Investigations on effect of the orientation on thermal comfort in terraced housing in Malaysia

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Abstract The design of residential buildings has a significant impact on people’s daily life. The ‘terrace house’ form constitutes the majority of the residential building stock in Malaysia. The lack of thermal comfort in terrace houses is mainly due to the poor thermal properties of the building materials and to design factors [1]. The evaluation is derived from a series of computer simulations using commercially available software. This paper concentrates on analysing the effect of the orientation of the existing case of a typical terrace house in Malaysia by finding the dynamic indoor air temperature for each orientation.

1. Introduction

This paper aims to study the dynamic factors of temperature variations (hourly) under the effect of different orientations (north, northeast, east, southeast, south, southwest, west and northwest). The climatic parameters in Malaysia (KL) are analysed over a thirty-year weather data period in order to find the typical ‘Design Day’. This data is vital to the calculation. The climate in Malaysia can generally be described as tolerable in terms of thermal requirements. The common prototype design has been chosen in this study to represent the terrace house in Malaysia. A series of computer simulations using commercially available software known as the BLAST is conducted to evaluate the dynamic indoor air temperature within 24 hours.

2. Research aim and objectives

The aim of this paper is to study and explain the effect of the orientation as a design variable in reducing the indoor air temperature, which is important to the designer and researcher. This will be valuable to designers in evaluating the thermal comfort significance for design decisions in architecture.

3. Orientation

The amount of solar radiation received by the building envelope depends on its orientation. An important clue in developing energy efficient facades is knowledge
about the distribution of solar radiation due to orientation. Buildings should be planned in such a way that benefit is obtained from shaded indoor and outdoor living areas when the weather is hot.

The high angle of the sun makes it easy to shade the house by a generous roof overhang. This is because the sun is much lower in the sky throughout the day, favoring the vertical surface (Fig. 1).

“The incident radiation on the east face in the morning and the west face in the evening is still high, but not as high as that on the north face during the middle of the day. The south face receives no direct component” [2]

Because in hot-humid regions close to the equator the diffuse radiation has a predominant share of the overall radiation and the fact that the distribution of the diffuse radiation is almost identical at all orientations, the orientation of the buildings might be more influenced by other external aspects, like the prevailing wind direction. [3]. Table 1 shows the orientations that are used in the analysis of this study.

4. Thermal comfort studies in Malaysia

For comparison purposes, the results of the criteria from several sources are summarized in Table 2. For example, the temperature range obtained from Zain [4] is between 24.5–28.0degC, which is lower than Abdulmalik [5] but higher than the range suggested by the Ministry of Energy, Telecoms and Posts.

This table comprises eight thermal comfort studies, four of which have been carried out on Malaysians either in climate chambers or as field studies. The outcomes of the studies differ slightly due to different test procedures. However, most of the studies seem to agree on a Malaysian comfort temperature of around 25 degC air temperature.
5. Simulation programs and BLAST program

Selecting the BLAST program (Building Loads Analysis and System Thermodynamics), for which seemed suitable the aims and methodology of the research. BLAST is a family of programs for predicting heating and cooling energy consumption in buildings and analyzing energy costs. HBLC (Heat Balance Loads Calculator) is an easy-to-use graphical user interface for the BLAST engine. Together BLAST and HBLC form a comprehensive thermal software package. Evans [9]. Supporting computer programs have been developed to facilitate weather file generation, automated simulation process, the extraction of key results and data analysis on microcomputers.

6. Building model: ‘the typical Malaysian terrace house’

The common prototype design has been chosen in this study to represent the terrace house in Malaysia. Thirty-seven layouts of terrace houses constructed in Malaysia were obtained from architectural firms in Kuala Lumpur. From these plans, a ‘typical terrace house’ was derived incorporating the most commonly occurring layouts and
space types and sizes. This typical terrace house is shown in figure 1, which shows a two-storied terrace house where each floor is divided into 4 or 5 spaces for the average Malaysian family of 5 persons living in terrace house. The terrace house consists of the ground floor, with spaces for living/dining area, kitchen, bedroom, bathroom and staircase and the first floor, with spaces for master bedroom (bathroom en suite), bedroom, child bedroom, bathroom and staircase (Ali) [7] Fig. 2.

7. Kuala Lumpur climate

The climatic parameters in Malaysia (KL) are analyzed over a thirty year weather data in order to find the typical ‘Design Day’. This data is vital to the calculation. The climate of Malaysia can generally be described as tolerable in terms of thermal requirements. Diurnal temperature variations are small due to the presence of clouds throughout the day. Cloud cover also occurs at night causing warmer nights. Heat trapped between the ground and cloud may cause the air temperature to rise due to re-radiation from the ground at night, especially when the wind speed is low and humidity is high. The daily climatic data indicates that the temperature rises as high as 32 deg C at 1300 hours when the global radiation is at its highest. Humidity of 67% RH is the lowest in the region and the average is more than 80%.

In spite of the fact that the wind has no dominated direction, its presence over most of the day helps to maintain comfort conditions inside buildings. (Ali) [7] Fig. 3, Table 3.

8. The analysis of hourly indoor air temperature in the living & dining room

Figure 4 shows that the best orientation of the living room in January is northward and in June is southward because both recorded a minimum indoor air temperature
Table 3. Records of monthly mean of temperature, humidity & wind speed for the last 29 years, Source: Ali. [7]

<table>
<thead>
<tr>
<th></th>
<th>Number of the years</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEMP.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEAN</td>
<td>30 years</td>
<td>26.9</td>
<td>27.2</td>
<td>27.5</td>
<td>27.6</td>
<td>27.7</td>
<td>27.8</td>
<td>27.3</td>
<td>27.1</td>
<td>27</td>
<td>26.6</td>
<td>26.6</td>
<td></td>
<td><strong>27.23</strong></td>
</tr>
<tr>
<td>MEAN OF MAX.</td>
<td>30 years</td>
<td>32.5</td>
<td>33.3</td>
<td>33.5</td>
<td>33.3</td>
<td>33.1</td>
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<td>32.5</td>
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<td>32.1</td>
<td>31.9</td>
<td></td>
<td><strong>32.79</strong></td>
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<tr>
<td>MEAN OF MIN.</td>
<td>30 years</td>
<td>23.1</td>
<td>23.4</td>
<td>23.8</td>
<td>24.2</td>
<td>24.3</td>
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<td>23.6</td>
<td>23.6</td>
<td>23.3</td>
<td></td>
<td><strong>23.71</strong></td>
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<tr>
<td><strong>Relative Humidity (RH)</strong></td>
<td>30 years</td>
<td>78.4</td>
<td>78.2</td>
<td>79.3</td>
<td>81.5</td>
<td>80.6</td>
<td>78.9</td>
<td>78.9</td>
<td>80.6</td>
<td>81.6</td>
<td>83.6</td>
<td>81.9</td>
<td></td>
<td><strong>80.20</strong></td>
</tr>
<tr>
<td>The Mean of Wind Speed (m/s)</td>
<td>30 years</td>
<td>1.02</td>
<td>1.10</td>
<td>1.06</td>
<td>1.00</td>
<td>1.00</td>
<td>1.07</td>
<td>1.17</td>
<td>1.15</td>
<td>1.03</td>
<td>1.16</td>
<td>0.97</td>
<td>0.90</td>
<td><strong>1.05</strong></td>
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with a peak value of 31.2 deg C. At the same time Figure 4 shows that the worse orientations in January are southeast and southwest because both recorded a maximum, mean indoor air temperature with a peak value of about 36.5 deg C. Meanwhile, in June the northwest and northeast-recorded maximum mean indoor air temperatures with a peak value of 35.4 deg C.

Figure 4A shows that the maximum mean variation among the indoor air temperature mean value in January ranges between 29.8 deg C and 36.7 deg C and in June between 30.3 deg C and 35.4 deg C as in Figure 4B.
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Table: Hourly Mean temperature

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Time</th>
<th>JAN.</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>north</td>
<td>28.9</td>
<td>30.8</td>
<td>31.2</td>
</tr>
<tr>
<td>northeast</td>
<td>29.8</td>
<td>30.4</td>
<td>31.0</td>
</tr>
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<td>east</td>
<td>30.9</td>
<td>31.4</td>
<td>31.6</td>
</tr>
<tr>
<td>southeast</td>
<td>31.8</td>
<td>32.0</td>
<td>31.8</td>
</tr>
<tr>
<td>south</td>
<td>32.7</td>
<td>32.8</td>
<td>32.7</td>
</tr>
<tr>
<td>southwest</td>
<td>33.5</td>
<td>33.6</td>
<td>33.2</td>
</tr>
<tr>
<td>west</td>
<td>34.2</td>
<td>34.2</td>
<td>34.0</td>
</tr>
<tr>
<td>northwest</td>
<td>34.9</td>
<td>34.9</td>
<td>34.6</td>
</tr>
</tbody>
</table>
| Living & Dining Room in Ground floor - 8 Orientation

Figure 4. A and B: The hourly temperature of the living and dining room in January and June. C and D: The hourly temperature Curves through eight orientations in January and June. E and F: The hourly peak values within occupancy hours in January and June.
Moreover, as seen in Fig. 4 for all orientations, it is observed that in both January and June, for 24 hours the hourly minimum indoor air temperature occurs in the morning from 6.00 am to 8.00 am, except northward and northward where the minimum indoor air temperature continues until 11.00 am.

The hourly maximum indoor air temperature usually occurs at 6.00 pm while with eastward it occurs from 3.00 pm to 4.00 pm. Peak hours occur from 2.00 to 4.00 pm with west and southeast orientations.

Figures 4 indicate that the indoor air temperature variation within one year is not more than 7 deg C since the minimum indoor air temperature value is 29.8 deg C and the maximum indoor air temperature value is 36.7 deg C.

However, the variations of means of indoor air temperatures among all orientations throughout a year are less than that because the minimum mean value is 30.5 deg C and the maximum is 34.0 deg C so the difference between them is less than 3.5 deg C.

Figure 5. Top) Hourly temperature for different orientations for the living room. Left) Table of the hourly mean indoor air temp. Value for all the spaces due to eight directions. Right) Curves mean of indoors air temperature to eight directions in one year.
9. The mean of indoor air temperature values through one year

The highest indoor temperature values are towards eastward, westward and the 
lowest are northward and southward, Figure 5 right curves.

It is interesting to note that the sequential arrangement of the mean temperature 
values, from the lowest to highest for the terrace house spaces throughout the year, 
is quite similar to that of January while it is slightly different from June observed 
only with bathrooms and first bedroom.

10. Conclusions and recommendations

The main points for the existing terrace house Orientation analysis can be summa-
rized as follows:

First, it has been found that the effect of orientation is one of the most important 
design variables upon the indoor temperature with a value of partial correlation equal 
to 58%.

Second, the orientation of the exposed walls of the terrace house should be on the North–South axis, i.e. facing North and South in order to minimize solar heat gain. The best orientations for all spaces, as a general rule, are ‘Southward and northward’. This is because both orientations have recorded the same minimum mean temperature throughout the year, with a peak value of about 32.2 deg C because of 
the Sun’s position in these directions (no direct radiation). The worst orientations

Figure 6. The best orientation for the terrace house in Malaysia.
are ‘Westward and Eastward’ both of which have recorded maximum internal mean temperatures throughout the year compared to other orientations with a peak value of 33.4 deg C. (Appendix A). Therefore, it will be useful to arrange the front and back façades of a terrace house to the North and South while there is no effect to the bad orientations East and West because these sides are attached already to the other adjacent houses as in Fig. 6.

Third, the effect of orientation on the indoor air temperature of the façade spaces is very high; it may reach up to 4 deg C during the night hours, increasing to 7 deg C during the day.

Forth, all the temperature curves for June are mirror images of the January temperature curves (Figures 5 and 6). Therefore, the temperature curve for the ‘North Front’ elevation in January has the same shape as the curve for the ‘South Back’ elevation in June. Since the terrace house has only two elevations (front and back) it becomes difficult to provide the best orientation for both of them at the same time.

Fifth, it is necessary to avoid windows on the eastern and especially the western face of the terrace house as these locations are particularly difficult to shade. The east and west facing surfaces receive the most sun in the mid-morning and mid-afternoon respectively. Western surfaces are especially difficult to shade; therefore, window areas on these surfaces should be minimized. The preferred orientation of windows should follow the same pattern, with the main windows facing north and south. The north façade is better as it is easier to shade.

References