Monitoring of a dwelling equipped with a demand controlled ventilation system
Indoor air quality has become one of the major concerns in Japan since notably the last national scale survey had revealed that the indoor concentration of formaldehyde in considerably large number of dwellings had been higher than the concentration guideline. Besides the hygienic aspects, the recent oil crisis has involved to reconsider the energy aspect in the Building. Considering that air renewal represents up to 50% of the total building consumption, the control and the management of the ventilation becomes a major concern for all the actors of the Building sector. The monitoring presented in this document aims thus at improving the knowledge and at helping developing efficient strategies regarding ventilation aspects.

Started in February 2008 in a 30 years old building in the centre of Tokyo, this experiment has consisted in measuring and recording several ventilation parameters during a couple of weeks in a monitored dwelling, to evaluate the performances of a humidity controlled mechanical ventilation system. Managed by the NILIM (National Institute for Land and Infrastructure Management), this project is the result of a cooperation with French Aereco Company. The dwelling, belonging to Tokyo Gas company, was composed of two bedrooms and three technical rooms for a total surface of 40 m² (height 2.50 m). The human occupancy was physically simulated by the mean of four water and heat emitters located in the kitchen, bathroom, and bedrooms, while the ventilation performances were measured through specific instrumentation located in each ventilation device (air inlets and air extract units).

**Ventilation system**

The dwelling is equipped with a demand controlled mechanical ventilation system: The polluted air is extracted though BXS air extract units from the wet/technical rooms. The demand controlled* air extract units distribute the exhaust airflow generated by the V4A fan according to the needs of each room. In this monitoring, the new air is distributed in the bedrooms by the mean of through-the-wall EHT humidity sensitive air inlets.

* humidity sensitive, presence detection and manual boost airflow

**Human presence simulation**

Special sophisticated emitters provided by the NILIM were used to simulate the human occupancy: the quantity of water is controlled and is set according to a scenario of occupancy. The principle is to simulate a couple with a realistic scenario of activity and presence during the day in the apartment. The human behaviour is simulated by the mean of a production of heat (130 W) and water (60 g/h)**, following the daily scenario presented Fig. 3 (see right).

**70g/h in the bedroom

**Measurement and data system**

Air inlets and air extract units were equipped with special sensors to measure:

- Relative Humidity
- Temperature
- Shutter position
- Pressure*

* only in the extract units, as pressure is too low to be measured at the air inlet.

**Regulation and requirements for ventilation in the dwellings**

The Building Standard Law applies for every new construction or large scale refurbishment. The ventilation part authorizes mechanical ventilation or natural ventilation systems. The requirements for residential buildings are given by a minimum airflow of 20 m³/h per person to exhaust the pollution emitted by the human metabolism and activities and by a new regulation since 2003 to solve the ‘sick house problem’. This new text expects to limit the concentration of VOC’s like formaldehyde notably, by requiring a minimum airflow level of 0.5 ACH when using a mechanical ventilation system.
To control the airflow according to humidity

During the measurement period (from 11th to 24th February 2008), average outdoor conditions are recorded: 4.8°C temperature, 43% relative humidity. The heating system is located in the bedrooms and in the kitchen. Heaters are controlled representing a realistic scenario in Japanese houses: shut on in the morning and in the evening, off the rest of the time when occupants are outside and during the sleep (see graph Fig. 4).

The dwelling air tightness has been calculated from the measured airflows (inlet and extract). It has been calculated that the air tightness follows the rule: $Q_{\text{infiltration}} (\text{m}^3/\text{h}) = 8.4 \times dP (\text{Pa})$, which means that the envelope can be considered as a giant filter. This result is not surprising as walls are made of poured concrete, therefore very air tight, and sliding windows are equipped with brush joins, reacting as a filter. It was then possible to calculate the level of the cross ventilation during all the experiment.

Several monitoring and studies realised in Europe notably have demonstrated the close link which exists between humidity level in the dwelling and indoor air quality. A monitoring realised in Holland, Belgium and France in 1989 has shown the relationship between CO$_2$ and H$_2$O in the technical rooms, to conclude that humidity is a particularly good revelator of the inner pollution in residential buildings, and that taking into account this parameter is a good way to improve the indoor air quality.

**Performance of the humidity sensitive ventilation**

The measurements realised on humidity sensitive air inlets and extract units have shown their ability to modulate the airflow according to humidity: on the graphs Fig. 1, we can see that the opening section of the air inlet has followed well the variations of humidity in the bedroom (We can notice that the elevation of humidity between 8.30 up to 17.00 is mainly due to the cut off of the heating). The extract unit has shown the same behaviour (Fig. 2). Equipped with both humidity sensor and boost facility (normally manually pulled when cooking), the extract unit has a minimum opening of 10 m$^3$/h and is able to extract up to 50 m$^3$/h when the humidity is high or when it is on boost mode. For the monitoring, the boost was running between 18.00 and 18.45 thanks to a programmable switch, like we can observe on the corresponding graph.

The reactivity of humidity sensitive devices has been evaluated by measuring the delay between a fast increase of humidity and the shutter opening of the extract unit. The graph Fig. 5 shows a time reaction close to 2 minutes, which guarantees a quick exhaust of the excess of humidity.

**Air tightness**

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**Inner relative humidity and indoor air quality**

Several monitoring and studies realised in Europe notably have demonstrated the close link which exists between humidity level in the dwelling and indoor air quality. A monitoring realised in Holland, Belgium and France in 1989 has shown the relationship between CO$_2$ and H$_2$O in the technical rooms, to conclude that humidity is a particularly good revelator of the inner pollution in residential buildings, and that taking into account this parameter is a good way to improve the indoor air quality.
To decrease heat losses to save energy

During all the heating period, the outdoor fresh air supplied by the ventilation system needs energy to be heated up to the comfort temperature. This specific energy consumption, which is called “heat losses”, can represent up to 50% of the total energy consumption of the dwelling, depending on the ventilation system.

A calculation, based on instantaneous variable airflows and outdoor/indoor temperature differences enables to determine the heat loss due to ventilation used for this monitoring*. On graph Figure 6, we can observe that the total airflow is quite stable, except during the boost airflow periods. The average airflow is at 44 m³/h, including boost ventilation, which can be considered low, while the real capacity of the ventilation system is 135 m³/h (50 m³/h in the bathroom, 50 m³/h in the kitchen and 35 m³/h in the toilets). It is obviously highly improbable that all the extract units run at their maximum capacity simultaneously as the boost facility and the bathroom high rate are reached only for a short period of time. But this high potential can be used each time the need is important, without penalising the energy aspect as the lasting is short.

This advantage leads to a good efficiency in terms of ventilation rate as well as in terms of energy consumption. Compared to a fixed and permanent ventilation system, the humidity controlled ventilation system enables more airflow when needed and less when the demand is reduced. The compromise between high capacity and low average airflows is reached.

The table Fig. 7 gives the energy consumption of Aereco ventilation system for 8 days measurements in comparison with fix 0.5 ACH and 0.7 ACH.

«Aereco system n.1» is the actual measured one (composed of 3 extract units); «Aereco system n.2» is an extrapolation of the measured system, with only 2 extract units (a single extract unit for bathroom with toilets, which is more used and representative for these kind of small dwellings). We can observe that the Aereco system saves 8% if compared with 0.5 ACH, and 35% if compared with 0.7 ACH.

Energy comparisons with other ventilation systems

<table>
<thead>
<tr>
<th></th>
<th>fix 50 m³/h (0.5 ACH)</th>
<th>fix 70 m³/h (0.7 ACH)</th>
<th>Aereco system n.1</th>
<th>Aereco system n.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption (heat losses) on 8 days measurements</td>
<td>28.20 kWh</td>
<td>39.47 kWh</td>
<td>31.48 kWh</td>
<td>25.84 kWh</td>
</tr>
<tr>
<td>Equivalent airflow (average)</td>
<td>50 m³/h</td>
<td>70 m³/h</td>
<td>55.83 m³/h</td>
<td>45.83 m³/h</td>
</tr>
<tr>
<td>Energy savings on heat losses / 0.5 ACH</td>
<td>-</td>
<td>+40%</td>
<td>+12%</td>
<td>-8%</td>
</tr>
<tr>
<td>Energy savings on heat losses / 0.7 ACH</td>
<td>-29%</td>
<td>-</td>
<td>-20%</td>
<td>-35%</td>
</tr>
</tbody>
</table>

Humidity controlled ventilation system: conciliating energy performance and indoor air quality

The humidity controlled ventilation system as a whole has performed well all along the monitoring. The humidity controlled devices – air inlets and air extract units – have modulated the airflow according to expectations, reducing the condensation risks and improving indoor air quality, in the wet rooms as well as in the dry rooms. The system has proved its compliance to the Japanese regulation, with an average airflow close to the 0.5 ACH minimum airflow rate requested.

It has been also demonstrated that the demand controlled ventilation system used in this monitoring was able to boost the airflow when needed, without impacting the average airflow. This last remains statistically at a low level, enabling thus to reduce heat losses up to 35% compared to a fix 70 m³/h airflow system. But the main advantage of this DQV system has been demonstrated by its ability to punctually go largely above this “low” average airflow without impacting the energy performance (maximum capacity up to 130 m³/h), because of the short lasting of these periods. The energy performance of the system was completed by the use of a low energy fan (15 W at 50 m³/h) which consumption is automatically optimised and reduced with the airflow.

Easy to install in the new as in refurbishment and requiring only a light maintenance, the Aereco humidity sensitive ventilation system has proven its efficiency and its adaptation to the Japan specificities.