Design Guide

Section 1: Methodology/tools used for Natural Ventilation Study

1. The common methodology/tools used for natural ventilation study during the design stage include wind tunnel and computer software such as CONTAM96 and CFD.

2. For the investigation of the airflow around buildings, taking into consideration the effects of surrounding obstructions such as multi-storey car parks, block shapes and arrangement, block spacing etc, a combination of wind tunnel and CONTAM96 could be very useful. Utilizing the wind tunnel facility, wind pressure at any surface location of the housing blocks under investigation can be obtained. The physical models usually in the scale of 1:100 to 1:200 can be fabricated fairly easily. With the wind pressure data, CONTAM96 can then be utilized to compute the air change rate of the residential units.

3. For detailed analysis of the airflow inside a typical residential unit, CFD software proves to be a very effective tool. The software could produce very detailed air distribution profiles inside the unit. The software could also compute the temperature, pressure as well as pollutant dispersal profile since it can model the heat and pollutant sources. Thus, this tool is very useful for the investigation of natural ventilation inside the residential unit, taking into consideration the effects of internal layout, window and door types, sizes, locations etc.

Section 2: Consideration of Singapore Climatic Condition

1. The natural ventilation performance of HDB flats is very much governed by the orientation of the window openings.

2. Table 11.1 shows the monthly wind frequency distribution and magnitude in Singapore. From the table, it is obvious that the prevailing wind directions are from North and South.

3. Subject to the constraint imposed by the site, it is imperative to orient the window openings facing the North and South directions. This is also an ideal orientation to minimize the solar heat gain in buildings.
<table>
<thead>
<tr>
<th>No</th>
<th>Month</th>
<th>Wind Direction</th>
<th>Frequency (%)</th>
<th>Magnitude (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>January</td>
<td>N/ NNE</td>
<td>68</td>
<td>2.70</td>
</tr>
<tr>
<td>2</td>
<td>February</td>
<td>N/ NNE</td>
<td>72</td>
<td>3.10</td>
</tr>
<tr>
<td>3</td>
<td>March</td>
<td>NNE/ E/ SW</td>
<td>51</td>
<td>1.90</td>
</tr>
<tr>
<td>4</td>
<td>April</td>
<td>Vary</td>
<td>-</td>
<td>1.40</td>
</tr>
<tr>
<td>5</td>
<td>May</td>
<td>Vary</td>
<td>-</td>
<td>1.40</td>
</tr>
<tr>
<td>6</td>
<td>June</td>
<td>SSE</td>
<td>46</td>
<td>2.10</td>
</tr>
<tr>
<td>7</td>
<td>July</td>
<td>SSE/SSW</td>
<td>53</td>
<td>2.00</td>
</tr>
<tr>
<td>8</td>
<td>August</td>
<td>SSE</td>
<td>53</td>
<td>2.70</td>
</tr>
<tr>
<td>9</td>
<td>September</td>
<td>Vary</td>
<td>-</td>
<td>1.80</td>
</tr>
<tr>
<td>10</td>
<td>October</td>
<td>Vary</td>
<td>-</td>
<td>1.10</td>
</tr>
<tr>
<td>11</td>
<td>November</td>
<td>NNE/NNW</td>
<td>34</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
<td>December</td>
<td>NNE/NNW</td>
<td>71</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 1: Monthly wind frequency and magnitude distribution in Singapore

**Section 3: Design of Internal Layout**

1. The layout of the residential unit should be such that it can reap the potential of cross ventilation.

2. Bedrooms should be designed to allow cross ventilation. Currently most bedrooms are designed to be single-sided ventilated. Thus, when the bedroom doors are closed, the natural ventilation performance of the bedrooms is drastically affected. The provision of louvers for the doors and/or above the doors that were used in the old days should be reconsidered.

3. Bedroom doors should also be placed strategically facing the direction cross ventilation could occur. This can in fact improve the airflow inside the bedrooms via better infiltration/exfiltration.

4. The use of passive stack effect relying on the temperature gradient is not a feasible solution based on these findings of this study. The temperature gradient was found to be too small to generate sufficient air movement for comfort.
5. An alternative solution is to use active stack effect. A prototype developed in this study shows that for a stack size of 0.4 x 0.4 m with a top mounted fan with air speed of 5.5 m/s could achieve the maximum velocity of about 0.67 m/s in the bedrooms installed with the stack.

6. Thermal Comfort and IAQ of residential units
   - Thermal comfort study shows that the HDB flats has achieved about 83% of acceptability by the HDB dwellers based on their thermal comfort perception.
   - Fanger’s equations of PMV and PPD were found to be unsuitable for thermal comfort study in HDB flats since the equations were developed based on air-conditioned environment.
   - Thermal comfort perceptions between flat types and floor levels are minimal though in general, the mid floor dwellers tend to exhibit higher dissatisfaction.
   - Wind sensation impacts the thermal perception critically thus design of the internal layout to optimize cross ventilation is critical.
   - Comparison of the IAQ of air-conditioned and naturally ventilated bedrooms show that the CO₂ levels of bedrooms using air-conditioning is significantly higher. The level can be higher than that recommended by ENV guideline. This is mainly due to the lack of fresh air provision.
   - Comparison of the particulate levels shows that naturally ventilated bedrooms are marginally higher than that of the air-conditioned bedrooms.
   - Occupants using the air-conditioned bedrooms also tend to exhibit more Sick Building Symptoms (SBS) than those using naturally ventilated bedrooms. The common symptoms include block nose, running nose, dry throat and dry skin.

Section 4: Design of Site Layout

1. Multi-storey car parks (MSCP)
   - The distance (set-back) between MSCP and the surrounding housing blocks may affect the ventilation performance of the of residential units but there are many other critical factors to be considered.
   - By having the housing blocks surrounding the MSCP, it is essential to have the housing blocks layout in such a way that an opening can be created to face the prevailing wind direction. This enable the layout to behave as a wind scoop to capture the prevailing wind thus enhancing the natural ventilation of the residential units.
The provisions of void decks are essential to allow the wind to flow across the housing blocks. This will improve the natural ventilation of the lower floors. This will also ensure that the car parks are adequately ventilated to dilute and remove the pollutants generated by the vehicles.

2. Block Shape and Arrangement
   - Linear Block
     i. Linear block should be arranged to have the window openings facing the prevailing North and South wind directions.
     ii. To ensure minimum obstructions by the surrounding blocks, the blocks should be arranged staggered to each other.
     iii. If there is variation in the block height, the taller ones should be positioned in the down stream area.
   - Point Block
     i. Due to the compact design of point block, they should be positioned together with other point blocks in the staggered position to ensure that the facades are able to capture the prevailing wind.
   - U-shaped Block
     i. The U-shaped block should be oriented towards the prevailing North and South wind directions.
     ii. It is not necessary for the orientation to be perpendicular to the prevailing wind direction. An oblique angle can also bring about good ventilation.
   - L-shaped Block
     i. The block should be positioned at an oblique angle to the prevailing wind directions so that the wind captured can spread evenly to the two wings of the building.

3. Block Spacing
   - There is no single optimum spacing between the blocks to optimize natural ventilation.
   - Optimum block spacing varies according to the layout of the blocks.
   - For housing blocks arranged in the regular grid, the optimum distance has been found to be around 27m based on this study.
   - For housing blocks arranged in staggered position, the ventilation performance increases with the increase in the block distance even up to 36m.