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Michael Wigginton | **The cost of sustainability**

https://doi.org/10.1017/S1359135505000163 Published online by Cambridge University Press

Analysis of the detailed design of a primary school classroom suggests that intelligent sustainable design can be both environmentally beneficial and cost effective.

The cost of sustainability: Witheridge Primary School 'Classroom of the Future'

Michael Wigginton

It is almost conventional wisdom that 'good' or 'well-designed' architecture is more expensive than its mediocre counterparts. Some may protest, claiming that 'good' architecture needs only the care and attention of a 'good' designer, and arguing that there need be no intrinsic difference in cost between different levels of architectural quality. But many with experience of design at the highest level will know this can be difficult to demonstrate, because it is all too easy to reduce the cost of a building, either in the initial design approach, or through a value engineering process, by reducing the quality of the specification.

Certain forms of building, particularly those with high envelope/floor-area ratios, will generate unavoidably greater costs than some notional mean, and the price of the specification can be very high. The envelope and finishes can both be major contributors to the cost of such a building, and therefore the most easy elements to address when cost is an issue. The structural and environmental engineering aspects of a project are often held at a certain level by regulation, and the envelope and finishes may be the only elements readily subject to cost reduction.

If this is true for design in general, it is even more so for what we now call 'sustainability'. Building sponsors and designers alike frequently complain that sustainability cannot be afforded and in this context it represented a gratifying challenge to be asked by Devon County Council to design one of their three 'Classrooms of the Future', funded by the programme set up by the Department for Education and Skills, with sustainability as a prime design criterion.

'Sustainability' is often said to be difficult to define, and capable of being construed in different ways. The difficulty is as much a problem of usage as of definition, as different constituencies have tried to claim it. Thus the term 'sustainable communities' may refer to a social agenda rather than imply sustainable building design.

The usage here is straightforward, and derived from that given by David Pearce in his book *Blueprint 3* published in 1993.[1] This working definition is derived from the Brundtland Commission report: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. This is expanded by Pearce in his definition of 'strong sustainability' to mean conserving 'the overall stock of capital, and pay[ing] special attention to the environment'. While current, and real, concerns about climate change have placed energy use and carbon emissions high in evaluations of criteria for sustainability, the author is of the opinion that this remains only one of a range of significant concerns properly set out by Pearce.

The Witheridge project

The Classroom of the Future project at Witheridge Primary School was one of three school projects initiated in 2001 by Devon County Council Education, Arts and Libraries Directorate (DCC EAL), as part of their proposals under the DfES 'Classroom of the Future Programme'. The educational and community objectives of the proposals were to address the needs of, and aspirations for, educational buildings in the future, considered in terms of Devon in particular, and the UK in general, to ensure the total contribution that school buildings can make to the community they serve. The design team set out 12 objectives to guide the design's evolution:

1 Replicability

It was considered essential that the design be replicable as part of the County's ongoing programme of school development. Temptations to create a highly individual or idiosyncratic building were therefore discarded in favour of solutions that could be produced repeatedly and affordably, with simple multiple-classroom configurations.

2 Plan development potential

The normative primary school comprises seven classrooms, each accommodating 30 children. Although the head teacher, who had wide experience in primary schools, advised the design team that the most appropriate number was between 17 and 23 (which offered an interesting perspective on the DfES objectives), the figure of 30 was an unnegotiable part

1 South-east corner

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of the brief. The principles of plan development meant that it was necessary to create a form that could be part of an 'assembly' of similar forms, facilitating the design of a multi-classroom school.

3 Daylight
The wish for daylight is as much a matter of personal conviction as of demonstrable research. Much discussion about it took place during the author's work in the European Union COST C13 Research Action 'Glass and the Interactive Building Envelope'. In relation to classrooms, daylight has been demonstrated as an important factor in educational progress, as in human well-being generally.[2] Two issues support the objective to employ daylight as the prime, or only, source of light in classrooms. First, the fact that human evolution has taken place in daylight and we are adapted to both its spectral composition and intensity. Second, the energy required to provide lighting is up to three times the amount converted into light: artificial lighting is a profligate use of energy. The design team determined on a strategy whereby daylight provided adequate and comfortable illumination whenever it was available, which happens to coincide with the school day in winter. The team was aware that glazing represents a weak thermal interface between inside and outside, but the extent of this was evaluated through computer modelling.

4 Sunlight
Sunlight represents a more speculative benefit, frequently contra-indicated by the potential for glare and overheating. The view was adopted that the sun should be welcomed into the building when needed, but that an automatic shading system should shield the occupants when the sun is too strong.

5 Energy conservation
The principle of energy conservation is essential in any building claiming to have sustainability credentials, and conventionally involves evaluation of consumption in use and of embodied energy. The design policy agreed was to reduce the annual energy consumption for environmental control to the minimum, by an appropriate balance of passive solar energy, daylight, and insulation. Evaluations carried out by the author over many years have demonstrated that zero-comfort-energy can be achieved in most building types. Schools represent an interesting exemplar of the metabolically designed building, by which is meant one in which the intrinsic building metabolism is harnessed to optimise heat flows diurnally and seasonally, to reduce the need for heating (or cooling) to close to zero. Schools contain young people at a density of 1.7 to 1.8 square metres per child – between five and six times that of an office building, and more than twenty times that of a house. The heat load is high when the room is full, but a problem can arise following a period when the building is empty over an extended period, such as the Christmas holidays.

Embodied energy is an important consideration in terms of overall evaluation of the life cycle energy cost of a building, but was not made part of the evaluation at Witheridge, other than in terms of prudent specification. Further comment is made below, in the discussion of the use of natural and benign materials.

6 Flexibility
It is now general policy in most communities that as much accommodation as possible should be made available for community use when the children are not using it. The objective at Witheridge was to create a form providing teachers and the community with the greatest flexibility in use, with large storage areas to house equipment and furniture.

7 Accessibility
It is, quite rightly, an imperative in all buildings that access which is easy, safe and caring should be available to all members of the community, whether adults or children.

8 Use of natural and benign materials
It was determined that, wherever possible, materials should be specified that were natural, of low embodied energy, and benign. There is a great deal of debate about what this means, and how strictly such criteria should be adhered to. Consideration of sustainability overlaps with issues of health and quality. Materials considered as potentially inappropriate in what is sometimes called a 'green' building range from glass and aluminium for their alleged high embodied energies, to PVC for its chlorine content. Timber can be considered variously as acceptable or unacceptable, depending on its source, and whether that source is renewable.

In terms of embodied energy, imported softwood has been given a figure of 8.1 GJ/tonne compared with 90 GJ/tonne for PVC and 12.6 GJ/tonne for glass. Aluminium is ascribed figures between 320 GJ/tonne and 16 GJ/tonne, depending on whether it is newly smelted or recycled.[3] Density and amount used can be significant in the assessment of the embodied energy of a building per square metre of its floor area, and the selection of a material must be based on the balance of a range of factors including embodied energy, renewability, toxicity, recyclability, life and maintenance.

Embodied energy is, in the opinion of the authority whose research provided the figures above, and of the author, one of the essential measures of sustainability. It is prone to misinterpretation since location is fundamental to measurement (given the energy expended on transport). It also varies with time, since the constituent energy figures implicit in original sourcing, processing, fabrication and multiple transportation, and final installation depend on how processing is carried out at the time of measurement.

The issue of recycling is also important. If a material can be totally reclaimed and/or recycled at the end of the building's life, it is possible to argue that its embodied energy as a component of the total embodied energy of a building will be small. It is interesting to speculate on the relationship between the embodied energy of a product and its real cost.

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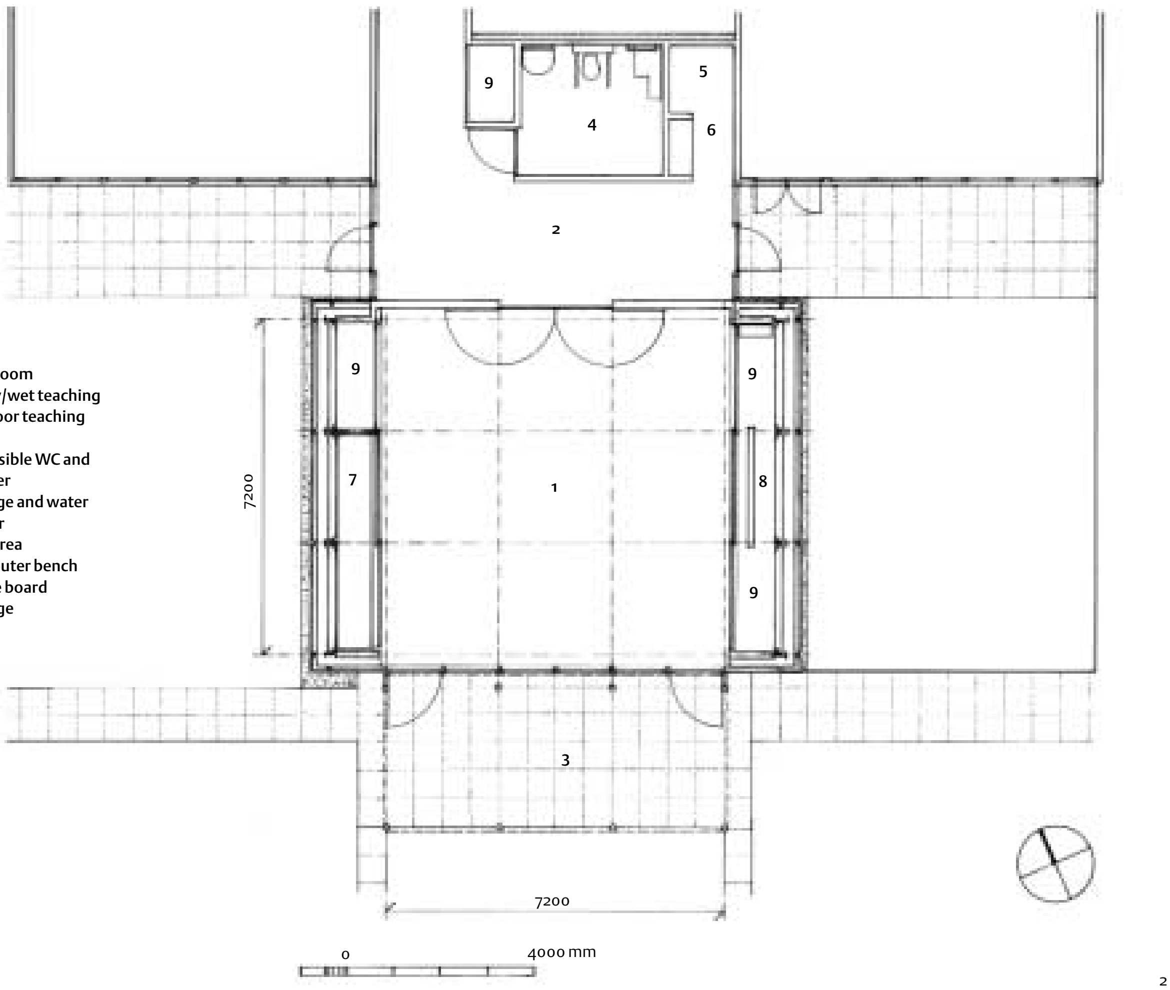

1 Classroom
2 Lobby/wet teaching
3 Outdoor teaching space
4 Accessible WC and shower
5 Storage and water heater
6 Sink area
7 Computer bench
8 White board
9 Storage

2 Plan

Embodied energy is also considered variously as being less or more important than energy in use. In work carried out by the author with Nigel Howard at the Scott Sutherland School of Architecture in 1994, it was demonstrated that, for the building type studied (a large university building), the lowest 30-year energy cost was delivered by the building with the highest embodied energy. While embodied energy is believed by the author to be one of the essential measures of sustainability, to be considered with toxicity and renewability in its value in a specification, its evaluation is complex, and is not addressed here. The final specification decisions at Witheridge included untreated timber for the cladding and framing, cellulose insulation, woollen carpets, and linoleum, in acknowledgement of their intrinsic low embodied energy, but also to ensure low maintenance and contribute to health.

9 Technical innovation

It may be considered irrelevant to include technical innovation as a design criterion in a sustainable building. It was included in the brief for Witheridge because of the intrinsic nature of the 'Classroom of the Future' project as set by the DfES, and because new materials, techniques and products are coming on to the market all the time, and must be evaluated as a matter of design routine.

The principal innovation at Witheridge, and no doubt in most other Classrooms of the Future, was the use of computing and information technology. This was discussed intensely during the early stages of design, particularly with the head of school, and all those involved were anxious about it, because of the suspected motives of the DfES. The enormous value of the Internet to deliver information, and the need for children to master the techniques to manipulate it, are beyond dispute. However, given the issue of class size referred to above, and the associated issue of teaching costs, it is hard not to be suspicious or even cynical. Whatever its role, IT poses specific issues for school buildings, related to energy use (and the delivery of heat), lighting, and external vision.

Technical innovations related to the construction of the building were set out originally in relation to the use of intelligent night cooling, and the roofing material. Unfortunately, a ventilated thermal storage wall had to be omitted due to its cost.

10 Exterior teaching space

The provision of a protected external teaching space was highlighted by the Devon County briefing team following precedent work carried out in Scandinavia. Fortunately for the project, this client-driven idea coincided with a proposition conceived in the first days of the project, discussed below.

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11 Contextual appropriateness and 'politeness'
This played an important part in the concept of the shape, height, and materials of the building, and of the planning application, but it did not play a significant role in the sustainable specification, other than the decision to use untreated timber as the cladding material.

12 Cost
This informed both the simplicity of the building's shape, and of its detailed design. A budget was set which evolved over time, as the design team and client developed the principles, with a view to establishing the real cost of a sustainable, and replicable, Classroom of the Future.

Design: form and performance

The approach was guided by the principal objectives described above, and of fundamental importance was the idea of 'replicability'. The team elected, after discussion with the Local Authority, to seek to establish a design for a classroom that could be considered a model for replication throughout the County's future building programme. The five prime influences were:

1. The nature of the teaching space in terms of size and shape, including the need to form one element in an economical, clustered plan.
2. The extensive need for storage set by the demand for versatility and security.
3. Location in relation to the existing building.
4. Orientation with regard to sunlight.
5. The need for daylight, balanced with the need for protection from direct sunlight.

The teaching space

The plan needed to ensure an internal space providing maximum flexibility in terms of teaching use. The head teacher indicated that an existing square classroom was excellent in terms of flexibility of furniture arrangement and subdivision, and a square space was therefore proposed for the new classroom *[2]*. The north side acts as the interface with the rest of the school and with a variable use space, which acted as a wet play and teaching area, a lobby connecting the classroom to the rest of the school, and an evening or out-of-term entrance lobby for use by the community. The south face of the main classroom has access to the sun, and to the


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3 View from east

4 View from south, with blind raised for maximum daylight

5 View from south, with blind lowered for solar shading

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external teaching space and open space beyond. The size is 7.4m by 7.4m, based on a structural grid of 2.4m and a component module of 1.2m, allowing for a 100mm zone all round to permit constructional tolerances and the details of edge conditions. The height is 2.44m. Comparative work was carried out in relation to the main structural frame, with timber and steel being considered. Steel, with its smaller sections, was selected out of consideration for the need to reduce the building's height to conform to that of the existing buildings.

Early discussion concerning the extensive need for computing and for varying use – and consequent need to store furniture within the classroom – led to the design of the flank walls as storage walls, 900mm deep to store children's effects, ITC and other equipment, furniture, and general teaching materials. The storage is behind sliding doors 2.4m high by 2.4m wide, incorporating an interactive white-board provision on one side.

Location and orientation: daylight and sunlight

Location and orientation were major concerns. Given the need for a usable external teaching space, a south orientation was preferred, to ensure that the building did not shade this space. A location south of the existing classrooms provided a good connection to the existing school without prejudicing the existing classrooms. It also posed the challenge of mitigating sunlight, particularly in winter when the sun is low *[1]*. Seasonally modulated south light was needed to ensure that the whole space was day-lit without the glare associated with large areas of glazing along a single side. This reduced the penetration of daylight and required the incorporation of a rooflight.

The south wall

This is a glazed wall designed on a 1.2m grid, with the end two bays comprising 1.2m wide doors, giving free access to the external teaching space. The upper panels are top-hung opening lights to provide ventilation.

The canopy

This is 2.7x3.3m, and 3m high, and sits to the south of the main classroom, providing a transparent roof immediately outside the classroom *[3]*. To provide

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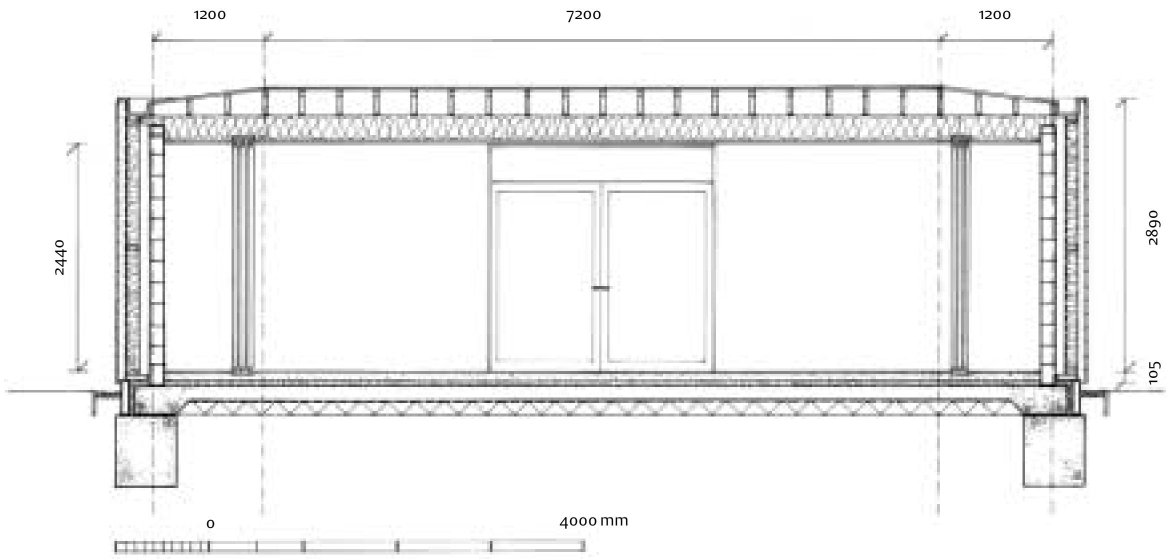

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6 **East-west section**
7 **Interior**

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environmental control, an automatic motorised roller blind is fixed at the top of the structure beneath the glazing and controlled by a solar cell linked to a thermostat inside the classroom (it descends when the sun comes out and the internal temperature is over 21 deg. C). When fully descended, the cut-off angle provides protection from solar radiation in the summer, and also cuts out glare in winter *[4, 5]*.

The canopy was glazed to ensure that the benefit of daylight from the winter sky is not lost. A proprietary self-cleaning glass was used, and experience has indicated that the coating is extremely effective. The canopy and blind provide the 'intelligent' aspect of solar control.

Thermal performance

The aim was to produce a building as close to 'zero-energy' as possible. This demands good 'passive' design, use of the building's intrinsic thermal metabolism *[6]*, and adjustability to cope with seasonal and diurnal variation, preferably with built-in intelligence. The occupancy patterns in a classroom have a significant impact on its thermal metabolism, ranging from periods when this is very high (when fully occupied by children *[7]*, generating a potential problem in summer), to when it is zero (during the Christmas holidays). Exploiting and conserving heat gains from occupants and equipment, careful limiting of ventilation, use of solar and sky radiation, and appropriate insulation, can bring a building close to diurnal energy equilibrium. The strategy adopted relied on the use of insulated thermal mass to store heat in winter, and to absorb it in summer. This demands seasonal variation in performance. It was clear that ventilation needed to be carefully controlled, particularly in winter: too little will benefit the heating equation, but can lead to stale air; too much will lead to an excess of heat being required to warm incoming cold air.

In summer, the high levels of occupancy (over five times greater than in offices) that help warm a building in winter, contribute to potential overheating. This was exacerbated by the high ITC equipment loads. Solar penetration can be mitigated by responding to changes in the sun path. A canopy or external blind system can be introduced with great effect, provided it can be withdrawn in winter. Ventilation is again a critical factor. It is difficult to produce interiors with dry bulb temperatures less than those outside, but night ventilation can be used to damp the diurnal temperature curve. Day time ventilation can be used to reduce the resultant temperature, both by reducing dry bulb temperature, and by creating cooling air currents across the room.

Computer modelling

Computer simulation was used to predict thermal and daylighting performance. It was also decided to evaluate the efficacy of the predictions by monitoring the completed building. Unfortunately this work has not yet been funded.

The chosen computer model simulates thermal conditions inside a building using a 3D model, constructed to incorporate the thermal performance characteristics of the building elements, and then evaluating its thermal behaviour in the context of the simulated input of external climate conditions. It permits the evaluation of internal thermal characteristics, in terms of dry bulb temperatures, resultant temperatures, or other indices, and also permits the assessment of heating and cooling loads, and ventilation requirements.

Various versions were modelled, and the results used to improve performance. The first thermal model excluded the rooflight, in order to establish a 'base case' or 'control' for thermal performance. It also assumed simple insulated block walls on the east and west faces. The second model included a rooflight, and then tested various glazing systems, to include the option of low-E glazing combined with a radiation reflecting frit on the inside surface of the outer pane of the double-glazed roof. It also included ventilated walls, whereby the east and west flank walls were used to generate night cooling in the summer (what was called 'the reverse Trombe wall' principle), using controlled openings for day and night ventilation in the summer. The final model removed the ventilated wall on grounds of cost.

Lighting was also the subject of a computer simulation study, with five iterations undertaken before the final configuration of rooflight was determined. This delivered a lowest recorded illumination level with a CIE sky, measured at 500mm intervals, of about 230 lux, equivalent to a daylight factor of about 4.7%. Significantly, the highest level was about 1490 lux. The difference, considered as an important measure in most daylighting evaluation, was about 6.5:1, which is three times as good as the generally judged maximum of 20:1.

The modelling indicated that, subject to achieving control over ventilation apertures, the building could deliver acceptable comfort conditions in both summer and winter.

Design: materials

Materials were chosen with six sets of criteria in mind: appropriateness to function; life; sustainability credentials; benign qualities; cost and procurement. Sustainability credentials included those which relate to sourcing and recycling potential. Wherever possible, materials were selected which were benign in their manufacture, incorporation and use. This tends to lead to the exclusion of PVC, materials such as mdf, which exhibit out-gassing properties, and man-made fibres. All these desirable qualities had to be seen in the context of cost. Procurement was also considered as paramount, given the timetable of the project, and that it would be unacceptable to specify a material that could not be obtained in time. The specification provided for substitution to optimise criteria.

The materials eventually chosen included the following *[8]*:

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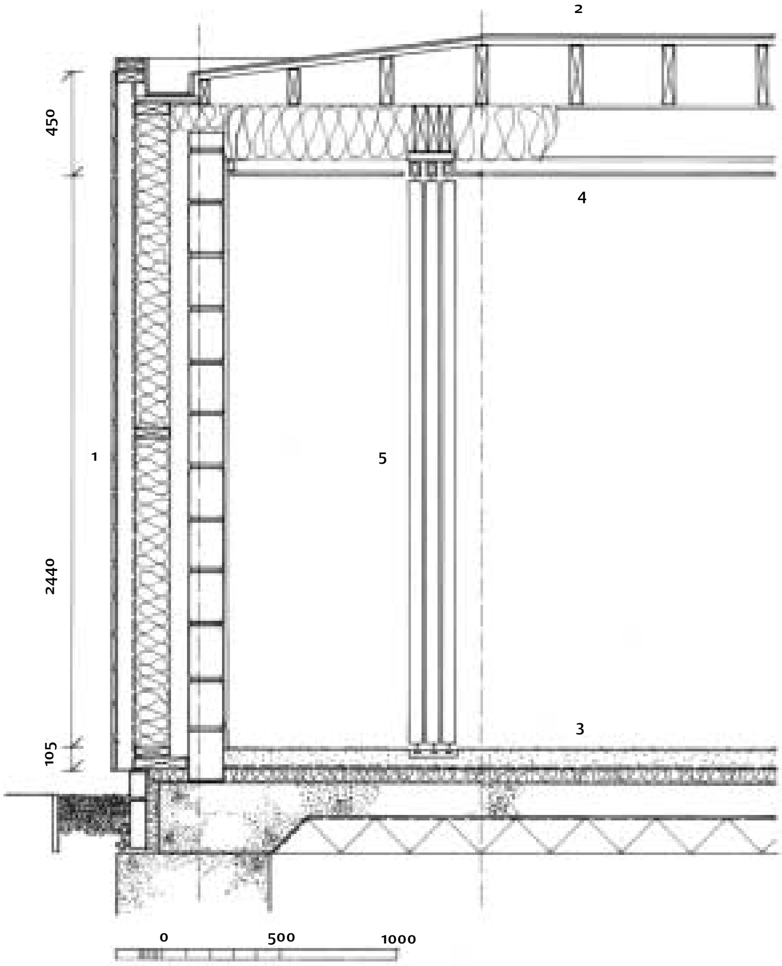
1 150mm x 20mm iroko boards mounted on battens
Breather membrane
150mm 'Vital' cellulose insulation
80mm cavity and space for diagonal bracing
150mm concrete block
20mm plaster

2 8mm RoofKrete roofing
25mm marine ply
Ventilated cavity
250mm 'Vital' cellulose insulation in steel beam zone

3 Wool carpet on nominal 100mm reinforced screed
50mm cellulose insulation
150mm reinforced concrete slab
150mm hardcore

4 2400 x 600 Ecophon 'Focus E' high density resin bonded recycled glass fibre ceiling tiles

5 Sliding doors comprising hollow-core door blanks



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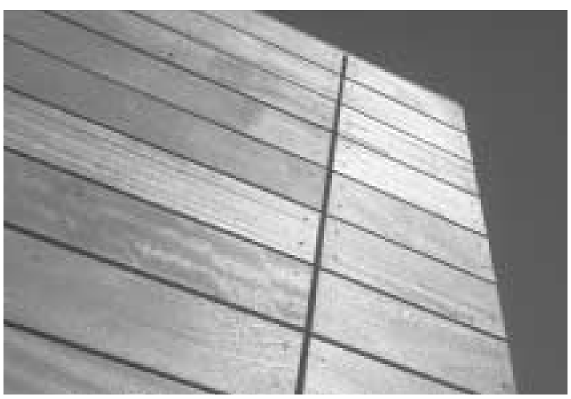
8 East-west section

9 South-west corner: iroko detailing

10 Junction of canopy with building showing solar cell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Structural frame: steel

Foundations and ground slab: concrete on insulation on waterproof membrane on sand on hardcore.

Flank walls: blockwork, with external 'Vital' cellulose insulation behind an iroko rainscreen cladding *[9]*, selected following the rejection of European larch due to its unacceptable quality in relation to knots and shakes, and the fortunate availability at the suppliers of some unused iroko.

Roof: 'RoofKrete' on ventilated roof construction, with 250mm of 'Vital' cellulose insulation in the steel beam zone.

Rooflight: flat double glazing, toughened glass over translucent laminated glass, to disguise bird droppings and other dirty deposits.

South-facing glazing: double Low-E glazing in untreated iroko framing to match rainscreen cladding (60 year life).

Lobby doors: double Low-E glazing in untreated hardwood framing to match rainscreen cladding (60 year life).

Flooring: in classroom, pure wool carpet on screed. Linoleum in 'wet' lobby area.

Internal flank wall panelling: 2.4m wide, 2.4m high, sliding doors, constructed from hollow-core door blanks.

Canopy structure: steel tube with diagonal stainless-steel cable bracing, supporting flat glazing (1:100 slope) *[10]*.

Cost

The main thrust of this paper is the cost of sustainability. By this is meant the cost implications of shape and specification when a sustainable agenda is followed. Davis Langdon and Everest, the quantity surveyors, suggested a range of costs for primary schools of £900-1250 per square metre at 2002 rates, without site-specific on-costs or landscaping. This range is generally the result of the level of services, fixtures, and spatial subdivision.

Analysis of the Witheridge project is complicated by the fact that the building has intrinsic features that are different from those which would be incorporated were the classroom to be part of a whole new school. Most significantly, it has three external walls. Incorporated into a typical seven-classroom primary school, each classroom would be separated from its neighbours by a stud partition, the acoustic performance of which would be mitigated by deep cupboards on both sides, and the cost of the two end flanking walls would be apportioned across all seven classrooms. The project also contained an exceptionally high component of electrical services related to information technology.

The best way to demonstrate the cost of sustainability, therefore, is to create a comparative cost plan in which the second column expresses the reductions implicit in transferring the costs into a theoretical seven-classroom primary school. The first schedule simply removes the exceptional costs for the cladding and roofing.

Item	*elemental cost actual*	*elemental cost spread*	*notes*
	£	£	
Substructure	6840	6840	highly insulated
Steel frame	5733	5733	
Roof exc. rooflight	10,046	9000	less perimeter detail
Rooflight	4480	4480	
External walls	2761	2761	blockwork and insulation only
Iroko rainscreen	10,080	1440	spread figure 1/7 of total
Windows and doors	6955	6955	
Internal walls	372	372	
Internal sliding doors	6635	6635	
Wall finishes	984	984	
Floor finishes	3736	3736	
Ceiling finishes	2190	2190	
Fittings and furnishings	4667	4667	
Disposal installations	535	535	
Electrical services	15,319	15,319	includes all IT work
Builders work in connection	393	393	
Total	**81,726**	**72,040**	
Preliminaries at 23.5%	19,206	16,929	
	100,932	88,969	

The floor area of the classroom was 70sq.m, indicating a spread rate of £1271/sq.m, including preliminaries, for the adjusted costs. The costs of the canopy, which can be considered as an optional extra for a classroom, were as follows:

Steel frame	£4747
Glazed roof	£13,440
Automatic motorised blind	£5915
Preliminaries	£2980
Total	£24,102

The cost of quality and sustainability

With the elemental costs adjusted, an analysis of the elemental rates permits the identification of those parts of the design and specification which have created the overall cost, and specifically those increases that are the result of energy conservation measures, benign specification, or product quality. This suggests that the cost of Witheridge, excluding the external canopy, is 1.7% higher than the upper level of the typical cost range for primary schools.

The question might then be asked whether or not costs of this order can be justified, or if they simply confirm that sustainable building is indeed more expensive than conventional building. Certain specification items can clearly be seen as generating additional costs as a result of their selection to satisfy the 'green' agenda, and the interest in testing new technology. In this regard the following aspects of the specification can be identified:

Electrical work: the rate for the electrical services at Witheridge was £219/sq.m. A typical rate in a primary school is £90/sq.m. At Witheridge an electrical underfloor heating system was installed, principally as a safeguard related to post-Christmas occupancy. This cost £3000, suggesting a rate over the 70sq.m of £43/sq.m. The lighting fittings at Witheridge were high performance Zumtobel fittings at £450 each, rather than the £75 which would generally be spent. For 12 light fittings this represents an enhancement of £4500, or £64/sq.m. If a conventional rate were applied to Witheridge, including the underfloor heating, the comparable rate would be £90 + £43 = £133/sq.m, or £9310. The additional cost at Witheridge was significantly related to the provision of power and information technology. The IT equipment itself was supplied outside the contract, but the electrical loading and network required amounted to a figure of the order of £6000.

Hardwood timber cladding: this was priced at £168 per sq.m of the element for the 60 sq.m concerned. If brick cladding had been used a figure of £50/sq.m would have been appropriate. The additional sum expended on the cladding was £7080 or £101/sq.m.

Insulation: Witheridge is a highly insulated building, with 150mm being the least thickness specified in any location in the building envelope above ground. The cost of insulation is highly dependent on its quality and thermal performance. Costs for conventional expanded polystyrene insulation can range from £7.50/sq.m for 100mm thick material to £17.50/sq.m for high-quality 50mm material. The material specified at Witheridge was Vital, a Finnish product made from oxygen bleached cellulose and the quantities used were: roof, 70sq.m; walls, 60sq.m; floor, 70sq.m. The total was 200sq.m. The installed cost was just over £30/sq.m. If an average figure of £15/sq.m is assumed for polymeric

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insulation, the additional cost of the benign material was £15/sq.m of material used, or £3000, equivalent to £43/sq.m over the building area.

Roofing: the roof covering was the innovative material known as RoofKrete manufactured in Newton Abbot in Devon. The system is a cementitious product of undisclosed specification, applied using a float over layers of fine galvanised steel mesh. Complex details can be formed in it, and it can produce a roof edge without the need for cappings or copings. This was selected partly because of its remarkable thinness (8mm), and its ability to be formed into gutters and other typical roof forms. The cost is £55/sq.m compared with the figure of £30/sq.m for a conventional roof covering. Over the 82sq.m of the roof, and with a comparative rate £15/sq.m higher, the additional cost of the innovative material was £1230, or £18/sq.m.

Carpet: a pure wool carpet was selected for its benign specification and toughness. Un-dyed materials were considered, but these are mostly pale in colour, and were rejected in consideration of the propensity for staining. The blue colour chosen was aptly named 'ink'. The cost, laid, was £40/sq.m as opposed to £20, which would be considered normal for schools. The additional cost over the 70sq.m of the classroom was £1400.

Fittings: the classroom incorporated six sliding doors, each 2.4m square, and specially designed computer benches and a white-board support. The doors cost £6392, and with the cost of the additional fittings the total 'fitting out' cost for fixed items was about £7000, or £100/sq.m.

Item	*elemental cost spread*	*elemental cost sustainable/educational technology items excluded*	
	£	£	
Substructure	6840	6840	highly insulated
Steel frame	5733	5733	
Roof exc. rooflight	9000	9000	
Rooflight	4480	4480	
External walls	2761	2761	blockwork and insulation only
Iroko rainscreen	1440	1440	spread figure 1/7 of total
Windows and doors	6955	6955	
Internal walls	372	372	
Internal sliding doors	6635	6635	
Wall finishes	984	984	
Floor finishes	3736	3736	
Ceiling finishes	2190	2190	
Fittings and furnishings	4667	4667	
Saving on iroko	0	-1010	substitute brickwork
Saving on insulation	0	-3000	substitute polymeric: reduce quantity
Saving on roofing	0	-1230	conventional
Saving on carpet	0	-1400	non-wool
Saving on fixtures	0	-6910	
Disposal installations	535	535	
Electrical services	15,319	9310	exc. specialist IT, inc. heating
Builders work IC	393	393	
Total	**72,040**	**52,481**	
Preliminaries at 23.5%	16,929	12,333	
	88,969	64,814	

The figure of £64,814 equates to a rate per square metre of £926 over 70sq.m, including preliminaries.

The evaluation of the changes in specification which produced what could be argued as the cost of benign sustainability (the incorporation of materials which decrease energy use and avoid pollutants), and increased educational sophistication through advanced technology, can be set out as follows:

Base cost	52,481	excluding preliminaries
Cost of benign sustainability		
Hardwood: low embodied energy, rainscreen	1010	iroko, at £14/sq.m of floor area
Insulation: natural materials, double normal thickness	3000	at £43/sq.m of floor area
Carpet: pure wool	1400	at £20/sq.m of floor area
Roofing: long life, non polymeric	1230	at £18/sq.m of floor area
Total	6640	excluding preliminaries
Cost of educational technology		
Fixtures and fittings	6910	
Electrical work	6009	

The total on-cost associated with sustainability can be seen as about 12.7%. However, each of the main elements concerned is associated with a different part of the sustainability agenda, and nearly 50% is related to reducing the energy use for heating to virtually zero. Further monitoring is necessary to establish whether the £3000 paid to install underfloor heating was necessary (i.e. whether the heating has ever been used).

Perhaps of equal significance is that the cost of the 'sustainable' school including preliminaries, but excluding the educational technology items, is [(£52,481 + £6640) x 1.235] = £73,014, or £1043/sq.m of floor area, which is at the average level of conventional primary school costs.

The cost of the canopy is excluded from this analysis. Were a canopy not to be installed, the external teaching area would be lost, but the necessary solar shading could be provided by a blind or awning fixed to the outside of the south-facing glazing.

Whether or not the costs as eventually achieved contribute to replicability is a matter for the client. However, the additional cost of 12.5% meant the out-turn cost was at the mean of primary school costs generally, and could clearly have been reduced if some issues of quality and benign specification had been sacrificed. The analysis of one building cannot amount to a justification, but must count as encouraging for those who wish to argue the case for sustainable design.

https://doi.org/10.1017/S1359135505000163 Published online by Cambridge University Press

Notes

1 David Pearce and others, *Blueprint 3: Measuring Sustainable Development* (London: Earthscan, 1993), p. 58.
2 L. Heschong, R. L. Wright and S. Okura, 'Daylighting Impacts on Human Performance in School', *Journal of the Illuminating Engineering Society*, 31 (2002), 101–114.
3 Embodied energy data assembled by Nigel Howard, Davis Langdon Consultancy.

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arq gratefully acknowledges:
Mandy Reynolds, 1, 3, 4, 5, 7, 9, 10
Author, all other images

Acknowledgements

The design team for Witheridge Primary School comprised of the Designers Collaborative (Architects), Buro Happold (Consulting Engineers) and Davis Langdon (Quantity Surveyors). The author is grateful to Peter Moseley of Buro Happold, and to Martyn Willcox of Davis Langdon, who assisted significantly in the preparation of the comparative cost data.

Biography

Michael Wigginton was Chair of Plymouth School of Architecture and Design until March 2006, and is now Director of the Plymouth Sustainable Architecture Research Unit. His book *Glass in Architecture* won the AIA Reference Book Prize, and *Intelligent Skins* became the basis for the European Research Action COST C13. He practised with SOM and YRM, before forming a practice with Richard Horden in 1985. He formed his present practice, the Designers Collaborative Limited, in 1994. Current projects include a sustainable farm in Devon.

Author's address

Professor Michael Wigginton
University of Plymouth
Faculty of Technology
Smeaton Buildingm, Drake Circus
Plymouth, PL4 8AA
UK
M.Wigginton@plymouth.ac.uk

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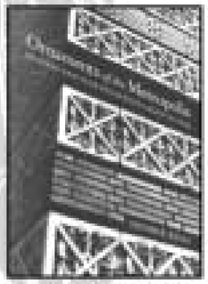

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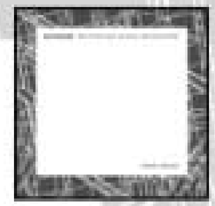

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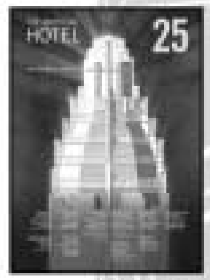

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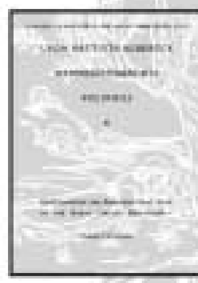

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