Extended pilot study of an energy efficient glazed office building during pre-design and design

Åke Blomsterberg (WSP och LTH)
Project participants

- Client: Midroc projects
- Design: WSP at fixed price based on draft document
- Contractor: PEAB (Midroc Construction)
- Turnkey contractor glazed facade: Preconal or Schüco
- Pilot study: Specialists from WSP, Skanska and LTH, funded by BELOK [www.belok.se](http://www.belok.se) (12 major property owners/managers)
- Tenant: WSP (half the building)
Aim of the pilot study during pre-design: to investigate, in a modern new office building with a larger window area than traditionally, the possibilities of

- efficiently using the increased availability of daylight and thereby lowering the use of electricity for lighting and at the same time improving the visual comfort
- lowering the use of electricity and at the same time arriving at a low sound level from the ventilation system
- guaranteeing good thermal comfort
- arriving at a reasonable energy use, at the same or lower level than a traditional modern office building
- arriving at a low use of electricity for the tenants
- being able to easily shift between cell and open plan office
Aim of the follow-up of the pilot study during design

- guaranteeing the results from the pilot study during the pre-design

- preparing for following-up the energy use and indoor climate during operation
Office building with 5 floors
90 m x 17 m x 21 m (l x w x h)
Glazed facade
Exterior movable solar shading
Daylight redirection
Demand controlled balanced ventilation with heat recovery
Good flexibility
District heating
District cooling
Performance specifications for indoor climate and energy use
Energy use with different window areas

Energy Use for the alternatives with triple clear pane

Reference building

Intermediate

Highly

Alternative

kWh/m²a

Space heating

Cooling

Lighting

Equipment

Pumps, fans

117

130

134

Åke Blomsterberg, 2006-05-18
Specific transmission losses and heat loss factor, triple pane (clear glass)

<table>
<thead>
<tr>
<th>Window area (share of facade)</th>
<th>53%</th>
<th>38%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>U x A facades, W/K</td>
<td>4712</td>
<td>3661</td>
<td>2788</td>
</tr>
<tr>
<td>U x A total, W/K</td>
<td>5147</td>
<td>4095</td>
<td>3223</td>
</tr>
<tr>
<td>Heat loss factor, W/K</td>
<td>7048</td>
<td>5996</td>
<td>5124</td>
</tr>
<tr>
<td></td>
<td>1.38</td>
<td>1.17</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Heating according to IDA ICE, kWh/m²year

<table>
<thead>
<tr>
<th></th>
<th>59.1</th>
<th>55.3</th>
<th>47.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.25</td>
<td>1.17</td>
<td>1.00</td>
</tr>
</tbody>
</table>
### g x A with Venetian blinds and triple pane (clear glass)

<table>
<thead>
<tr>
<th>Window area (share of facade)</th>
<th>53%</th>
<th>38%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>g x A with Venetian blinds (south, east and west)</td>
<td>380</td>
<td>272</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td>2.07</td>
<td>1.48</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooling according to IDA ICE, kWh/m2year</th>
<th>10.1</th>
<th>9</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.44</td>
<td>1.29</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Energy use for different window alternatives
Reference building 117 kWh/m²a

Alternative with low U- och g-values

Energy Use for Highly glazed alternatives
### Share (%) of window area of facade area

<table>
<thead>
<tr>
<th></th>
<th>North</th>
<th>East</th>
<th>South</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor plan 1</td>
<td>40</td>
<td>26</td>
<td>75</td>
<td>35</td>
</tr>
<tr>
<td>Floor plan 2</td>
<td>47</td>
<td>49</td>
<td>47</td>
<td>36</td>
</tr>
<tr>
<td>Floor plan 3</td>
<td>48</td>
<td>51</td>
<td>72</td>
<td>46</td>
</tr>
<tr>
<td>Floor plan 4</td>
<td>48</td>
<td>51</td>
<td>72</td>
<td>46</td>
</tr>
<tr>
<td>Floor plan 5</td>
<td>46</td>
<td>48</td>
<td>69</td>
<td>44</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>46.2</strong></td>
<td><strong>39.6</strong></td>
<td><strong>67.8</strong></td>
<td><strong>39.2</strong></td>
</tr>
</tbody>
</table>
WSP HUSET Malmö November 2005, after pre-design

Facade north
WSP HUSET Malmö November 2005, after pre-design

Façade south
Resulting requirements on the design – based on calculations during the pre-design

- Roof, walls, and floor: max U-values incl. thermal bridges
- Windows: max area = 53 % of facade; max U-value = 1.1-1.2; min daylight transmittance = 55 %
- Solar shading (S,E,W): max solar energy transmittance for glazing + solar shading g\textsubscript{system} = 0.1
- Heat recovery on air: min efficiency = 70 %
- Ventilation: average SFP = 2.0 kW/m\textsuperscript{3}/s
- Lighting: max installed power = 10 W/m\textsuperscript{2}
- Servers: max use of electricity (5000 W) and cooling
- PC: max use of electricity = 125 W incl. screen
### Average U-values facades incl. windows - requirements

<table>
<thead>
<tr>
<th></th>
<th>North</th>
<th>East</th>
<th>South</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor plan 1-2</td>
<td>0.65</td>
<td>0.55</td>
<td>0.83</td>
<td>0.57</td>
</tr>
<tr>
<td>Floor plan 3-5</td>
<td>0.69</td>
<td>0.71</td>
<td>0.91</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Major changes during the design

- Single skin facade with exterior movable solar shading replaced by double skin facade
- Comparable investment costs
- Protected movable solar shading
- Better sound attenuation towards the outside ute
- Window airing possible irrespective of outdoor climate
- Return to VAV ventilation, air cooling thanks to
  - 80 % presence instead of 100 %
- Double skin façade entails somewhat better solar shading
- Increased space for ducts and fans
Major changes during the design

- Separate daylight redirection replaced by upper 1/3 of Venetian blind with fixed angle of offset
- Complicated with separate movable upper 1/3
- Higher investment and operation costs with separate upper 1/3
- No separate inner facade lighting to create similar light to daylight redirection
- Hard to motivate
U- and g-values of double skin facades in Sweden

The values for existing buildings are according to Per-Olof Carlson, ACC-glasrådgivare.

<table>
<thead>
<tr>
<th>Building</th>
<th>$U_{\text{window}}, \text{W/m}^2\text{K}$</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamnplan</td>
<td>1.1</td>
<td>0.10</td>
</tr>
<tr>
<td>Kronoberg</td>
<td>1.2</td>
<td>0.14</td>
</tr>
<tr>
<td>ABB</td>
<td>1.2</td>
<td>0.11</td>
</tr>
<tr>
<td>Kista Science Tower</td>
<td>1.1</td>
<td>0.14</td>
</tr>
<tr>
<td>Arlanda Pir F</td>
<td>1.2</td>
<td>0.11</td>
</tr>
</tbody>
</table>
# UA-, gA-values and heat loss factors

<table>
<thead>
<tr>
<th></th>
<th>Reference building</th>
<th>Requirements on real building</th>
<th>Real building incl. additional window losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>UA-value facades, W/K</td>
<td>2788</td>
<td>3298</td>
<td>3541</td>
</tr>
<tr>
<td>UA-value total, W/K</td>
<td>3223</td>
<td>3732</td>
<td>3976</td>
</tr>
<tr>
<td>Heat loss factor, W/K</td>
<td>5124</td>
<td>5633</td>
<td>6067</td>
</tr>
<tr>
<td>gA-value with Venetian blinds (S,E,W)</td>
<td>184</td>
<td>127</td>
<td>143</td>
</tr>
</tbody>
</table>
Daylight and solar shading

- Upper 1/3 of Venetian blinds fixed angle of offset e.g. 15 degrees
- Control of Venetian blinds based on solar radiation and inner luminance, upper/lower and angle (studied at LTH)
- Separate control of Venetian blinds for resp. facade and floor plan, and sectioning of south facade (3)
- Manual control of glare curtains facing north might be needed
- Ev. glare curtains for the other facades
- Lighting turned on by presence in open plan and manually in cell offices
- Lighting: turned off by presence sensor
- Lighting: constant light level control (not north)
- Requirements on reflectance factors for inner surfaces (NUTEK, SS)
Real building buildings

$U_{window} = 1.1 \text{ W/m}^2\text{K}$ i.e. $U_{profile} = 1.8$ (promised, presented 2.1, desired 1.3),
$U_{glass} = 1.0$

Future buildings?

$U_{window} = 0.9 \text{ W/m}^2\text{K}$ i.e. $U_{profile} = 1.3$, $U_{glass} = 0.8$

$U_{window} = 1.1 \text{ W/m}^2\text{K}$ i.e. $U_{profile} = 1.0$, $U_{glass} = 0.55$
Conclusions

An office building with larger glass area compared with a traditional building (50 % vs. 20 %) has been designed, which has the chance to

- efficiently utilize the increased availability of daylight
- reduce the use of electricity for ventilation
- guarantee good thermal comfort
- arrive at a reasonable energy use
- arrive at a low use of electricity for the tenants
- easily shift between cell and open plan office
Guaranteeing energy efficiency and good indoor climate for a glazed office building

- Energy use and environmental requirements as performance specifications are drafted in the brief
- Energy and environmental coordinator from the brief phase until first year of operation
- Energy simulations from the brief phase
- A governing quality and environmental program with performance requirements from the brief phase, which is refined during the building process
- Better simulation tools for daylight – lighting – use of electricity e.g. more user friendly DAYSIM
- Better energy simulation tools for DSF. IDA ICE is being improved.
Guaranteeing energy efficiency and good indoor climate for a glazed office building

- Cooperation between designers: architecture, HVAC, structural engineering, electrical engineering and building physics
- ”Network” energy and climate specialists ---- designers
- Cooperation between client, designers and contractors
- LCC
- Separate performance specifications for the glazed facade based on analysis of the entire building
Needed studies in Sweden

- Indoor climate questionnaire survey in glazed office buildings
- Investigation of energy use and indoor climate in existing glazed office buildings
Glazed Office Buildings
Energy Use and Indoor Environment

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PhD Student
Division of Energy and Building Design
Dept of Architecture and Built Environment
Lund Institute of Technology
Lund University

Web address:
http://www.ebd.lth.se/avd%20ebd/main/personal/Harris/default.html
4 Step Methodology

**Step 1 (Licentiate Thesis):**
Single Skin Glazed buildings
Simulations - recognize the problems of the 100% glazed buildings

**Step 2 (Currently):**
Simulations of the DSF Cavity (cavity level – WIS 3)
Possibilities and limitations of DSF cavities

**Step 3 (Future):**
Simulations Double Skin Facades buildings (building level – IDA ICE)

**Step 4:**
Comparison of Single and Double Skin Façade buildings
Optimization in terms of:
- Energy use
- Indoor Climate
**Step 2: Double Skin Façade Cavity**

*Software used* for the simulations of the cavity: **WIS 3**

**Input of the Simulations:**
- Boundary Conditions
- Geometry of the cavity
- Number and type of panes used
- Position and properties of shading devices

**Output of the Simulations:**
- Airflows
- Temperature profile along the cavity
- Temperature of the inner layer
- U and g values
Step 2: Double Skin Façade Cavity

Goals of step 2:

1. Study the possibilities and limitations of DSF cavities (for step 3)
Step 3: Integration of DSFs

Will be studied after summer 2006

Output:

- Article with Lars Sjöberg (SKANSKA) and Åke Blomsterberg
- Part of final PhD thesis
Step 3: Integration of DSFs

**Step 1:**
Recognize the problems of the 100% Single Skin Façade Building

**Step 2:**
Understand the function and performance of different cavity alternatives

**Step 3**
Integrate the Double Skin Façades into the buildings
Step 3: Integration of DSFs

Goals of step 3:

1. Optimize building performance with DSFs regarding to
   • Façade orientation
   • Building use
   • Site and location of the building (shading of the building, noise reduction, possibility for natural ventilation, etc)
   • HVAC Strategy
**Step 4**: Optimization of Glazed Office buildings (Single and Double Skin Facades)

Will be finished before June 2007

Output:

- Conclusions of final PhD thesis
- Part of the guidelines of Åke Blomsterberg