DOUBLE-SKIN FAÇADE BUILDING MONITORING

FERNANDO MARQUES DA SILVA

LNEC - PORTUGAL
The presentation shows the data collected in two measuring campaigns on a DSF façade building sited in Lisbon, the first one in mid September, and the second in December, 2005.

This Advanced Integrated Façade (AIF) is a Transparent Vertical Façade (TVF) multi-storey (MS) type, mechanically ventilated (MV), with an outdoor air curtain (AOC), according to the classification proposed within the Annex 44.

Temperature measurements were made at glazed panes and air gap, indoor and outdoor. It was also measured external and internal vertical radiation, external horizontal radiation. Energy consumption, comfort, lighting and acoustics were also measured.
DOUBLE-SKIN FAÇADE BUILDING MONITORING

THE TEAM

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Heat Flux Meter

Hygro-thermometer

Thermocouples

Ti; RHi

Pi Piranometer

Pe
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OUTDOOR TEMPERATURE

INDOOR TEMPERATURE
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Gap Temperature mid-heigh, last storey

05-09-13
05-12-16
05-12-17

05-09-13

Hor. Rad
Vert. Rad.
Tgap (T8)
T ind.
T outd.
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T (ºC)
0 5 10 15 20 25 30 35 40 45 50 55

x (cm)
0 100 120 140 160 180 200 220 240 260 280

05-09-13
Tgap max
9:00
15:00
05-12-16
Tgap max
9:00
15:00

indoor
outdoor
inner glass
outer glass
shading

Tglass at Tgap max
Tglass 9:00
Tglass 15:00

05-09-13
Tgap max
9:00
15:00

05-12-16
Tgap max
9:00
15:00

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**Graphs and Data**

- **Horizontal Profile**
  - 05-09-15 Tgap max
  - 05-09-15 9:00
  - 05-09-15 15:00
  - 05-12-17 Tgap max
  - 05-12-17 9:00
  - 05-12-17 15:00

- **Indoor Outdoor Comparison**
  - Tgap max
  - Tgap 9:00
  - Tgap 15:00

- **Temperature vs. Height**
  - Tgap max
  - Tgap 9:00
  - Tgap 15:00
  - Tglass at Tgap max
  - Tglass 9:00
  - Tglass 15:00

**Data Points**

- 05-09-15 Tgap max
- 05-09-15 9:00
- 05-09-15 15:00
- 05-12-17 Tgap max
- 05-12-17 9:00
- 05-12-17 15:00

**Graph Details**

- **x (cm)**
- **T (ºC)**
- **h (cm)**
The air temperature in the DSF air gap is a function of outdoor air, incoming radiation and in lesser extent indoor temperature.

Maximum temperature in the gap is related to the incoming radiation (outdoor temperature is the same on both September days) and outdoor air (radiation is the same on both winter days).

During the morning period, air gap and outdoor temperatures are closely related, the departure from each other starting approximately 1.5 hour before incoming vertical radiation reaches the façade. This can be explained by the accumulated heat within the DSF due to low ventilation mass flow, black shading devices (on three stories) and the stack effect.

An unexpected behaviour is the close dependency of air gap temperature from outdoor temperature in the evening when both decrease (the former showing a high rate of decrease) when incoming vertical radiation is still increasing.
According to this figures, one can conclude that the black roller blind is responsible for the large increase in the air gap temperature, almost 9°C compared with the solution with the roller blind opened. If a white roller blind was used, the blind temperature could be reduced in 11°C, with inside glass temperature of 35°C and the solar factor of almost half the value of the black roller blind.

<table>
<thead>
<tr>
<th></th>
<th>W/ blind</th>
<th></th>
<th>No blind</th>
<th></th>
<th>White blind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outd. (ºC)</td>
<td>29,5</td>
<td>29,5</td>
<td>29,5</td>
<td>29,5</td>
<td>29,5</td>
</tr>
<tr>
<td>Ext. pane (ºC)</td>
<td></td>
<td>44,6</td>
<td></td>
<td>38,9</td>
<td>43,2</td>
</tr>
<tr>
<td>air (ºC)</td>
<td>46,9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blind (ºC)</td>
<td>53,5</td>
<td>53,4</td>
<td>46,9</td>
<td></td>
<td>42,2</td>
</tr>
<tr>
<td>air (ºC)</td>
<td>42,9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In. pane (ºC)</td>
<td>29,4</td>
<td>42,1</td>
<td>38,9</td>
<td>37,4</td>
<td>35</td>
</tr>
<tr>
<td>Ind. (ºC)</td>
<td>26,4</td>
<td>26,4</td>
<td>26,4</td>
<td>26,4</td>
<td>26,4</td>
</tr>
<tr>
<td>Isol (W/m²)</td>
<td>531</td>
<td>531</td>
<td>531</td>
<td>531</td>
<td>531</td>
</tr>
<tr>
<td>Int (W/m²)</td>
<td></td>
<td>139</td>
<td></td>
<td>243</td>
<td>61</td>
</tr>
<tr>
<td>g</td>
<td>0,49</td>
<td></td>
<td></td>
<td>0,65</td>
<td>0,24</td>
</tr>
</tbody>
</table>

**temperature estimates were performed according to prEN 13363-2**
The heat flux meters provided the heat flux data through each glass layer, with negative values representing an incoming heat flux. In general, during daytime, the DSF gap behaves as a heat source supplying the adjacent environments (indoor and outdoor) and at night time heat flows from inside to outside (through both glass layers).
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Power/Max(Power) vs Temp.[°C]

P/Max(P) [kW/kW]

T[°C]
DOUBLE-SKIN FAÇADE BUILDING MONITORING

Portuguese Regulation (2002)

\[ D_{2m,n} = L_{1,2} - L_2 - 10 \log \left( \frac{A}{A_0} \right) \text{ dB} \quad (1) \]

\[ R_w = L_1 - L_2 \quad \text{dB} \quad (2) \]

\[ D_{2m,n,w} \geq 30 \text{ dB} \]

\[ R_{\text{w}} = 20 \text{ dB} \]

\[ R_{\text{w}} = 35 \text{ dB} \]
DOUBLE-SKIN FAÇADE BUILDING MONITORING

Comfort thermal environment parameters measured in the centre of the analysed rooms (rooms 1 and 2), at the height of 0.6 m above the floor (abdomen level), according to the Standard EN ISO 7726:2001:

- air temperature \( (T_A) \),
- mean radiant temperature \( (T_{MR}) \) or operative temperature \( (T_{OP}) \),
- air relative humidity \( (RH) \),
- air velocity \( (v) \).

<table>
<thead>
<tr>
<th>Survey</th>
<th>Room</th>
<th>Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>060916</td>
<td>1 1</td>
<td>09:40</td>
</tr>
<tr>
<td></td>
<td>2 2</td>
<td>11:00</td>
</tr>
<tr>
<td></td>
<td>3 1</td>
<td>14:45</td>
</tr>
<tr>
<td></td>
<td>4 2</td>
<td></td>
</tr>
<tr>
<td>061221</td>
<td>5 1</td>
<td>11:00</td>
</tr>
<tr>
<td></td>
<td>6 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 1</td>
<td>14:30</td>
</tr>
<tr>
<td></td>
<td>8 2</td>
<td></td>
</tr>
</tbody>
</table>
# DOUBLE-SKIN FAÇADE BUILDING MONITORING

## Measured Survey

<table>
<thead>
<tr>
<th>Survey</th>
<th>Room</th>
<th>Tar (ºC)</th>
<th>Tmr (ºC)</th>
<th>HR (%)</th>
<th>va (m/s)</th>
<th>Top (ºC)</th>
<th>PMV</th>
<th>PPD</th>
<th>DR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>24,5</td>
<td>26,4</td>
<td>45</td>
<td>0,08</td>
<td>25,4</td>
<td>+ 0,36</td>
<td>8</td>
<td>5,5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>24,5</td>
<td>26,1</td>
<td>47</td>
<td>0,04</td>
<td>25,3</td>
<td>+ 0,33</td>
<td>7</td>
<td>1,0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>24,1</td>
<td>26,9</td>
<td>49</td>
<td>0,07</td>
<td>25,5</td>
<td>+ 0,39</td>
<td>8</td>
<td>4,2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>24,3</td>
<td>26,1</td>
<td>48</td>
<td>0,03</td>
<td>25,2</td>
<td>+ 0,31</td>
<td>7</td>
<td>0,5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>24,4</strong></td>
<td><strong>26,4</strong></td>
<td><strong>47,3</strong></td>
<td><strong>0,06</strong></td>
<td><strong>25,4</strong></td>
<td><strong>0,35</strong></td>
<td><strong>7,5</strong></td>
<td><strong>2,8</strong></td>
</tr>
<tr>
<td><strong>Standard Dev.</strong></td>
<td></td>
<td><strong>0,19</strong></td>
<td><strong>0,38</strong></td>
<td><strong>1,7</strong></td>
<td><strong>0,02</strong></td>
<td><strong>0,13</strong></td>
<td><strong>0,03</strong></td>
<td><strong>0,58</strong></td>
<td><strong>2,4</strong></td>
</tr>
</tbody>
</table>

## Evaluated Survey

<table>
<thead>
<tr>
<th>Survey</th>
<th>Room</th>
<th>Top (ºC)</th>
<th>PMV</th>
<th>PPD</th>
<th>DR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>25,4</td>
<td>+ 0,36</td>
<td>8</td>
<td>5,5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>25,3</td>
<td>+ 0,33</td>
<td>7</td>
<td>1,0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>25,5</td>
<td>+ 0,39</td>
<td>8</td>
<td>4,2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>25,2</td>
<td>+ 0,31</td>
<td>7</td>
<td>0,5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>25,4</strong></td>
<td><strong>0,35</strong></td>
<td><strong>7,5</strong></td>
<td><strong>2,8</strong></td>
</tr>
<tr>
<td><strong>Standard Dev.</strong></td>
<td></td>
<td><strong>0,13</strong></td>
<td><strong>0,03</strong></td>
<td><strong>0,58</strong></td>
<td><strong>2,4</strong></td>
</tr>
</tbody>
</table>

**Note:** The table includes measured and evaluated data for various rooms, with columns for temperature, relative humidity, air velocity, and comfort parameters such as PMV and PPD.
## Results of radiant temperature asymmetry

<table>
<thead>
<tr>
<th>Survey</th>
<th>Room</th>
<th>Radiant temperature asymmetry, $\Delta T_{PR}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DSF Wall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wall Wall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ceiling Floor</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2.4 1.3 2.8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>4.5 2.0 4.3</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0.3 0.3 0.6</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0.5 0.7 0.7</td>
</tr>
</tbody>
</table>

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**Notes:**
- DSF: Double-Skin Facade
- Room: Survey location
- Wall: Wall temperature asymmetry
- Ceiling: Ceiling temperature asymmetry
- Floor: Floor temperature asymmetry
Concerning acoustic performance, a conclusion comes out: the DSF sound insulation index fulfils the Portuguese acoustic requirements for the type of building under analysis. This evidence leads to the assumption that the noise field established in the reception compartment can be considered, in acoustic terms, suitable for the development of professional activities inside the building.

Regarding daylighting and visual comfort performance, and based only on the campaign, the main conclusion to be drawn is that occupants tend to use the blinds half-closed in order to attenuate glare problems (due to the direct incidence of solar radiation on working planes and also due to the excessive brightness of the sky seen through the windows). Daylight conditions under these conditions may be considered adequate. However, when, due to solar incidence, it is necessary to fully close the blinds, daylight conditions are very poor.

In terms of thermal comfort, considering the International Standards EN ISO 7730:2005 [11] and ANSI/ASHRAE 55:2004 [12], the results of the surveys carried out in two rooms of the DSF building indicate that the thermal environmental conditions are perfectly acceptable for both periods.

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