NON-DOMESTIC BUILDING DESIGNS INCORPORATING PASSIVE ENERGY SYSTEMS

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A series of design studies is being sponsored by the Department of Energy to investigate the practical application of passive solar technology in non-domestic buildings. The first set of eight studies managed by Ove Arup is complete and two further sets managed by Halcrow Gilbert Associates (HGA) and Building Design Partnership are under way. These studies illustrate the opportunities to produce marketable low energy designs in which the architectural form plays the major role in generating a comfortable internal environment. The studies also show that such designs need cost no more than their conventional counterparts.

DESIGN STUDIES

The objectives of the current set of HGA design studies are to:

- produce a series of case studies demonstrating best practice in the application of passive energy systems to a range of building types.
- act as a mechanism for transferring technology from R&D projects to the architects and clients involved in the studies, and ultimately to the design community and construction industry at large.
- generate data on the cost, performance and amenity benefits of non-domestic passive buildings.
- develop practical building designs that can act as a seed bed for live building projects.

In each design study, the suitability of various passive energy techniques is explored for a particular building type by asking a firm of architects to propose a design that uses them effectively. The brief for each study is prepared in consultation with a client who has offered to cooperate in the study. These "quasi-clients" are also involved in the evaluation process. In each case the brief set is for a hypothetical building that is unlikely to be realised in as a direct result of the design study, although the results of the studies are expected to influence the future buildings of the clients and architects involved.

The key factors used to evaluate the proposal are energy performance, environmental performance, amenity, and capital cost. In order to judge these factors in context, a 'typical' reference building of a more conventional design is also assessed. To be successful the proposal must not only use less energy than the reference, but the value of the energy saving must be seen to justify the capital cost of providing it. The design proposal is developed through an interim sheme to a final sketch design with formal assessment at both stages.

The twelve non-domestic design studies managed by Halcrow Gilbert Associates have been divided into four groups of three. Each group of design studies concentrates on a particular building sector.

INDUSTRIAL BUILDINGS

A recent study has shown that fairly simple energy conservation measures such as; reducing fabric U values to ~0.4W/m²K and incorporating high performance loading bay doors, can reduce the space heating requirement of industrial buildings by up to 40% ([1] Hughes, 1989). After applying these energy conservation measures there is only limited potential for further displacing space heating with passive solar gains. This is particularly true of buildings which have a high level of internal heat gains. There is however, considerable scope for saving energy by displacing artificial lighting with daylight, and since the energy saved is electricity the financial value and environmental benefits have greater significance.

The three types of accommodation typically provided by industrial buildings, offices, workshops and warehouses have distinct requirements for temperature, lighting levels and other environmental criteria. In the schemes presented below, the architects were asked to consider carefully the environmental requirements of each space at the outset of the design.

Jestico + Whiles Design

The furniture maker SunarHauserman required a high quality building with a strong visual image for its European HQ. In their proposal, Jestico + Whiles designed each of the three main areas, offices, assembly shop and warehouse, with an environmental responsiveness appropriate to its function.

A 2120m² warehouse is located at the north end of the building in the form of a well insulated box with small windows. The storage of light sensitive materials and the low comfort temperature requirement of this space meant that daylight and solar heat gains would not have been welcome.

The central section of the building is occupied by a 1030m² assembly shop which is daylit through two south facing rooflights running the length of the building. Facing the brighter southern horizon, a smaller glazed area is required to achieve a given level of daylight and hence heat loss can be reduced. Each rooflight is shaded by a series of louvres suspended in an extension of the curved roof frame. These shading devices allow diffuse light and low altitude solar radiation to enter, but reject high altitude summertime solar radiation. Ductwork and service zones have been designated in order to limit the obscuration of the rooflights.

The 1530m² offices are located to the south of the assembly space, separated by a courtyard which enables an otherwise deep plan office to be daylit and natural ventilated, as well as providing a pleasant recreation space. On the southern elevation horizontal shading extends through the fenestration to form an internal light shelf with the intention of improving the distribution of daylight by reducing daylight levels close to the window and increasing them further away. The luminaires and their control system have been carefully designed to respond to the availability of daylight.

Scheme Assessment. Nearly 60% of the lighting energy demand should be saved by comparison with the reference buildings, but the heating demand likely to be 50% higher. In energy cost terms the design achieves an overall saving of 22% compared to the reference building. It is important to realise that savings in lighting energy demand do not translate directly into energy cost savings since the maximum demand element of the tariff is unlikely to be reduced in the winter period when lights will be on at least part of the time. Generally, the value of daylighting and solar heat gains outweigh the cost of the heat lost through the windows and rooflights. The exception is the north office facade onto the courtyard which is excessively glazed.

By comparison with the reference buildings, which suffer badly from overheating (a common complaint in many factories), prediction for the final design show no overheating in any area of the building. Visual comfort should be considerably enhanced in all areas as a result of the careful design of external and internal shading devices.

The estimated cost of the final design at £450/m² is within the original client budget of £485/m² and shows a cost reduction of £42/m² from the interim sheme design. SunarHauserman's managing director concluded that "the design represented an excellent investment .... and could be funded by normal financial institutions."

The Ryder Nicklin Partnership Design

Graphex Industrial Art are a design conscious company who required a new facility for manufacturing signs and exhibition materials. In their compact square shaped design, the Ryder Nicklin Partnership provided 1762m² of double-height workshop and 894m² of office space on two floors. The main feature of the design is the so-called "responsive roof" which comprises five 'Toblerone' shaped rooflights with sloping faces orientated north/south. Reflective roller blinds operate under the south face of the rooflights responding to temperature and solar radiation in order to combat overheating and glare. At the interim design stage the building had six rooflights and a substantial amount of side glazing in the workshop, the combined effect of which were very high levels of daylight. Removing one rooflight and much of the side glazing reduced both the building heat loss and the capital cost without affecting the lighting energy savings.

In this design the offices are located at the north end of the building since the extent of internal heat gains suggested that solar gains during the heating season would not be useful. Facing north, it was possible to size the double glazed windows to provide adequate daylight without the need for shading. Daylighting in the first floor office is supplemented by one of the rooflights which has a horizontal leylight underneath it to prevent cold down draughts and to diffuse incoming solar radiation.

Scheme Assessment. Nearly 60% of the lighting energy demand and 20% of the heating energy demand should be saved by comparison with the reference building. In energy cost terms the design achieves an overall saving of 36% compared to the reference building. On balance, the value of daylighting and solar heat gains are substantially larger than the cost of heat lost through the windows and rooflights.

The rooflights provide evenly distributed, adequate levels of daylight in nearly all areas. The roller blinds under the south face of the rooflights, and openings for natural ventilation in the north face combine to limit overheating to less than 2% of the working year in the workshop.

The estimated cost of the final design at £412/m² is £4/m² less than the estimated cost of the reference building and shows a cost reduction of £55/m² from the interim proposal. In the client's opinion "...the advantages of daylight and a view to the outside can not be overestimated. The design appears to offer ample opportunities to create an excellent working environment." Graphex were "very impressed" with the predicted annual energy cost saving of £2,150.

The ECD Partnership Design

English Estates presented The ECD Partnership with a very tight budget (£332/m²) within which to design a speculative industrial building containing 1600m² of workshop space and 600m² of office space. English Estates normally require the provision of rooflight areas at least equivalent to 10% of the floor area in their speculative industrial buildings. In response to this brief ECD applied considerable effort to optimising the size and location of rooflights in order to obtain good daylighting with minimal overheating.

As with the Ryder Nicklin design, offices, workshops and stores are all enclosed in a simple rectangular building. GRP rooflights are incorporated in continuous strips as far as possible on the north facing slopes of the roof. Physical scale models were used to establish daylight levels and distribution patterns. The resultant uniform distribution of daylight in the workshop allows the artificial lighting system to be controlled by a single switching circuit. The offices in this design are located on two floors at the north of the building and are daylit by north facing windows, thereby avoiding the need for expensive solar shading.

Natural ventilation of the workshop is achieved in the summer months by opening the loading bay doors, and if necessary operating fans at high level in the east and west facades. In the offices, natural ventilation is enabled through controllable low level vents and opening skylights.

Scheme Assessment. The ECD design gives rise to 50% savings in lighting energy demand and only a small increase in heating energy demand compared to the reference building. Overall, the annual energy cost savings amount to 30%, or £1,570. The design is estimated to cost £6/m² (2%) more than the reference building due to larger rooflight areas and lighting controls.

Diffusing GRP rooflights located on the north facing roof slopes will reduce glare, but are unlikely to eliminate it. The predicted incidence of overheating at 4% of the working year is substantially less than that predicted for the reference building.

Overall, the design is a credible and attractive solution to the provision of this type of low cost industrial building. Recognising the wide range of potential tenants and owners for their buildings, English Estates felt that this design approach could be best employed where the type of building occupant was identified at the outset.

TABLE 1 - Energy and cost data for light industrial designs and references

Client Architect		SunarHauserman Jestico + Whiles		Graphex Ryder Nicklin		English Estates ECD Partnership	
		Design	Ref.Bldg	Design	Ref.Bldg	Design	Ref.Bldg
Capital Cost	£/m²	£450	£485	£412	£416	£338	£332
Heating	kWh/m²/yr	53.7	35.7	29.1	35.7	42.3	36.3
Lighting	kWh/m²/yr	14.5	33.0	14.3	33.0	15.7	33.8
Heating Cost	£/m²/yr	£.94	£.62	£.51	£.62	£.74	£.64
Lighting Cost	£/m²/yr	£.80	£1.61	£.91	£1.61	£.93	£1.74
Fuel Cost	£/m²/yr	£1.74	£2.23	£1.42	£2.23	£1.67	£2.38
% of Year Overheated		0%	25%	2%	25%	4%	22%

Important Lessons

This group of design studies has so far revealed that:

- there is considerable potential for saving energy through the exploitation of daylight in industrial buildings.
- both north and south facing rooflights can be employed to daylight workshops, but south facing rooflights must be shaded.
- integration of artificial lighting systems and their controls with daylighting is vitally important if energy savings are to be realised.
- performance and cost assessment undertaken at the early stages of design can lead to improved energy performance at a lower capital cost.
- the final design costs are very close to the targets - demonstrating that low energy design need not involve higher capital expenditure.
- predicted energy savings have both significant financial value and important environmental benefits.

OFFICE BUILDINGS

The second group of studies managed by HGA involving three office designs, have progressed to the interim assessment stage and preliminary results are presented in Table 2.

TABLE 2 - Energy and cost data for ofice designs and references

Client / Architect		Lansdown / MEPC RMJM		Avon C C Feilden Clegg		IBM UK Ltd Denton Scott	
		Design	Ref.Bldg	Design	Ref.Bldg	Design	Ref.Bldg
Capital Cost	£/m²	£825	£1,060	£795	£800	£980	£1,190
Heating	kWh/m²/yr	26.4	16.1	40.8	15.5	54.3	33.6
Lighting	kWh/m²/yr	16.3	31.6	18.4	28.9	12.6	31.0
Fuel Cost	£/m²/yr	£1.64	£3.31	£1.95	£3.15	£1.99	£3.54

NB Ref.Bldg costs include air-conditioning, except Avon CC which is client target cost. All designs avoide the need for air-conditioning.

The performance of the above design (and reference buildings) is very much in line with some of the best office buildings in the UK that have recently been studied by BRECSU and are currently being reported in a series of case studies [2].

All the designs utilise rooflights in some form to enhance daylight penetration into the office spaces. The effectiveness of the daylight design in each scheme has been assessed using detailed scale models in an artificial sky.

RMJM Design

In their design for Lansdown Estates/MEPC, RMJM have provided a central lightwell in the core of a speculative office building designed for single or multi-let. Figure 4 illustrates the interim design.

The interim design compares favourably with the reference. However, opportunities exist for improvements in energy and environmental performance and reductions in capital cost.

Feilden Clegg Design

In their design for a new headquarters building for Avon County Council, Feilden Clegg Design have arranged a sequence of departments along a central glazed street. The architects have undertaken the detail design of one department in the building to demonstrate how the principle of the glazed street continues through to each of the wings. Figure 5 illustrates the interim design.

The interim design compares favourably with the reference. It is likely that the window and rooflight area will be reduced in the final design to minimise heat loss whilst maintaining good daylighting.

Denton Scott Associates Design

In their design for a new marketing building for IBM UK Ltd, Denton Scott Associates have devised a modular approach, combining cellular and open plan offices to meet the needs of team working. Figure 6 illustrates the interim design.

The interim design compares favourably with the reference. At the final design stage adjustments will be made to the area of rooflights and windows according to whether the module is located in the centre or on the perimeter of the development. These adjustments will be prompted by results from the assessment of the scale model in the artificial sky.

Important Lessons

This group of design studies has so far revealed that:

- there is considerable potential for saving energy through the exploitation of daylight in office buildings.
- adopting a north / south orientation simplifies the approach take to solar shading by avoiding west facing windows.
- performance and cost assessment undertaken at the early stages of design can lead to improved energy performance at a lower capital cost.
- physical scale models provide a very useful tool to analyse the daylight potential of complex building forms.
- there is some scope for improvement in the performance of all the designs and this should be acheived with no additional capital cost.

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1. Hughes, D., Feb. 1989, The CIBSE J. 11, 61 "Low Energy Factory Buildings".

2. BRECSU, 1989/90, "Good Practice Case Studies", Building Research Energy Conservation Support Unit, BRE, Watford WD2 7JR.

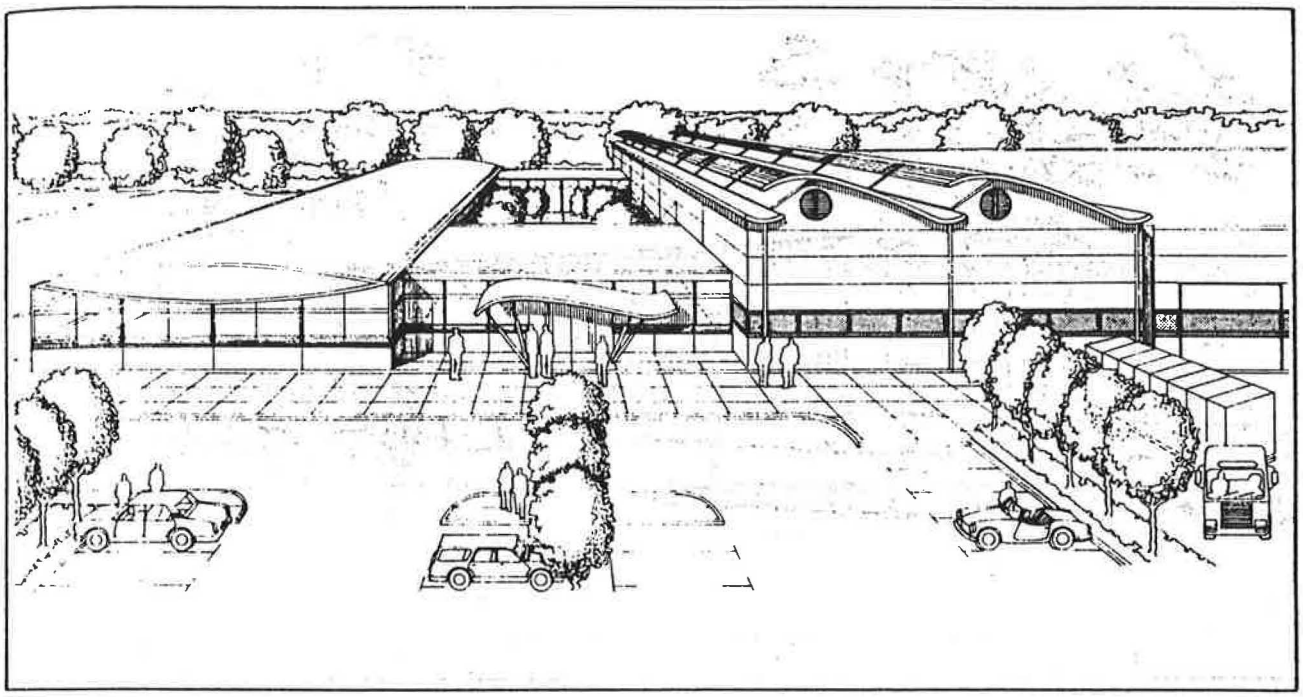

Figure 1 Jestico + Whiles design for SunarHauserman

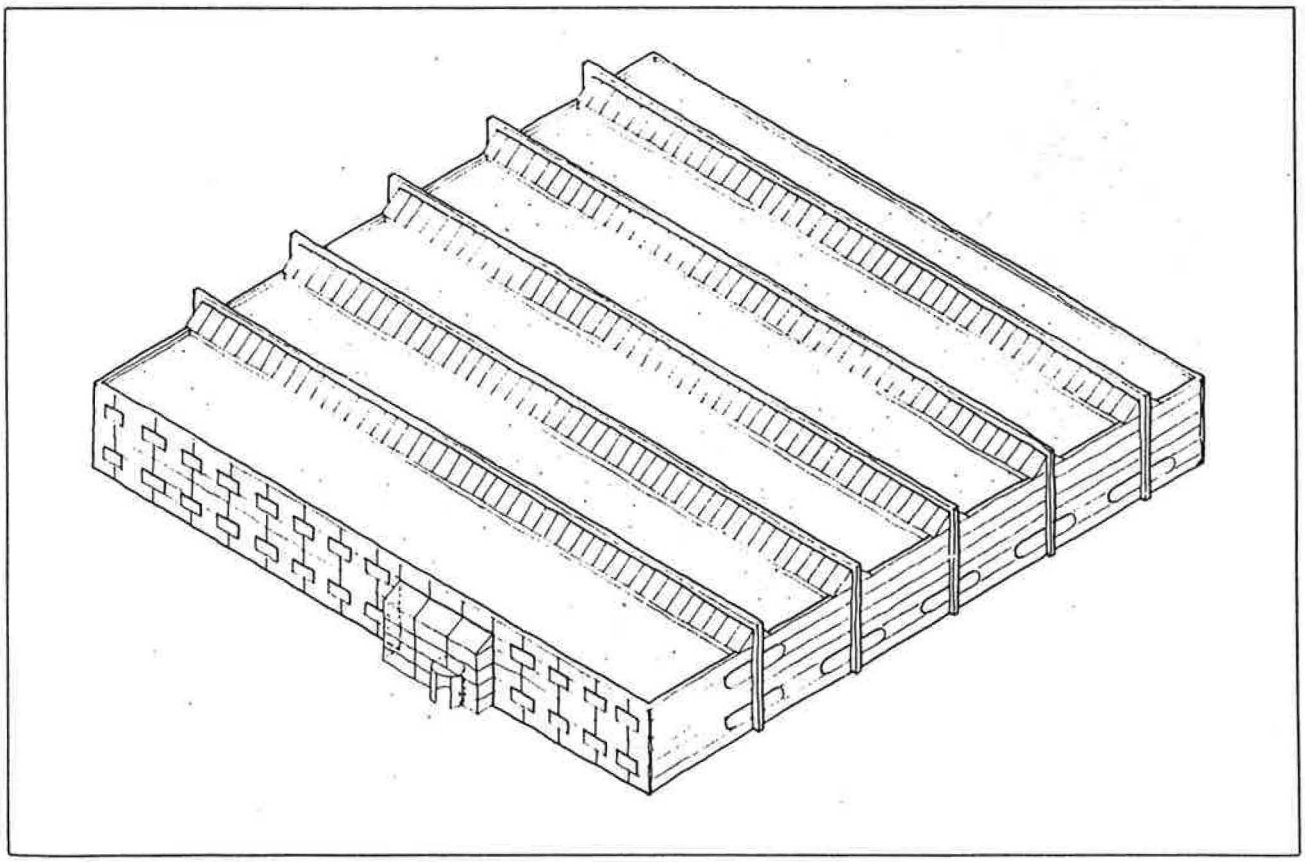

Figure 2 Ryder Nicklin design for Graphex

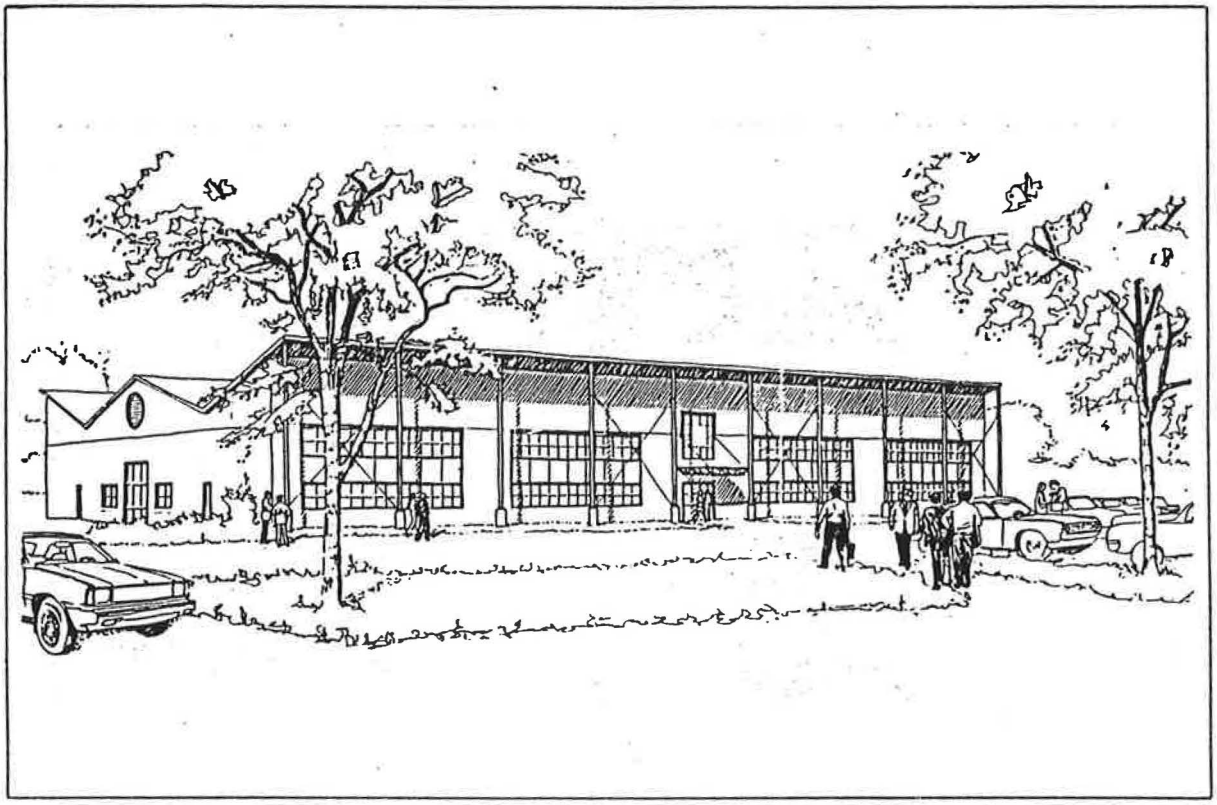

Figure 3 ECD Partnership design for English Estates

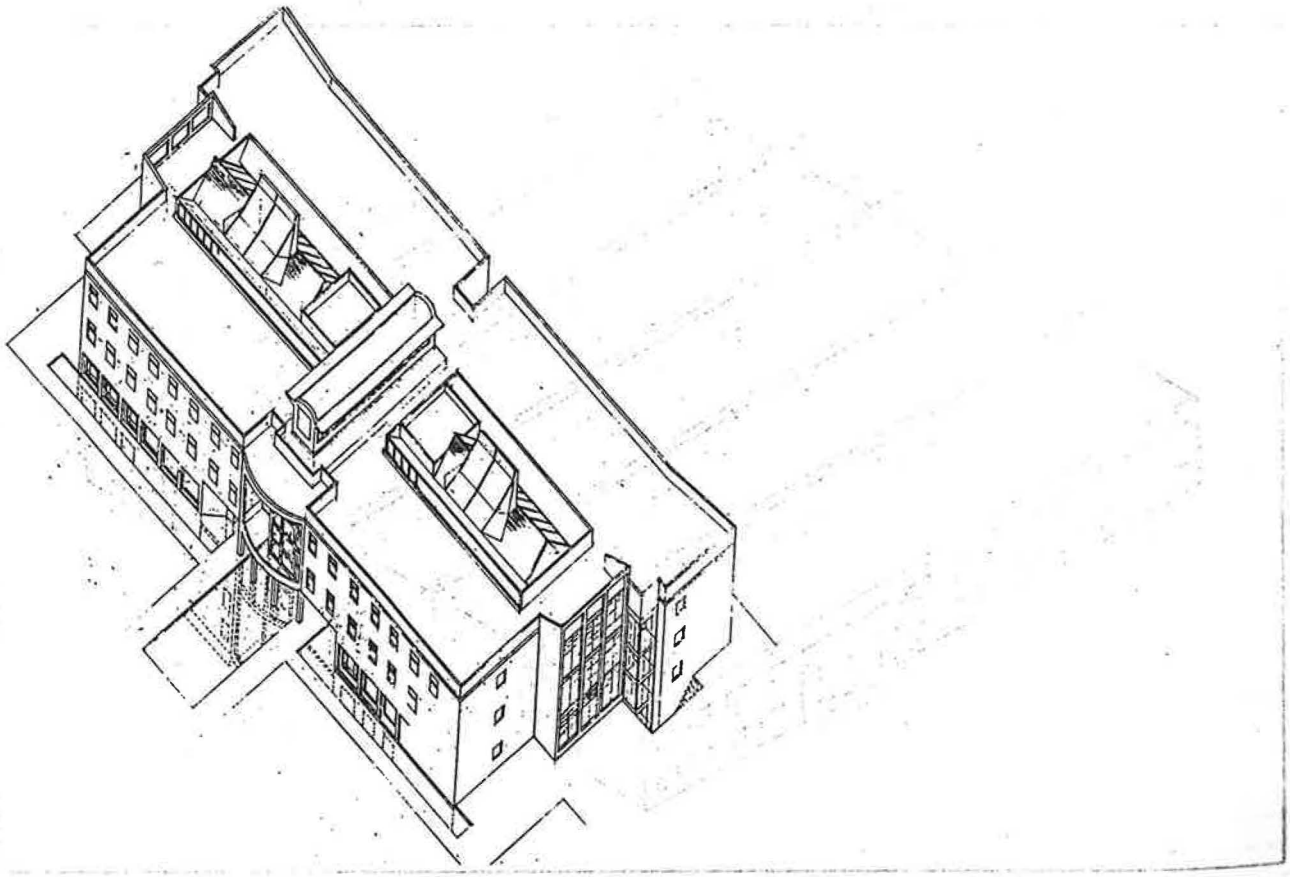

Figure 4 RMJM interim design for Lansdown Estates / MEPC

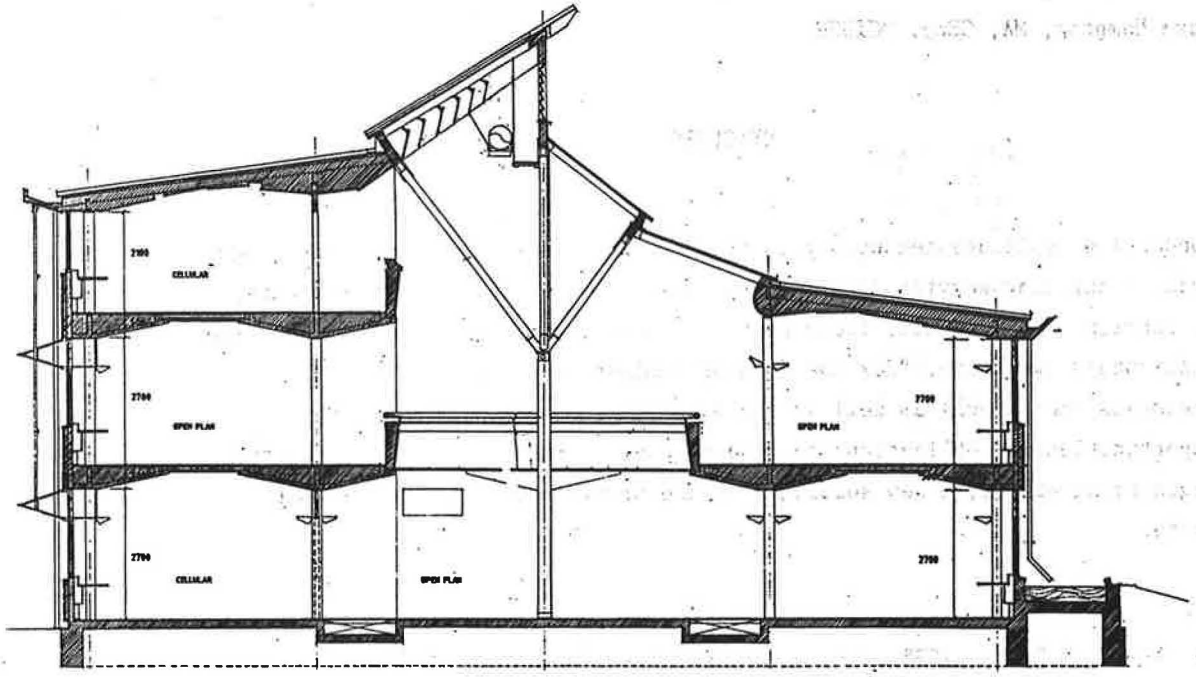

Figure 5 Feilden Clegg interim design for Avon County Council

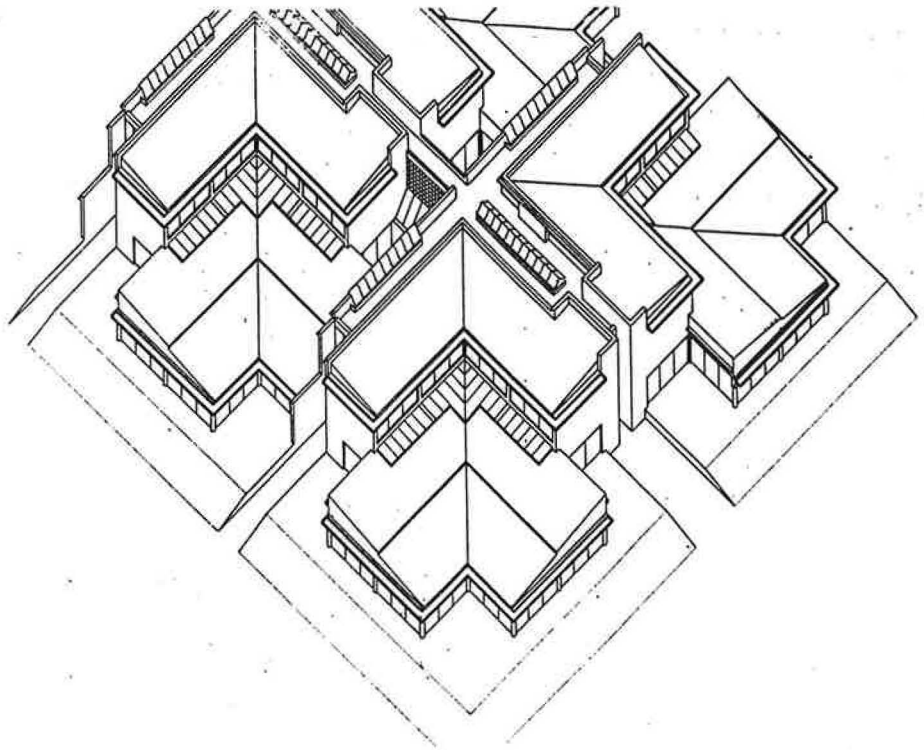

Figure 6 Denton Scott Associates interim design for IBM UK Ltd