IEA Task VIII – the UK experience

Improving the design of low energy passive solar houses

SIMPLE DESIGN TOOLS HAVE LIMITATIONS FOR THERMAL MODELLING. A SIGNIFICANT AMOUNT OF WORK STILL NEEDS TO BE DONE IF SIMULATION MODELS ARE TO BE RELIABLE

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D. Bloomfield and R. Brewer from the Building Research Establishment, I. Cooper and S. Lera from Eclipse Research Consultants and B. Stringer from the Energy Technology Support Unit at the Harwell Laboratory describe the UK experience gained by participation in the International Energy Agency programme on passive solar gain and hybrid low-energy building. It concludes that much work is still to be done on modelling, that presentation of design guidelines needs to be appropriate to the audience, and building practice and occupant behaviour should not be underestimated when collaborating on international ventures.

D. Bloomfield et R. Brewer du BRE, I. Cooper et S. Lera d'Eclipse Research Consultants et B. Stringer de l'Energy Technology Support Unit d'Harwell Laboratory décrivent l'expérience acquise par le RU en participant au programme de l'International Energy Agency consacré aux apports solaires passifs et aux bâtiments consommant peu d'énergie grâce à différentes méthodes. La conclusion de l'article est qu'il reste encore beaucoup à faire en matière de modélisation, qu'il faut adapter la présentation des guides de conception aux personnes concernées et aux professionels du bâtiment et ne pas sous-estimer le comportement des occupants lors des travaux des projets impliquant une collaboration internationale.

Overview

Task VIII

The overall aim of Task VIII has been to gain an improved understanding of:

- the design and performance of new low-energy residential buildings containing passive solar features
- how the techniques for achieving energy savings interact
- how they can be combined effectively in different climates.

The five-year programme began in 1982. Apart from the UK, ten European countries took part along with the US, Canada and New Zealand. The programme was co-ordinated through the US Department of Energy and divided into five Subtasks, led by different countries.

The UK was involved directly in two of the Subtasks:

- Subtask B: Modelling and simulation. This involved surveying and evaluating mainframe computer simulation models suitable for use in the development and analysis of designs containing passive solar features and
- Subtask C: Design methods. This was concerned with surveying and evaluating existing design tools, and preparing a series of information booklets on the design of low-energy buildings containing passive solar features.

The paper reviews the experience gained by participation in this Task, paying particular attention to the use of thermal models in the design process, to the provision of information to design teams and to the importance of collaboration between groups with a wide range of disciplines brought together in this international work.

The use of models in passive design

The progress made in this area of the work should be seen against the background of the original plan, i.e. to:

(a) identify suitable thermal models through surveys conducted by all the participating countries.
(b) Conduct validation studies on the most promising simulation models using high-quality test cell data.
(c) Compare the results obtained from a selection of simplified models ('design tools') with each other and with the more detailed ('simulation') models used in (b).
(d) Exchange the best detailed simulation models between countries and then conduct parametric studies based on an agreed set of buildings to derive guidelines for use in practical design situations.

The intended outputs were a design handbook – based principally on information generated in (d) – and recommendations on simple design tools for direct use by designers.

The objectives and actual progress in the above areas are now considered in more detail.

Survey of models

A questionnaire was used to obtain details of the models, their availability, applicability, hardware requirements, suitability for different stages of the design process, ease of use and other information. The resulting IEA report (ref. 1) was a useful product for identifying available tools in the participating countries.

The quality of the detailed information obtained was very much a function of the views and experience of the individuals providing the information. It was difficult to obtain up-to-date information as most models are constantly being revised.

Overall, the survey informed the Task participants about the availability of modelling methods and gave qualitative views of model features and usability. The published document represents a fairly comprehensive snapshot of the situation at the time.

Evaluation of models

Many other attempts to validate thermal models have been made and there is no doubt that this is a very difficult process, both to perform and to explain to others who have not had direct experience in so doing. A major study has been conducted by the Solar Energy Research Institute, USA (ref. 2) and more recently in the UK (ref. 3). One of the present authors has been co-ordinating the latter work and participating in this four-year programme. A few points are of relevance in interpreting the significance of the work conducted in the IEA Task.

Firstly, empirical validation should not simply mean the direct comparison of a measured parameter (or a time series describing the evolution of this parameter) with the predicted value(s). In practice there are uncertainties associated with both predicted and measured values – those due to measurement inaccuracy of the output variables and those due to the effects of uncertainties and errors in the assumed model input parameters.

Investigations in the UK work have demonstrated that, even in the best quality measured data available, the effects of the inaccuracies in input data, when propagated through the model, can lead to a substantial range in uncertainty of the model's predictions.

Secondly, an empirical validation study can only ever give information on model performance for one highly specific set of conditions – building type, operating conditions, climate, etc. 'Good' agreement for one or even several empirical exercises can only be used as a rough guide to the extrapolation of performance for a different set of conditions.

Three different approaches were adopted in the course of the Task:

1. Comparison with test cell results

As part of Subtask B three sets of measured data were chosen so that empirical validation of the more promising detailed simulation models could be conducted.

- Direct gain – National Research Council of Canada building.
- Sunspace – Los Alamos, USA test cell.
- Trombe wall – Eclubens, Switzerland test cell.

The UK was only interested in the first two of these techniques and conducted comparisons for them with the models ESP and SERIRES.

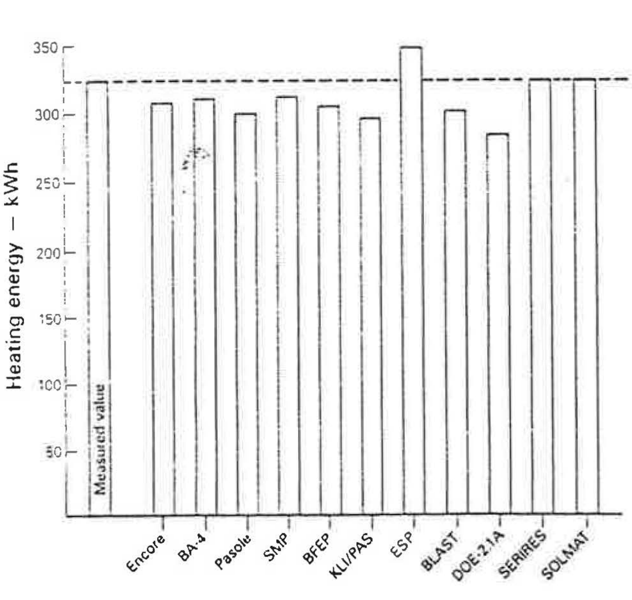
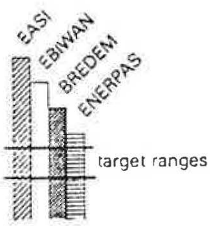


Fig. 1 Comparison of auxiliary heating requirements for two weeks in Ottawa (Canadian direct gain building)



	Mass	Window	Ventilation	Set points heating	Set points cooling
0	lightweight	opaque	not ventilated	20°C	20°C
1	lightweight	opaque	ventilated	20°C	20°C
2	heavyweight	opaque	ventilated	20°C	20°C
3	lightweight	real	ventilated	20°C	20°C
4	heavyweight	real	ventilated	20°C	20°C
7	lightweight	opaque	ventilated	20°C	27°C
8	heavyweight	opaque	ventilated	20°C	27°C
9	lightweight	real	ventilated	20°C	27°C
10	heavyweight	real	ventilated	20°C	27°C

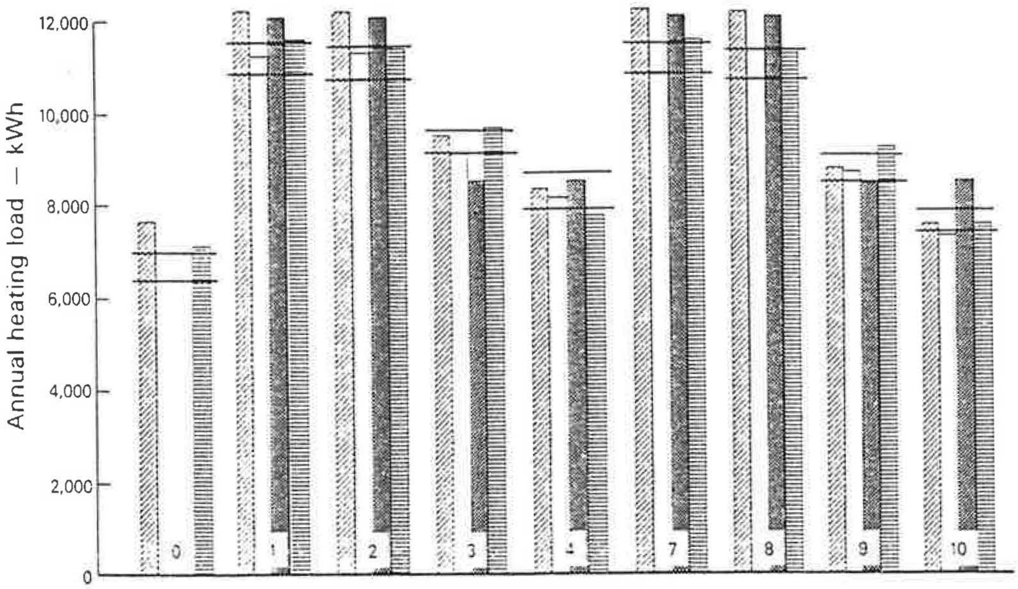


Fig. 4 Copenhagen heating loads

At a late stage in the project a new subgroup was formed to carry out a more detailed design tool evaluation exercise. The participants (Austria, Canada, Denmark, Germany, the Netherlands, UK and US) devised a structured set of variants of a simple building, with thermal properties chosen so as to emulate a more realistic dwelling.

The differences

The main differences between this and the previous exercise were:

- a great deal of attention was paid to producing an unambiguous well-specified building description,
- the tests were structured initially to stress one physical process (conduction) and then to introduce others progressively (infiltration, windows, controller, set-point deadband, etc.),
- comparisons between the predictions of a number of well-regarded simulation models were obtained, taking care to apply checks on the correctness of input data and on the comparability between results.

Fairly good agreement was obtained (see Fig. 4) and led to the notion of using these results to produce target ranges for other models or tools to be tested against.

The main conclusions from these inter-model comparisons are:

- The structured build-up of test cases from the simplest (no window, no infiltration, etc.) to the more complex situations proved successful in allowing the identification of both input and model errors.
- All the data necessary to define the building, the climate and the operating conditions must be unambiguously specified using terminology agreed by all participants.
- If the exercise is to be conducted correctly and if the results are to be properly interpreted, it is essential that the modellers have a good understanding of the models used, the assumptions made in developing them and that these should be well documented.
- The data actually input to the model must be carefully checked for errors.

Any future evaluation studies should consider the above points carefully from the outset.

Parametric studies for the production of design guidelines

The original intention was that a set of standard buildings would be produced and used by all the participants to perform parametric simulations using design tools. This, together with other available information, would then be compiled into design guidelines. There was a feeling that such a process should bring a degree of comparability between conditions in the various participating countries.

As the previous work had not identified any single, portable, design tool capable of reliably dealing with the passive solar measures to be investigated, most participants used SERIRES for these studies.

The Subtask decided on a simple set of continuously heated, single zone buildings. A minimum set of heating and cooling load outputs was specified and most participants restricted themselves to these. The UK

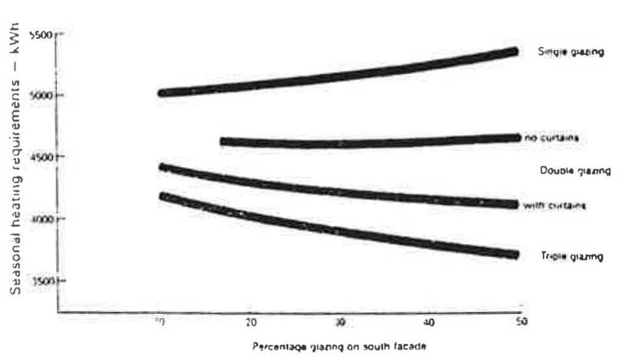


Fig. 5 Effect of south glazing on heat load; IEA Task VIII semi using SERIRES and one period intermittent heating

completed the set of standard runs using UK climatic data as its contribution to the international efforts on climatic similarity studies. To produce UK design guidelines, however, a detailed seven-room semi-detached (half-duplex) house was defined in detail together with a number of different operating schedules. The latter included detailed assumptions about the patterns of occupant behaviour, and used extreme night-setback of heating typical of UK practice. Variations in performance due to changes in wall construction, window size and type, etc were then predicted using SERIRES. A typical set of results is shown in Fig. 5. A number of sensitivity analyses was also conducted to investigate the importance of such issues as zoning assumptions (e.g. 7, 2 or 1 zone modelled explicitly), nodal scheme employed in the model, the building plan shape (narrow, wide frontage), variations in set-point temperatures, venting when maximum temperatures are exceeded, etc.

Assumptions documented

As a result of these detailed investigations the UK became convinced of the absolute necessity for all the assumptions, either implicit or explicit, made in a modelling study to be documented and so opened to scrutiny. Ideally, the effect of variations in these assumptions should be investigated. Certainly without first documenting the assumptions it is quite impossible for a third party to come to any informed decision on the applicability of the results.

Evidence was found for the ease with which different design guidelines could be produced, with the same model, depending on the assumptions made in input data. One example is the general guideline that increasing thermal mass decreases auxiliary heating. This may be true if the North American practice of heating a relatively lightweight dwelling to a constant temperature continuously is adopted. It is not true for a typical intermittently heated UK building and so it is essential to make such assumptions explicit if the user is not to be misled.

In view of the importance of documenting and understanding the assumptions lying behind modelling studies, the UK developed a simple questionnaire for completion by all participants.

UK conclusions

The importance of the model user and the entire set of assumptions both he and the model itself make cannot be over-estimated. When this fact is combined with the difficulty of specifying a building and its operating conditions, many of the large discrepancies between model results in past inter-model comparisons and in empirical validation exercises become easier to explain.

There is a move in the UK, encouraged by both BRE and ETSU, to promote the adoption of much greater standardization of modelling input data and of modelling procedures. One important forum for doing this will be the recently formed UK Building Environmental Performance Analysis Club (ref. 7) which will try to bring together those involved in developing, using and funding the use of thermal models. The formation of a European Society is also currently being considered.

In any future work, the set of modelling and data input assumptions and operating conditions should be chosen carefully to suit the locality for which guidelines are to be produced. These assumptions should be thoroughly documented and the robustness of the advice resulting from the model outputs should be tested by means of sensitivity analyses (and of course real experience if possible). The UK Department of Energy is sponsoring such work as part of its passive solar programme.

Information for house designers

In parallel with the work on thermal modelling techniques, the UK team was concerned with the methods for presenting the design information to potential users. Research carried out by BRE and others (refs 8, 9) had shown the importance of understanding the users' needs and tailoring the technical information to meet these requirements. This led to the following activities:

- a survey of existing passive solar design handbooks
- the production of a new design guidelines booklet suitable for users in the UK
- the testing of these new UK design guidelines on prospective users
- the production of a booklet to emphasize the importance of feedback from the practical experience of designers of low-energy houses

Survey of existing handbooks

As part of the early work for IEA Task VIII, Eclipse Research Consultants (ERC) were asked to produce a short report evaluating the passive solar design handbooks available at that time (ref. 10). The team carrying out the survey were practising architects and the handbooks were looked at from a specific point of view – that of designers considering passive solar design for housing for the first time. Seventeen publications were selected for review by Eclipse Research Consultants (ERC) of which only two were aimed directly at a UK audience. All had been published during the previous eight years. The stated audience varied widely from solar hobbyists to research workers but the large majority of handbooks claimed to be for building design professionals.

The handbooks were reviewed on their relevance to UK design professionals who were expected to have an interest in, but no specific knowledge of, low-energy design. ERC also considered the soundness and validity of the information provided as well as its validity to the UK audience.

Overall conclusion

There was a clear need for a new design guide for the specified audience which:

- reflected the design processes and design practices adopted in the UK

- was more explicit on the ranges of applicability of the guidance given
- provided sufficient information for the cost effectiveness of decisions to be assessed during the design process
- addressed areas such as site analysis and site supervision to ensure building quality together with the necessity for feedback on the design's actual performance.
- was concise enough for a designer to be prepared to pick it up and use it.

These aspects provided the driving forces for the production of new guidelines.

Production of design guidelines

The main output of the international group's work was in the form of Design Information Booklets. An original aim to produce one Design Information Booklet giving guidelines on passive solar design that could be used worldwide did not turn out to be a practical proposition. Most of the participants produced their own national versions.

The UK guidelines booklet was drafted by Eclipse Research Consultants. Their aims were to survey existing literature, discover any obvious gaps and anomalies, use Task VIII contacts and then specify new parametric studies to provide the missing answers. This total package of information would then be used to draft the document for wide circulation to the peer group and the actual intended users (including architects in practice, college lecturers and architectural students). Once these groups had all had the opportunity to comment, their views were to be taken into account when producing a version for official publication.

The plan was not fully adhered to for various reasons:

- The survey of current literature turned out to be never-ending.
- Many of the apparent gaps in present knowledge could not be filled without new research.
- The number and complexity of parametric runs required in order to provide answers to some outstanding questions turned out to be much greater than originally envisaged.
- Views of the peer group were very wide ranging. The results obtained from semi-structured interviews with potential users of the guidelines were much more useful.

Testing of UK design guidelines booklet

A working draft of passive solar guidelines was completed and tested on a wide range of practitioners and on staff and students in academic institutions. This draft was developed by reviewing existing information in great detail. The resulting document contained a distillation of this information covering the areas of glazing and solar gain. Other areas such as condensation and ventilation were not included.

Draft guidelines tested

The draft guidelines were distributed to a dozen architectural practices ranging across the private and public sectors. A small sample of the draft guidelines was produced to artwork stage (including the use of colour) so that potential users could comment on the presentation as well as the content. The practices chosen represented designers who were already well known for 'energy efficient' design, others who had expressed an interest in this area but had little or no experience, or practices which had never attempted energy-efficient design before. Individual practitioners in each office were interviewed about the usefulness of the draft in support of their own particular work.

The draft was also tested using undergraduate and diploma students in British schools of architecture and with higher degree students in academic institutions offering courses related to energy-efficient design.

Basic findings

- The architects liked the idea of having such a document. They had not already got a similar publication on their bookshelves. They felt they could make good use of it when designing houses and appreciated the amount of data provided. They were mostly willing to accept these data at face value and were not worried by the apparent anomalies of data found by the authors when drafting the guidelines. Summaries of each chapter giving just 'the rules' were asked for – i.e. they wanted decisions made for them (or only wanted to have to read the first page of each chapter!).
- The lecturers in architectural institutions also appreciated the document. They thought it would be useful to their students in providing concise information where either their own teaching expertise was thin or where specialist staff were not available fully to support studio work. One overall problem was the lack of priority given to teaching environmental matters such as conserving energy or occupant comfort. The main emphasis of architectural teaching in the UK is on the 'formal' or 'aesthetic' qualities of the design.
- From the answers given by students (who were given the opportunity to use the draft guidelines to support their current housing design projects), it was obvious that they paid little attention to using energy efficiently. Some who did use data from the draft did so to try to overcome the inherent environmental problems posed by their own initial decision making.

The importance of post-construction activities

Design guidelines are not the only information required by the design team to encourage the uptake of successful low-energy design. The UK team holds strong views on the need for all designers to obtain feedback on the overall performance and usability of the constructed dwelling.

The advantages to the designer of good feedback are:

- more self confidence in his design methods
- more credibility in the eyes of his client
- more efficient design of future projects.

The mechanisms to achieve this can include:

- government-sponsored research (in the UK via bodies such as ETSU and BRE)
- from designers living in their own passive solar homes
- designers regularly visiting their own schemes or special developments (such as the UK Milton Keynes Development Corporation (MKDC) 'Energy World' scheme (ref. 11))
- by occupiers of houses keeping logbooks, recording their opinions and experiences on the practicality of energy-efficient features.

In future ETSU will carry out more monitoring in the UK as part of their Energy Performance Assessment scheme. Some UK house developers are providing extra information in the form of occupant manuals. Others, such as MKDC, aim to monitor housing to see if it does meet the standards of energy use put forward at the design stage. Architects in general still need to be persuaded to put 'feedback' into their initial contract. Someone has to persuade the client (usually a developer) that it is vitally important to have happy occupants and to know how well a house design is really working. It may well save the developer money in future.

Architects should go back, not just to do a standard inspection for defects at some specified interval but to treat visits as an opportunity to both look and listen. They need to inspect and record the condition of any energy-efficient features and the pattern of household energy consumption. They should talk to the occupants, ask questions and listen to what the occupants say in reply. Designers may then be able to construct more realistic images of the occupants and so make more robust assumptions about some passive solar design features.

Practicalities of international collaboration

Participation in the IEA Task VIII has been very valuable for the UK. Although some of the original expectations have not been achieved and the methodology has often evolved over the course of the Task, this should not be surprising in view of the ambitious nature of the original objectives. The degree of contact between experts from many countries and between different disciplines (architects, physicists, information transfer specialists, etc.) has been high and has led to a much better understanding of different ways of working, national conditions and priorities.

The need for more work on, and a more general understanding of, models has emerged strongly from the Task. If models are to be of use they must be credible.

Any future international effort in the modelling field should seriously consider the mechanics of how real collaboration can be achieved; working together in a small group for an extended period proved very effective on the one occasion it was tried within the Task.

Conclusions

(i) Before selecting any model for a performance assessment, it is important to be clear on the use to which it is to be put and the range of uncertainty within which results are acceptable.

(ii) In practical design situations, it will continue to be difficult to use detailed simulation models until better user interfaces, improved checking facilities and more universally accepted methods for their use have been developed. Currently the effect of the model user can be very large but linking with CAD and expert systems offers the promise of improvements over the next few years.

(iii) Simplified design tools are more appropriate in the early stages of design but no single, suitable tool (or sets of tools) was identified. An improved methodology for inter-model comparison has been suggested within the Task. It is anticipated by the Design Tool Evaluation Working Group that this will lead to better aids for selecting and assessing the applicability of such tools.

(iv) The detailed specification of the problem being modelled is difficult but extremely important. All assumptions made, as well as the data used, should be documented. This is probably only practical if sets of 'standard' assumptions and procedures are devised. There is no unique set of assumptions which would be appropriate – they will be dependent on the location and on the user habits, amongst others.

(v) The form and quality of presentation of information in design guides is very important if they are to be accepted and used by house designers. An important part of ensuring acceptance is to obtain feedback from the intended audience.

(vi) There is evidence that, even with appropriate design guides, attitudes to teaching in some UK architectural schools will need to change to ensure sufficient emphasis on energy issue as part of the design process.

(vii) A strong case is made for designers themselves (and the various housebuilding authorities) to obtain early feedback on the performance of constructed dwellings. This would accelerate the confidence in and resultant uptake of improved energy-efficient designs.

(viii) In planning any future international ventures, the difference between countries in building practice and occupant behaviour as well as climatic conditions should not be underestimated when assessing the opportunities for collaboration.

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