Do simple performance modelling tools help the architect to achieve buildings that are more energy efficient?

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ABSTRACT: To investigate the effectiveness of simple performance modelling, six houses in North Oxford were simultaneously modelled and monitored. The modelling and monitoring told the same story: in a well insulated building there is little energy to be saved in careful orientation of the building, contradicting the received wisdom and expectation that south orientation is important for energy saving.

However the story is more complicated than that. Although the energy use was broadly similar, living rooms in the south facing houses were always warmer, winter and summer. They required an input of careful management by the household to achieve good conditions.

In the monitored houses the energy use varied by a factor of three; the largest influence on energy use was the occupant- how he or she chose to run the building.

As modern, well insulated houses, the units failed to perform well in a number of ways. This might reasonably give cause for concern nationally.

Conference Topic: 2 Design strategies and tools
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INTRODUCTION

Buildings in Britain account for around 50% of the total national energy consumed. There is evidence that man is over-exploiting nature: long term effects must be considered. To reduce impact on global and local environments buildings need to be designed to consume less energy. Architects need to have a better understanding of how decisions they take affect the physical processes which occur in their buildings. The interaction of buildings, occupants and environments is extremely complex and sophisticated tools are developing which help architects and engineers to appreciate the interaction of design strategies. To be helpful, tools need to provide guidance quickly and reliably.

The effect of orientation on energy use was investigated by modelling and monitoring a group of six speculative houses.

It was anticipated that south facing orientation of main windows/conservatory would achieve the best comfort and energy performance and that performance modelling with simple models was unlikely to generate unexpected information to an experienced designer.

2. DESCRIPTION OF HOUSES

2.1 Physical conditions

The houses were first occupied in the year 2001/2002 and are larger than the national average family home at 250 square metres of floor area, arranged over three storeys, with a garage of 18 sq m. The houses are detached with approximately one metre between adjacent units. The site is flat and the houses have similar exposure.

2.2 Construction

They are masonry built, with a concrete slab at first floor, and timber construction at second floor. The design includes a conservatory on the side of the house opposite to the entrance. External fabric is generally insulated to the 1995 Building Regulation standard. The external walls are dry lined with plasterboard. The houses were built in a number of orientations.

The houses were not constructed anticipating any special sort of testing or monitoring so it seems reasonable to assume that construction standards in these large and expensive speculative houses are broadly representative of the national average for houses built to the 1995 standards.
2.6 Details of occupancy patterns

Occupation patterns in the units were similar, though one household employed a nanny for their children so the house was occupied through the day; one household included retired people, see table 1 below.

<table>
<thead>
<tr>
<th>House</th>
<th>No of person</th>
<th>% house normally used</th>
<th>Average % house used related to time</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>2 + 2</td>
<td>70</td>
<td>41</td>
</tr>
<tr>
<td>S2′</td>
<td>2 + 2</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>N1</td>
<td>2 + 1</td>
<td>54</td>
<td>28</td>
</tr>
<tr>
<td>N2′</td>
<td>2</td>
<td>63</td>
<td>45</td>
</tr>
<tr>
<td>E1</td>
<td>2 + 3</td>
<td>67</td>
<td>30</td>
</tr>
<tr>
<td>E2</td>
<td>2 + 3</td>
<td>99</td>
<td>59</td>
</tr>
</tbody>
</table>

1. Daytime nanny during weekdays
2. Retired couple who go away frequently for long spells, and who have family to stay especially at weekends and school holidays

Table 1 Average house usage developed from survey information about areas of house and time of occupancy

The percentage of the house occupied in normal use by the families seems to suggest that there is over provision of space, perhaps because the family purchase anticipates space requirements to increase, or because ownership of these units is seen as an investment opportunity. In terms of use of resources, this oversizing of recently occupied housing must contribute to problems of escalating energy use.

3. METHODOLOGY

3.1 Measurements in existing houses

Temperature monitoring was carried out over the hottest period of the year (July 2003) and fuel consumption measured and compared for a full year. Subsequently the monitoring was extended to include sample winter weeks (February 2004) because the original data gave unexpected results. At this point we anticipated that the variations observed in energy use were attributable to skilful management of the building.

For performance modelling purposes, the house was perceived as five zones (two per floor on opposite sides of the building and one in the attic space.) Loggers were positioned in each zone of the house. The loggers were a mixture of l-button temperature loggers and Tinytalk loggers and were mounted, as far as possible on furniture, to measure air temperature rather than the temperature of the structure.

3.2 Performance modelling

The models used to predicted and compare the performance of the houses built to the same design in three different orientations (conservatory facing south, east and north) were:

- Building toolbox, Edward Matthews, University of Pretoria, South Africa
- Ecotect, Andrew Marsh, Australia and now Cardiff School of Architecture
and a simple excel model set up by the researcher.

<table>
<thead>
<tr>
<th>Design day, internal temp 18.5°C</th>
<th>North</th>
<th>South</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excel, internal temp 18.5°C</td>
<td>22,561</td>
<td>21,448</td>
<td>22,286</td>
</tr>
<tr>
<td>Building toolbox Preliminary design</td>
<td>20,384</td>
<td>20,264</td>
<td>20,366</td>
</tr>
<tr>
<td>Ecotect, incl. adjoin houses, no shading, int temp 18.5°C</td>
<td>23,372</td>
<td>22,747</td>
<td>23,067</td>
</tr>
<tr>
<td>Generated recorded gas readings</td>
<td>26,425 (N1)</td>
<td>25,106 (S1)</td>
<td>7032 (E1)</td>
</tr>
<tr>
<td></td>
<td>24,656 (N2)</td>
<td>27,561 (S2)</td>
<td>28,848 (E2)</td>
</tr>
</tbody>
</table>

Table 2 Comparison of modelled and recorded energy use (kWh/year)

The modelling tools were run using real weather data and the overheating was investigated (predicted and real) for the hottest monitored day, 10 July 2003.

<table>
<thead>
<tr>
<th>Zones</th>
<th>Building toolbox</th>
<th>Ecotect</th>
<th>Real measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservatory/family room</td>
<td>24</td>
<td>13</td>
<td>11.7</td>
</tr>
<tr>
<td>N1, N2</td>
<td>24</td>
<td>12</td>
<td>11.1</td>
</tr>
<tr>
<td>S1, S2</td>
<td>24</td>
<td>10</td>
<td>8.8</td>
</tr>
<tr>
<td>E1, E2</td>
<td>24</td>
<td>14</td>
<td>10.9</td>
</tr>
<tr>
<td>Master Bedroom (on same side as conservatory)</td>
<td>24</td>
<td>19</td>
<td>0.5</td>
</tr>
<tr>
<td>N1, N2</td>
<td>24</td>
<td>14</td>
<td>10.9</td>
</tr>
<tr>
<td>S1, S2</td>
<td>24</td>
<td>13</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 3 Overheating. Comparing modelled performance with measured data

4. DISCUSSION OF RESULTS.

4.1. Modelling
The performance modelling, with all three models, suggested rather similar amounts of energy use for each of the three dwellings, which was relatively close to the actual energy used. Generally the modelling indicates very little energy saving could be anticipated from orientating the main windows south: in the measured data this is not the case, the south facing blocks use the most energy, but it is of course a very small sample.

Modelling the temperatures in the dwellings was much less satisfactory: the models tended to substantially over estimate the overheating problem in summer. This is unhelpful, as use of these tools might tend to discourage use of passive strategies.

Broadly the energy use fell within the predicted loads in the performance models. The east facing house (E1) uses considerably less fuel than other units.

The amount of energy, measured or modelled, is substantially in excess of the benchmark calculated for a regular Building Regulations house, generally around double. This is disappointing. The inclusion of the conservatory within the house shell and the overall lack of airtightness may be largely the cause.

4.2 Measuring temperatures in the houses.
In summer conditions the temperatures measured in the six family rooms varied by up to 6°C in the day and around 2°C at night (see figure 3 below). In S1, the south facing house that is not occupied much during the working week, following a week of hot weather the family room peaks around four degrees hotter than the external conditions. Management strategies in the second south facing house control the internal conditions in this room to temperatures similar to outside.

Figure 3 Family room temperatures 9-10 July 2003
It is interesting to note from figure 4 that the notional heavy weight masonry structure has an effective damping effect on the temperatures experienced on the middle floor, where there is less glazing. Temperatures are much steadier and on the hottest days the peak internal temperature is lower than outside.

Figure 4 Bedroom temperatures, 1st floor, 9-10 July 2003
Further temperature monitoring was carried out in the winter 2003/04, mainly to investigate the very low energy use achieved by the east facing house, E1. From figure 5 below, it can be seen that the temperatures in the two south facing family rooms are higher than the other houses. They are warmer by more than 4 degrees and, in the house unoccupied
during the working day, it seems likely that a midday peak is associated with solar gains. One of the east facing houses almost never achieves temperatures as high as 16°C although, from the peaks in late evening, it is clear that these units are heated.

5.2 Importance of management strategies

In summer the conservatory room fluctuates in temperature by nearly 10 degC. In the best managed south facing house in peak conditions, external and internal temps are similar; in the less well managed house (occupants out through the day) temperatures considerably exceed peak external temperatures.

Where building occupants are at home through the day to control solar gains, it appears that the south facing windows offer considerable benefits, generally not in energy saving, but in increased internal temperatures. This was not represented in the performance modelling. Where the buildings are not occupied during the day, sophisticated control mechanisms would reduce over heating in the south facing spaces in summer

5.3 Effect of thermal mass

The bedroom summer temperatures are steadier; there are smaller windows and more thermal mass so on peak days the external temperature exceeds the internal. In general (non peak) summer conditions the first floor rooms exceed external temperatures by around 5 degC.

The bedroom winter temperatures are steadier with no appreciable influence of weather conditions though the south facing rooms are on average around 5 degC warmer than the others.

5.4 Comfort temperatures

The winter temperatures suggest that the lowest energy use house actually experiences temperatures much colder than the other units- their room temperatures do not follow the generally accepted centrally- heated comfort temperatures in these houses.

In winter conservatory room temperatures vary over about 8-10degC with higher temperatures for the south facing rooms. Temperatures in E1 reach comfort conditions very rarely though this is unlikely, because of location etc, to be because of fuel poverty, and is attributed to preference.

5.5 Bench mark comparison

These units use twice as much heating energy than the bench mark standard: this seems a serious flaw and may partially be a result of the living room open to the conservatory space.

As the south facing rooms are always warmer, it seems reasonable to conclude that the boiler controls are insufficiently sophisticated to utilise these solar gains. (There is a single zone for the whole house with a temperature sensor located in the ground floor hall) single zone per floor, with temperature sensor located on the landing.

More studies are needed to establish the effectiveness of the Building Regulations in reducing energy use in buildings.

5.6 Use of simple predictive tools

The tools generally gave energy information that was reasonably accurate. Temperature predictions were unhelpful, particularly as a designer might conclude that passive strategies were bound to be ineffective in producing a comfortable building.
These simple tools do not influence the scheme towards improved design standards or reduced energy use; they provide just a prediction of building performance.

Much more was learnt about housing design from the careful analysis of the built houses than from the modelling.

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