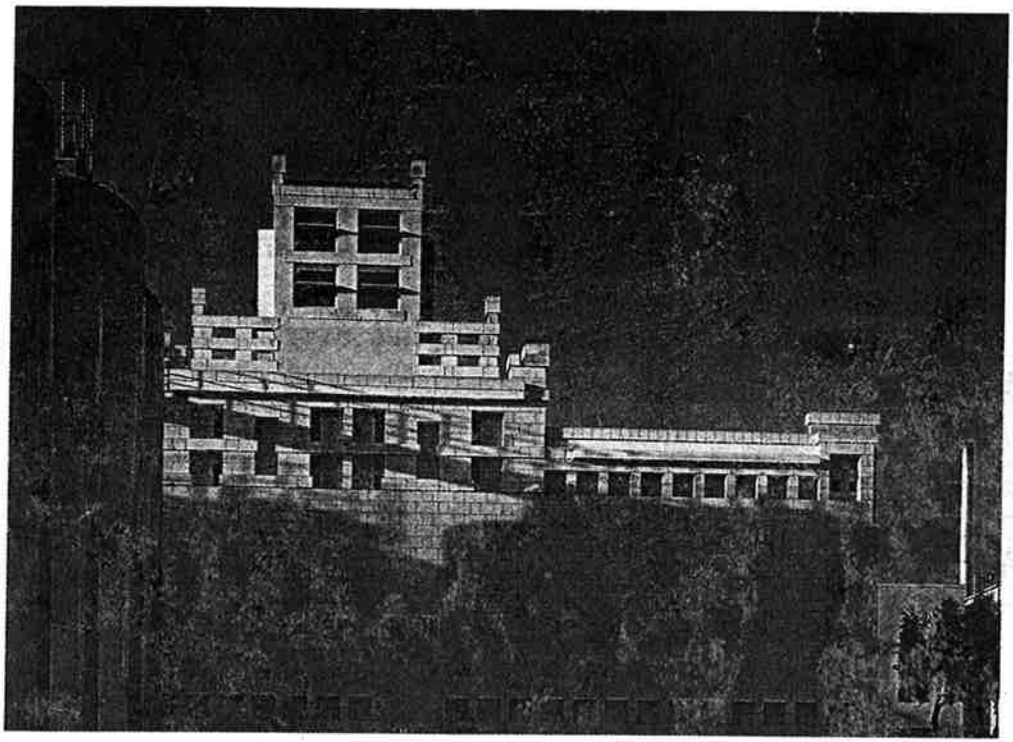
CI/SfB 28 (M)

PASSIVE COOLING

An alternative to air-conditioning

Using a building's form and fabric for cooling is still in its infancy, but the results of a year's monitoring of the Malta Brewery indicate that it is performing as well as the computer models predicted

BY BARRIE EVANS



PETER COOK

The Malta Brewery with one of the south ventilation towers in an otherwise largely opaque wall

Simmonds Farson Cisk's Malta Brewery is a factory building in which no cooling services system is used despite outdoor summertime temperatures of 35°C and above. A year's monitoring of the building in use shows that it is performing much as predicted, which is good news both for the client and for the designers, Alan Short and Brian Ford – at the time partners in Peake Short & Partners, now constituted as Short Ford & Associates.

Building specifications

The process building at the Malta Brewery is a two-storey factory, near-square in plan, with a 3m-wide corridor running like a jacket around the outside of the process hall. At first-floor level, the corridor floors are mostly gantry walkways so that air can flow vertically. Ventilation towers project above roof level to the north and south.

The process vessels are highly insulated for temperature control; indeed the fermentation vessels stand outside in the sun. But temperatures within the process hall must be controlled for the few staff and because liquid there stands in less-insulated pipes. The design temperature range is 24-27°C with a maximum of 30°C. Within the corridor (above 30°C), temperatures run more freely – the considerable air movement there is some compensation.

The limestone and Baroque traditions of Malta continue at the brewery: the stone is cheap and skilled craftsmen are available. Outer walls are of limestone: a 230mm inner leaf, 75mm empty cavity then 150mm outer leaf. The inner walls separating the corridor from the process hall rise 2.5m in 230mm concrete block, then are single-glazed above. Floors are reinforced concrete with vitrified tiles.

The 25kN/m^2 floor capacity for process plant requires a 270mm thick concrete first floor. The stepped roof is 50mm slabs on 50mm dense foam on lightweight screed to falls on 120mm concrete planks. The overall effect is of considerable thermal mass, though there are a significant number of openings in the outer skin and the ventilation towers

Environmental objectives

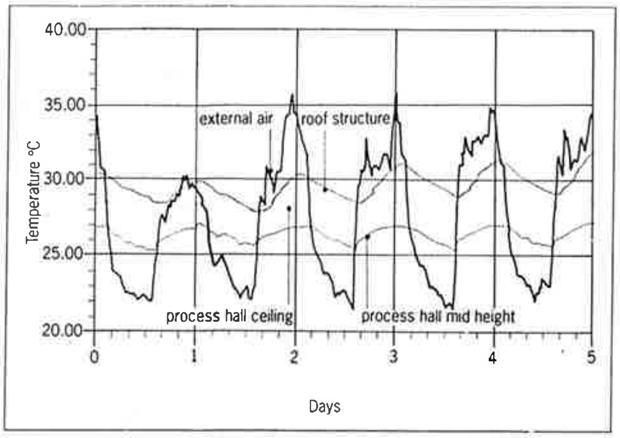
The building form is shaped significantly by four environmental objectives:

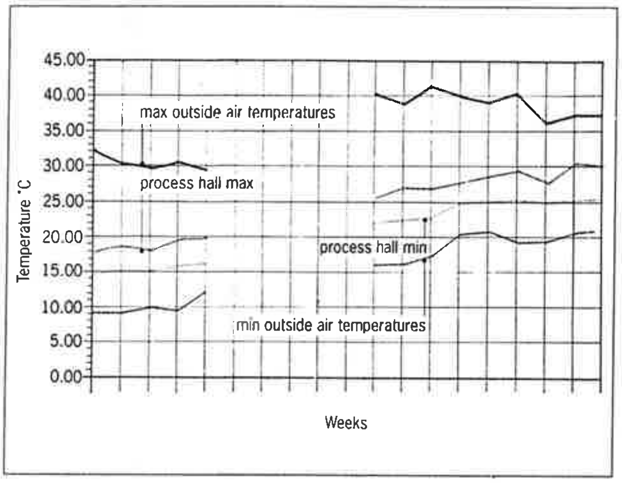
- to minimise daytime solar heat gain by preventing direct solar radiation entering the process hall
- to use the thermal capacity of walls, floors and roof to even out diurnal temperature fluctuations (which can be 20°C or more), preserving night-time coolness
- to encourage ventilation at night to remove heat from walls and roof
- to provide good daylight without attendant solar gains, relying on reflected light from the corridor and diffuse northern light through openings.

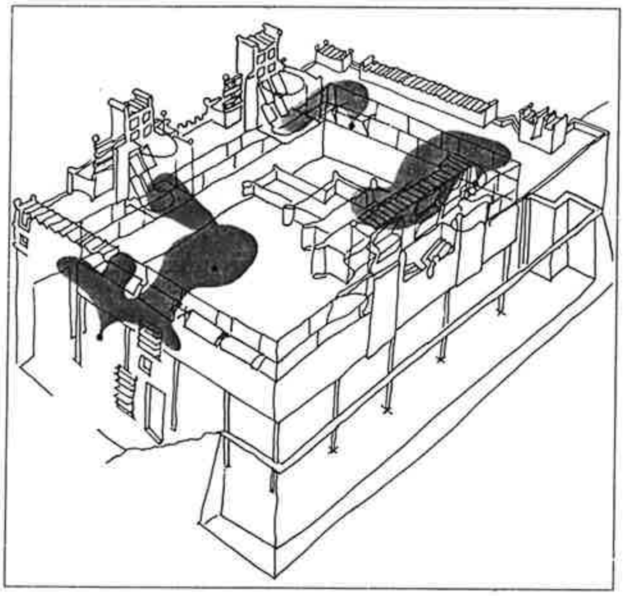
Summer cooling is a combination of daytime and nighttime operation. In both cases the windows and vents in the towers are permanently open. By day the roof and walls soak up much of the solar heat. Re-radiation from the roof to the interior is limited, and re-radiation of heat from the outer walls into the corridor and heat gain in the towers themselves produces stack-effect air movement. A lag of approximately eight hours is the objective.

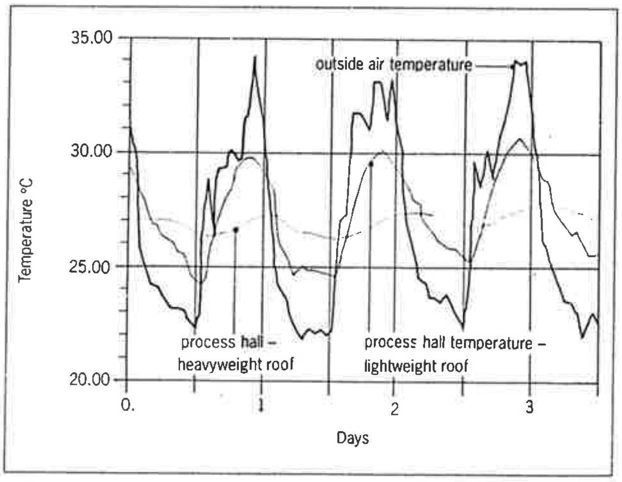
At night, high-level vents are opened in the production space and air is drawn through them into the towers by stack effect, so cooling the production space and its fabric. Smoke tests have confirmed that the stack effect of the corridor provides a driving force entraining air from the production space.

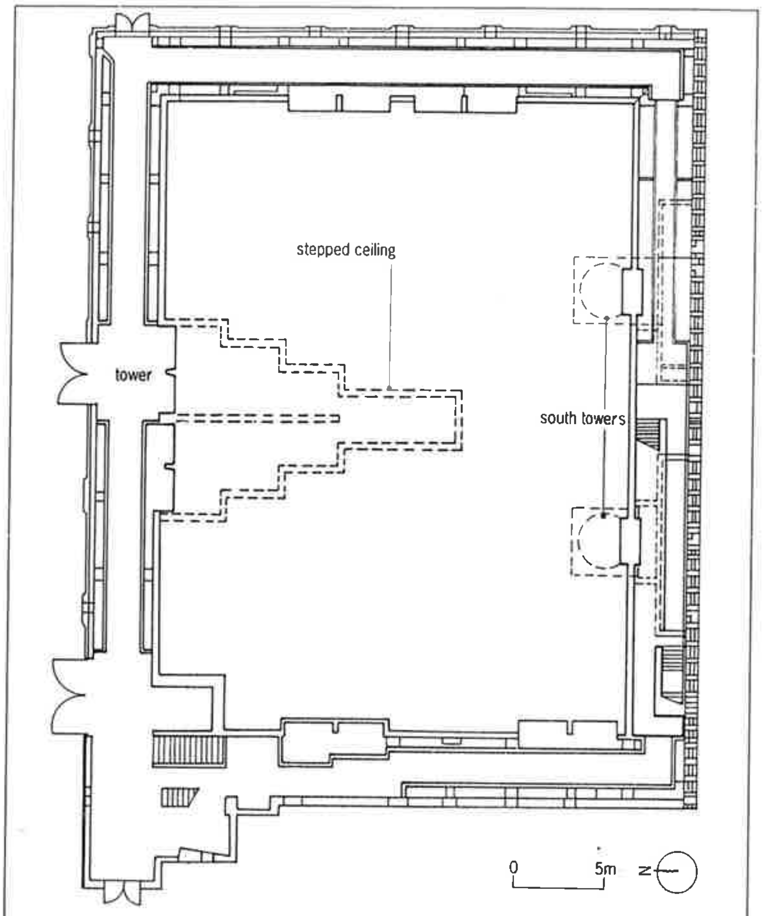
There is considerable stratification of air in the 5.5m-high production space so that ventilating at higher levels is enough. Hot air is encouraged to flow towards the north towers by the local stepped section of the roof. Smoke tests indicate that air flow near the ceiling is somewhat inhibited by downstand beams.

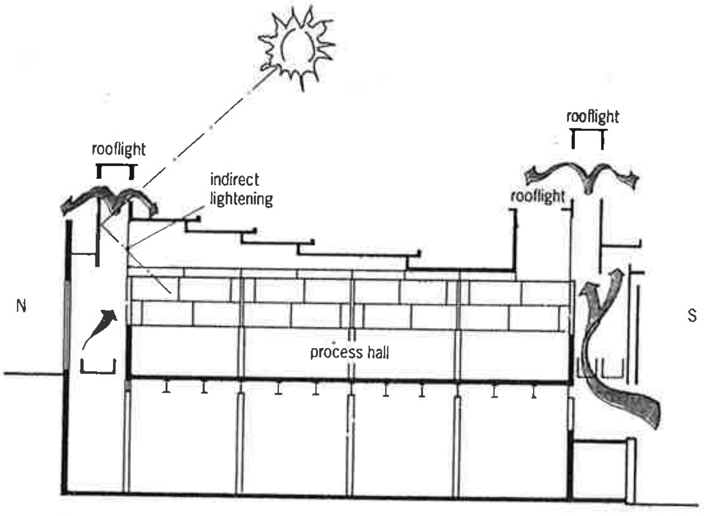




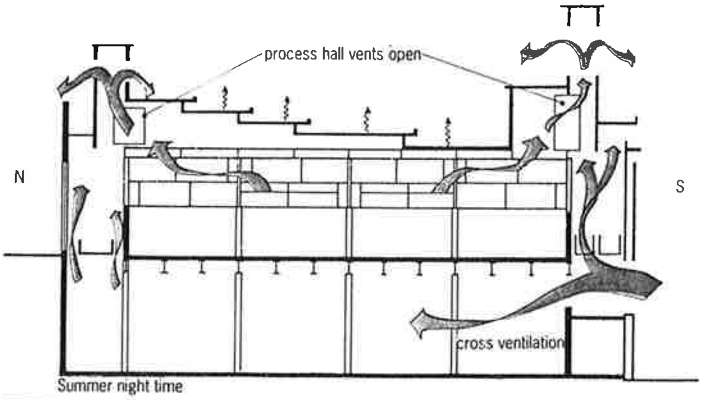








Summer daytime



Summer night time

Improving cooling performance

Monitoring of temperatures over the year and air-movement smoke tests have confirmed that the building is performing as predicted, indicating acceptable, stable internal temperatures while external temperatures fluctuate considerably. However, monitoring in early summer and in the August peak confirmed that there was not enough cooling to prevent longer-term heat build-up. Some options are still available to improve cooling performance:

- during the warmest days the external air is at a higher temperature than that in the corridor, thus counter-productively warming it. Though there are some large permanent openings to the south, the client should try closing corridor ventilation as much as possible in the daytime, including the tower vents
- nighttime stack effect produces a good draught, currently removing 20-30 per cent of daytime heat gain. It could be more effective if the air was ducted direct from the outside to the process hall rather than coming via the warm corridor.

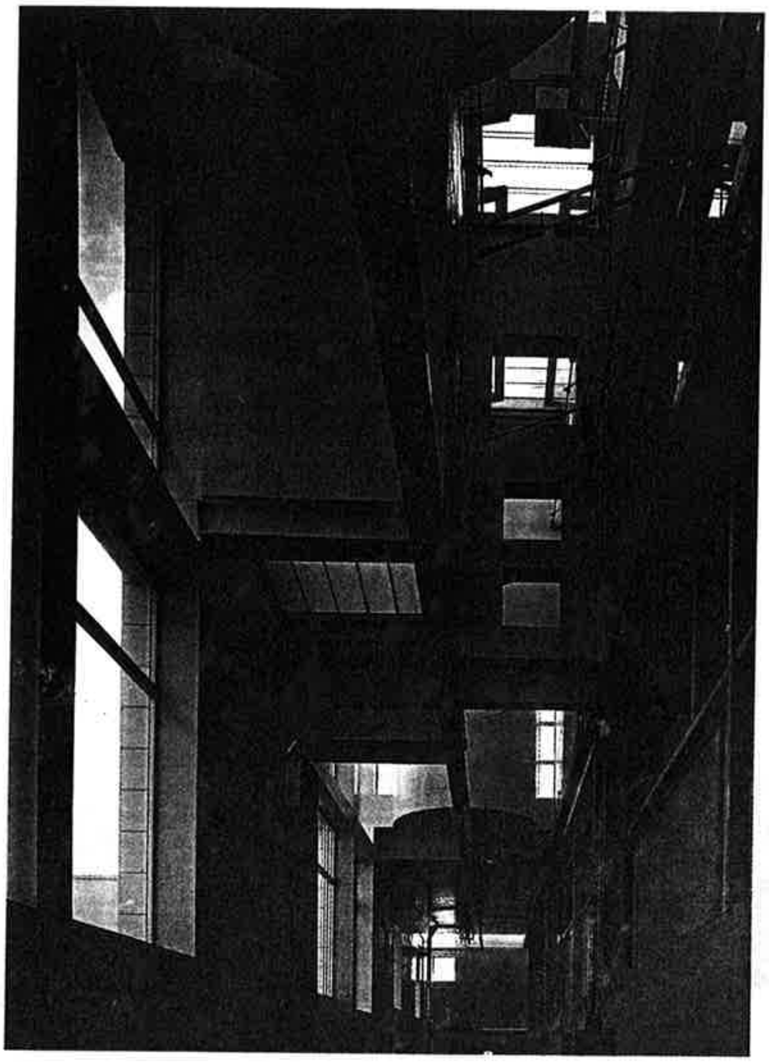
The wind factor

Another area of investigation was the effect of wind on the operation of the towers. Though they have openings on only two sides, these are big enough to receive wind from any direction. They contrast with low-energy schemes that have appeared in the UK recently with towers like scoops with their backs to the prevailing wind. This approach makes limited sense given the variability of wind direction.

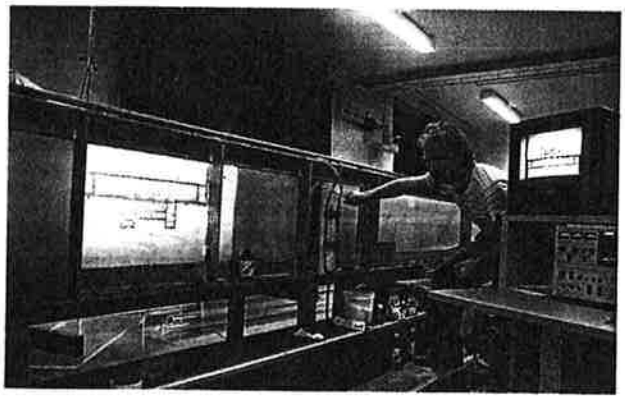
Wind effects must be accepted when using towers to promote stack effect, as air-flow rates and the proportion of air leaving each tower becomes difficult to predict. On the few occasions windspeeds gusted above 5m/s, the air flow went into reverse. With the roof sloping north, when the wind was in the opposite direction, nighttime ventilation was inhibited and pulled the air to the south. Depending on wind speed, it also tended to become static.

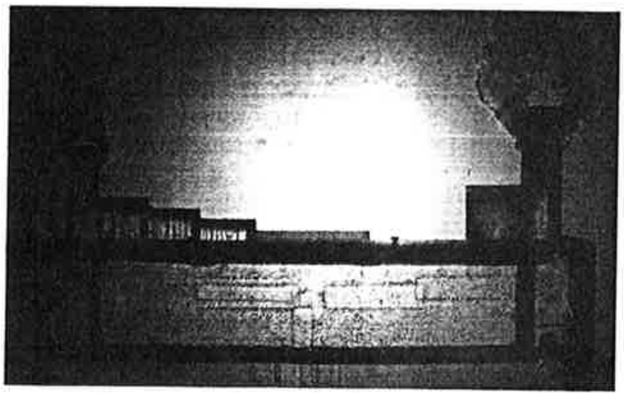
Lighting levels, though somewhat different from those predicted using model tests, are acceptable. Light entering the east and west corridor rooflights and the towers and reflected off walls into the process hall was less intense than predicted, while that from the northern windows was more intense, giving less light than predicted at the centre but still achieving a two per cent daylight factor for an overcast sky.

Right: corridor/buffer space between outside and process hall. Below: saline bath simulation of movement in the laboratory rig at Cambridge. The density of fluids results in the building being simulated upside down. Bottom: inverted view of the Perspex model under test. Opposite, fig 1: summer daytime: the process hall closed up. Fig 2: summer nighttime: stack effect used to cool the process hall. Fig 3: plan showing the corridor/buffer space around the process hall. Fig 4: example of temperature stability achieved with heavy structure. Fig 5: two phases of monitoring showing temperature build-up from May to August. Fig 6: example of use of smoke tests to show movement of air to towers. Fig 7: comparing the effects of light and heavyweight roofs



PETER COOK





Using models

Different models serve different purposes – no one can yet offer most of the answers. The designers used FRED (Finite Resistance Energy Determinator), a computer model developed by Nik Baker of Cambridge Architectural Research. It is not the most complex, which makes it easier to use at sketch stage and so ask 'what if?' For example, what is the consequence of using a light rather than a heavyweight roof? FRED is also one of the few computer models addressing both stack and wind effects.

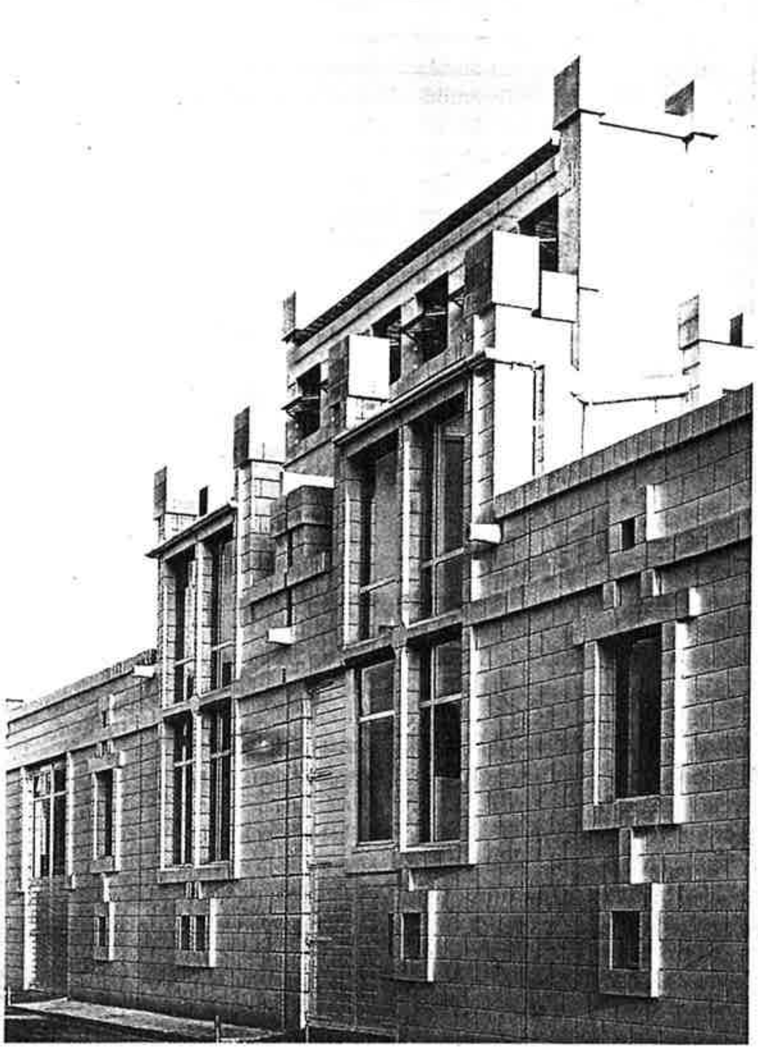
Models generally have some way to go in indicating the precise routes of air movement in complex spaces, in modelling heat transfer between air and adjacent surfaces, and in detailing air movement around obstructions of very different scales. Smoke testing in this building filled some of those gaps.

Another approach which shows how air moves round building elements is a physical rather than computer model, a saline bath being developed by Dr Paul Linden at Cambridge University Department of Applied Mathematics and Theoretical Physics. The designers looked at this only after the design was complete but are using it again for later schemes.

What the future holds

Avoiding air conditioning saves on capital and running costs, reduces output of CO_2 and can provide a quality of indoor air via natural ventilation which is often preferred. But rising insulation and air-tightness standards and heat generated by IT equipment combine to make summertime cooling an increasing problem in the UK. When buildings need cooling systems, it is a question of how far we can go in using the form and fabric of the building instead of air conditioning to create acceptable environments?

Right: northside tower with more openings for daylight than the south. Below: looking up at the tower



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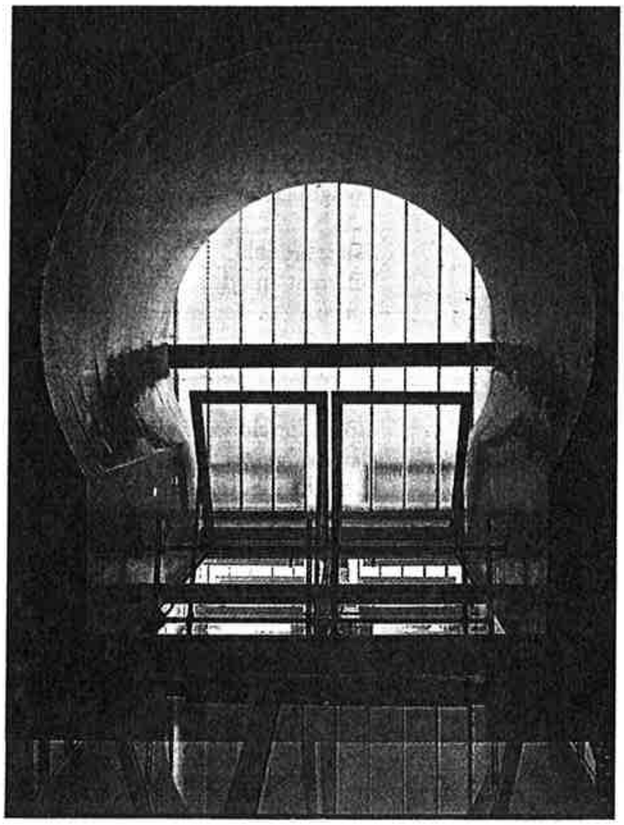

PETER COOK

There is much empirical knowledge, ranging from our experience of houses to massive masonry cathedrals. But the engineering of buildings to provide an acceptable environment for occupants, to a price, and thus to keep the liability lawyers at bay, needs to be precise. This requires dependable modelling, especially for passive cooling. If the engineering of a cooling services system is wrong the first time it may be relatively easy to resize a fan or pump or tweak the controls. If the form and fabric of a passively cooled building is wrong, resizing may be impossible, and at best likely to be expensively disruptive to users. Liability is a real issue here.

The knowledge base on passive cooling is growing. Computer modelling is advancing. In AJ 12.8.92 we reported on a recent BRE study of six office buildings whose thermal capacity had been used to limit summertime overheating. Useful rules of thumb emerged, though our not being allowed to identify and describe the buildings (liability again) blurred the message.

The Malta Brewery could not be exported wholesale to the UK – we do not have the temperature differences to drive the air flows nor the same sort of cooling loads.

Nevertheless there are ideas that can travel. The growing availability of modelling makes such passive cooling more practical.

The building makes evident the order of magnitude of the features, such as the towers, that are required. And they get bigger if the driving temperature differences are smaller, or air flows need to be slower for human comfort.

Despite our climate there are opportunities to use thermal capacity and induced ventilation to cool buildings. Short Ford & Associates has already started building like this for De Montfort University at Leicester.

If the dreaming spires of Oxford were the university symbols of the past, perhaps the green university of the future will be marked by its dreaming flues. ☐

Timber buildings

BY PATRICK HISLOP

A significant number of recent projects show the growing interest in using timber among architects in the UK, although we still fall behind the continent and North America in the number and scope of notable timber buildings.

UK examples range from buildings that are almost all timber to composites of timber and steel to those with an increasing proportion of timber components. This growth may be due to the waning of Post-Modernism, where structure and its materials are not expressed, and to an increasing ecological awareness. Timber has a good ecological standing as a renewable resource with low-energy requirements for conversion and the potential for design of energy efficient buildings.

There is justifiable concern about the destruction of tropical and old temperate forests, but considerable progress has been made by the producing countries toward establishing properly managed forests that match long-term environmental benefits with an adequate income for their peoples. Architects need to maintain a balanced view, but the necessary information is gradually becoming available to specifiers so that they can make up their own minds about the suitability and acceptability of any species.

Patrick Hislop is chief architect of TRADA Technology

TECHNICAL ADVICE

TRADA Technology

TRADA offers:

- an advisory service
- inspection and assessment of timber in existing buildings
- design consultancy on architectural and joinery detailing, energy efficient design, etc
- structural design or appraisal.

Building Research Establishment, 0923 664664

BRE's Advisory Service includes information on the use of timber.

TRAINING AND CPD

TRADA Technology

TRADA's CPD lectures and seminars are advertised in the AJ and other journals. They include:

- CPD lectures and seminars, organised by arrangement with RIBA regional CPD organisers
- lectures for universities, professional institutes and associations
- seminars on environmental design, European standards, architectural detailing, Building Regulations, specifying timber, etc.

Building Research Establishment

Seminars, conferences and road-shows on timber-related subjects.

INFORMATION SOURCES

TRADA Technology, Stocking Lane, Hughenden Valley, High Wycombe, Buckinghamshire HP14 4ND, 0494 563091

Frequent publications including (prices to non-members):

- annual list of British and European standards relevant to timber (£20)
- 'Updata Standards', a monthly updating service on British, EC and ISO standards relating to timber and standards development in progress (£85 per year)
- 'Wood Information Sheets' on specific products and applications (£2)
- a wide range of in-depth publications – list available
- 'Panel Products Database' available in print or on specific enquiries by telephone.

Professional Associate Membership of TRADA at £100 per year + VAT for up to 10 staff reduces the cost of publications and consultancy fees and includes the Updata service.

Building Research Establishment, Garston, Watford, Hertfordshire WD2 7JR, 0923 894040 (information sales 0923 664444)

Publications especially on joinery and timber treatment. See:

- 'Defect Action Sheets', series finished
- 'BRE Digests', singly £4.50

The BRE Update package is a monthly mailing of all new Digests, Information Papers and Good Building Guides, plus *BRE News* and the annual Publications Guide (£65 per year)

British Woodworking Federation, 82 New Cavendish Street, London W1M 8AD, 071 580 5588

A variety of publications on joinery.

Forest Forever, c/o The Timber Trade Federation, Clareville House 20-27 Oxendon Street, London SW1Y 4EL, 071 839 1891

Current information on the availability of timber from well-managed sources.

American Plywood Association (APA), Southern Pine Marketing Council (SPMC) and Western Wood Products Association (WWPA), Regent Arcade House, 19-25 Argyll Street, London W1V 1AA, 071 287 2625 (APA), 071 287 2718 (SPMC and WWPA)

Information on US plywoods (APA) and on American woods generally (SPMC and WWPA).

Council of Forest Industries of British Columbia, Tileman House, 131-3 Upper Richmond Road, Putney, London SW15 2TR, 081 788 4446

Publications on Canadian softwood for timber framing, cladding, joinery, etc.

Swedish Finnish Timber Council, 17 Exchange Street, Retford, Nottinghamshire DN22 6BL, 0777 716616

Information on Scandinavian softwood for timber framing, cladding, joinery, etc.

BUILDINGS TO VISIT

The Burrell Collection, Glasgow (AJ 19.10.83)

A composite structure of laminated timber, steel connections and concrete columns.

Architect: Barry Gasson Architects.

Fountains Abbey visitors centre (AJ 12.8.29, AR November 92)

Steel framing but innovative and extensive timber cladding, roof deck and windows.

Architect: Edward Cullinan Architects.

The Children's Zoo, Whipsnade, Bedfordshire

Timber construction throughout.

Architect: John S Bonnington Partnership.

Littledown swimming pool, Bournemouth

Large covered pool using curved laminated beams and wooden roof deck.

Architect: W H Saunders & Son

Sheringham pool, Norfolk, (AJ 7.9.88)

All-timber pool building with lattice beam and column construction and plywood external cladding. Architect: Alsop & Lyall.

Visitors centre, West Stow, Suffolk

An all-timber pole structure with timber cladding, roofing and decking. Architect: TRADA Architects

Gwalia housing project, Swansea

Prize-winning timber framed housing.

Architect: PCK Architects.

TRADA HQ building, High Wycombe (AJ 10.11.76)

Structural hardwood frame, plywood decks and cladding. Architect: TRADA Architects.

Hooke Park, Beaminster, Dorset, (AJ 20.11.85, AR September 1990)

Experimental catenary and arched structures of green pole forest thinnings.

Engineer: Buro Happold. Architect: ABK.

Cost summary

Existing building	*Total cost*	*Cost per m²*	*Percentage of total*
SUBSTRUCTURE	**25,616**	**15.55**	**2.03**
SUPERSTRUCTURE			
Frame	10,095	6.13	0.80
Upper floors	5,804	3.52	0.46
Roof	67,120	40.75	5.34
Stairs	5,248	3.19	0.42
External walls	5,500	3.34	0.44
Windows & external doors	29,684	18.02	2.36
Internal walls, partitions	12,333	7.49	0.98
Internal doors	67,025	40.70	5.34
Group element total	*202,809*	*123.14*	*16.14*
INTERNAL FINISHES			
Wall finishes	33,430	20.30	2.66
Floor finishes	42,182	25.61	3.36
Ceiling finishes	26,647	16.18	2.12
Group element total	*102,259*	*62.09*	*8.14*
FITTINGS	**48,209**	**29.27**	**3.84**
SERVICES			
Sanitary appliances	6,869	4.17	0.54
Disposal installations	5,696	3.49	0.46
Water installations, Space heating/air treatment	254,544	154.54	20.26
Electrical installations	161,331	97.95	12.84
BWIC	18,716	11.36	1.49
Builder's profit, attendance	28,243	17.14	2.25
Group element total	*475,399*	*288.65*	*37.84*
EXTERNAL WORKS			
Site works	66,630	40.46	5.31
Drainage	37,014	22.47	2.94
Minor building works	86,451	52.49	6.88
Group element total	*190,096*	*115.42*	*15.13*
PRELIMINARIES	**183,130**	**111.19**	**14.57**
CONTINGENCIES	**28,995**	**17.60**	**2.31**
TOTAL	**1,256,512**	**762.91**	**100**

New building	*Total cost*	*Cost per m²*	*Percentage of total*
SUBSTRUCTURE	**277,208**	**48.92**	**4.71**
SUPERSTRUCTURE			
Frame	108,241	19.10	1.84
Upper floors	140,956	24.88	2.39
Roof	414,851	73.22	7.05
Stairs	61,152	10.79	1.04
External walls	260,256	45.93	4.42
Windows & external doors	296,263	52.29	5.03
Internal walls, partitions	143,907	25.4	2.44
Internal doors	234,542	41.39	3.98
Group element total	*1,660,175*	*293*	*28.19*
INTERNAL FINISHES			
Wall finishes	133,223	23.51	2.26
Floor finishes	206,962	36.53	3.52
Ceiling finishes	100,933	17.81	1.71
Group element total	*441,118*	*77.85*	*7.49*
FITTINGS	**331,830**	**58.56**	**5.64**
SERVICES			
Sanitary appliances	103,490	18.27	1.76
Disposal installations	19,597	3.46	0.33
Water installations, Space heating/air treatment	875,682	154.54	14.87
Electrical installations	555,011	97.94	9.43
Lift, conveyor installations	111,431	19.67	1.89
BWIC	56,583	9.98	0.96
Builder's profit, attendance	104,715	18.48	1.79
Group element total	*1,826,509*	*322.34*	*31.02*
EXTERNAL WORKS			
Site works	229,219	40.45	3.89
Drainage	127,337	22.47	2.16
Group element total	*356,556*	*62.92*	*6.05*
PRELIMINARIES	**858,040**	**151.44**	**14.58**
CONTINGENCIES	**135,850**	**23.98**	**2.31**
TOTAL	**5,887,279**	**1039**	**100**

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