The Design of an Energy Efficient Highly Glazed Office Building

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ABSTRACT

Many modern office buildings have highly glazed facades. Their energy efficiency and indoor climate is, however, being questioned. Therefore, when a modern office building (new construction) with larger glazing areas was planned, an investigation was carried out to determine the possibilities to:

- efficiently use the increased access to daylight and thereby reduce the use of electricity for lighting and at the same time improve the visual comfort
- ensure good thermal comfort
- arrive at a reasonable total energy use, which is at the same level or preferably lower level than a traditional office building.

The work was done by a project group that supported the design team with advanced energy, indoor climate and daylight simulations. Detailed performance specifications on energy use and indoor climate were worked out. The results show that the aims can be fulfilled if the following main requirements are fulfilled:

- The glazing area should not exceed 45 % of the façade area.
- The total solar transmittance of the glazing combined with solar shading must be lower than 0.1.
- The U-value of the windows must be lower than 1.1 W/m²K.

A double skin façade was chosen. An important conclusion is that coordination and cooperation throughout the building process is absolutely necessary. The building will be finished in 2007.

KEYWORDS

Energy efficiency, design, double skin façade, glazed façade, office building, simulations.

INTRODUCTION

The potential for energy savings and improvements in indoor climate is often high for modern office buildings. Many modern office buildings may have a lower energy use for heating, but have on the other hand often a higher use of electricity than older office buildings, which is due to a higher energy use for ventilation, cooling, lighting and office equipment. Even in older office buildings the use of electricity has increased, mainly due to office equipment. Especially during the nineties office buildings with glazed facades have been built e.g. in Germany, but also in the Nordic countries. The increased use of glazed facades has been enabled thanks to the development of façade construction technology and improved physical properties of glass during the last decade. There has been and is a growing interest among Nordic architects to design glazed double skin facades. Some ten buildings with this kind of facade has been built e.g. in Stockholm. The purpose of these double skin facades has mainly been to reduce the high temperatures in the building behind during the summer and to lower the heat losses during winter compared with a glazed single skin façade. Very rarely has the double skin façade in the Nordic countries been coupled to the ventilation system and thereby been completely integrated into the building i.e. an additional glazed façade has only been added to a traditional glazed building. Very seldom daylight redirection has been implemented i.e. to make active use of daylight as a means of lighting.

Why are fully glazed facades being built? Architecturally an airy, transparent and light building is created, where the access to daylight can be higher than in a more traditional office building. In practice the use of electricity for lighting may very well be at the same level for an office building with large windows as for an office building with traditional window sizes (Poirazis 2005). This can be true if traditional solar shading (fixed exterior or intermediate Venetian blinds) with traditional control (none of manual) is installed. In buildings with a glazed façade the daylight is often not utilized. Often glare problems occur, which is often dealt with by the solar shading.

Office buildings with glazed facades are likely to have a higher use of energy for cooling and heating than an office with a traditional façade. With traditional improvements in the design of windows and solar shading this difference can be lowered to an energy use 15 % higher (Poirazis 2005). A traditional glazed façade increases the risk for an unsatisfying thermal comfort close to the façade and glare further inside the building. Glazed buildings require more planning and have less tolerance for design and construction errors (Brunner 2001).

Therefore a complementary pilot study (Blomsterberg 2006) was initiated and carried out during pre-design: to investigate, for 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

A follow-up study (Blomsterberg 2006) of the pilot study during design was also initiated and carried out in order to

- guarantee the results from the pilot study during the pre-design
- prepare for monitoring the energy use and indoor climate during operation.

METHODS

This project comprises a complementary pilot study during pre-design and design i.e. work usually not carried out during traditional design. The building is to be built in

Malmö Sweden. The client is Midroc Projects. The design was carried out by WSP at a fixed price based on a draft document. The contractor is PEAB (previously Midroc Construction). A turnkey contractor will be chosen for the glazed façade. The pilot study was carried out by specialists from WSP, Skanska and Lund University. Several of these specialists participate in the research project Glazed Office buildings – Energy use and indoor climate, www.ebd.lth.se. The tenant will be WSP (half the building).

The draft document for the planned office building stated: office building with 5 floors, 90 m x 17 m x 21 m (length x width x height), fully glazed façade, exterior movable solar shading, daylight redirection, demand controlled balanced ventilation with heat recovery, good flexibility, district heating, district cooling, and performance specifications for indoor climate and energy use.

Daylight, use of electricity for lighting and visual comfort were analysed using simulations and estimates. A parametric study for a single skin glazed façade with exterior solar shading was carried out using the software DAYSIM, based on Radiance (a daylighting analysis software that calculates the annual daylight availability in arbitrary buildings as well as the lighting energy use of automated lighting controls compared to standard on/off switches. http://irc.nrc-cnrc.gc.ca/ie/lighting/daylight/daysim). In parallel the solar shading was analysed using the simulation tool Parasol http://www.parasol.se. These analyses were made for a building with a traditional window percentage i.e. 25 % and for a larger window percentage 55 %, according to the final proposal of the architect and an intermediate level 38 %. Several combinations of glazing and solar shading were investigated.

Thermal comfort and total energy use were analysed for above mentioned alternatives using the dynamic energy simulation tool IDA ICE (Equa 2002).

RESULTS – PRE-DESIGN

The calculations and analyses carried out show that for a modern office building, with larger glass percentage of the façade than traditionally (45 % instead of 20 %), it should be possible to

- efficiently utilize the increased access to daylight using daylight redirection and thereby lowering the use of electricity for lighting with about 25 % (about 4 – 6 kWh/m^{2}year) and at the same time improve the visual comfort. During the summer the use of energy for cooling due to daylight redirection may however be comparable to the alternative of using artificial lighting. Major parts of the remainder of the year daylight redirection can be used without a cooling penalty. Redirection of daylight means that the upper third (one meter) of the solar shading, for each floor, is controlled by the inner luminance.
- ensure good thermal comfort (operative temperature 21 °C – 25 °C, 0,8 m from the facade) by choosing a glass with a U-value $<$ 1,1 W/m^{2}K and efficient solar shading (Poirazis 2005b). To maintain a PPD level $<$ 10 % during $>$ 90 % of the working hours the air temperature should be between 22.5 °C and 23.5 °C. Efficient solar shading means for a glazed façade that solar protecting glazing is combined with exterior solar shading. The exterior solar shading can however be

installed in an double skin facade. The solar shading serves two purposes: reducing the solar heat radiation and ensuring visual comfort.
- arrive at a reasonable energy use (Poirazis 2005b), which is at the same level or lower than for a traditional modern office building (reference) calculated to be 120 kWh/m^{2}year (district heating + use of electricity by the tenants + use of electricity for lighting + district cooling excl. for servers + use of electricity for operation excl. for servers). In order to arrive at a reasonable energy use the window percentage of the façade was reduced from about 70 % (fully glazed looking from the inside) to about 50 %, g-value for glass + solar shading facing south, west and east from about 0.35 to about 0.1 and glazing U-value from 1.8 to 1.2 W/m²K. This means that the g x glazing area is similar for the real and the reference building.

The simulations supporting the pre-design resulted in detailed performance specifications for the design e.g.:
- Roof, walls excluding windows, and floor: U-values incl. thermal bridges of
- < 0.12, < 0.22 and < 0.32 W/m²K.
- Windows: area < 53 % of facade; U-value < 1.1-1.2 W/m²K; daylight transmittance > 55 %.
- Solar shading (south, east, west): solar energy transmittance for glazing + solar shading g_{system} < 0.1
- Heat recovery on air: efficiency > 70 %
- Ventilation: average SFP (specific fan power) < 2.0 kW/m³/s
- Lighting: installed electric power < 10 W/m²
- Servers: use of electricity (< 5000 W) and cooling
- PC: use of electricity < 125 W incl. screen.

RESULTS – DESIGN

The single skin façade with exterior solar shading was replaced by a double skin façade facing south, east and west for floor 3 – 5. The double skin façade is a multi-storey façade, where the cavity is naturally ventilated through an opening at the top and the bottom. During winter the opening at the top is closed by a damper. The reasons for choosing the double skin façade were the following:
- investment costs comparable with the single skin alternative.
- protected movable solar shading. The building will at times be subject to strong winds, snow, rain and freezing temperatures
- better sound attenuation towards the outside
- window airing possible irrespective of outdoor climate.

The double skin façade was to fulfil the same requirements on U-value and g-value as the single skin façade or preferably better. A separate detailed performance specification was worked out for the façade, based on a Swedish report (Carlson 2003).

A reasonable glass combination would be, from the outside: Clear 6 mm – 0.6 m air cavity with a venetian blind – Hbl 6 mm – Argon 15 mm – Clear 6 mm (Pilkington Suncool HP Brilliant). Assuming that the venetian blind has a diffuse solar reflectance of 70 % (upper side) respectively 30 % (under side). For the venetian blind the lamella distance is equal to the width, and the lamella angle is 30° i.e. direct solar radiation is shielded for projected solar heights above 30°. The visual transmittance of the double skin façade with the venetian blinds up is about 60 %, which fulfils the requirement on 55 %. The g-value of the double skin façade with the Venetian blinds down as described above and with a non-ventilated cavity has been calculated with WIS (http://windat.ucd.ie/wis/) and Parasol (www.parasol.se) to be 0.14. If the cavity is ventilated (fully or half open at the top and at the bottom) the g-value is < 0.10, compared with the requirement on 0.1. The U-value (glass) of the double skin facade, with non-ventilated cavity and the venetian blinds up has been determined to 0.9 W/m^2K i.e. for the centre of the pane. If the cavity is somewhat ventilated the U-value will be 1.0 W/m^2K. Assuming profiles with a U-value < 1.8 with an area percentage of 10 %, results in a U-value of 1.1 W/m^2K for the window, which fulfils the requirement.

As to the redirection of daylight the system was changed due to the choice of a double skin façade. The separate daylight redirection was replaced by an upper 1/3 of the venetian blind with a fixed angle of offset. This because it was considered too complicated and would result in higher investment and operation costs with a separate movable upper 1/3. This solution is likely to result in a reduction in the savings in use of electricity for lighting. As DAYSIM does not allow simulations of double skin facades, the simulations could not be repeated.

The venetian blinds will be controlled by the solar radiation on the façade and the inner luminance. The artificial lighting in the open plan office will be presence controlled (prepared for manual switch on) and in the cell offices manual switch on. The lighting is switched off by the presence sensors. The artificial lighting in the rooms facing south, east and west are controlled to keep a constant light level. Glare curtains might be needed facing north, to avoid glare from the sky.

The total energy use for the final choice of façade, solar shading and lighting, including the energy use for servers (electricity and cooling) has been determined to 116 kWh/m^2year. As the used software, IDA ICE 3.0, does not yet include a double skin façade model, the above calculated U- and g-values had to be used as inputs for the energy simulations. A double skin façade model is currently developed for IDA.

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

In order to arrive at a glazed office building with a reasonable energy use and good visual comfort the following actions are required:

- energy use and environmental requirements as performance specifications are drafted in the brief
- there is an energy and environmental coordinator from the brief phase until first year of operation
- energy simulations are carried out starting already during the brief phase
- a governing quality and environmental program with performance requirements is worked out starting already during the brief phase, and is refined during the building process
- better simulation tools for daylight – lighting – use of electricity are needed e.g. a more user friendly DAYSIM
- better energy simulation tools taking into account double skin facades are needed e.g. IDA ICE with an double skin façade model.
- good cooperation between designers to ensure a well performing system: architecture, HVAC, structural engineering, electrical engineering and building physics
- a “network” with energy and climate specialists and designers
- good cooperation between client, designers and contractors
- a life cycle cost analysis is carried out to avoid prioritising investment costs and neglecting operating, maintenance and energy costs
- a separate performance specification is worked out for the glazed facade based on analysis of the entire building, to avoid sub optimisation

The energy use, indoor climate and visual comfort will be monitored in the finished building.

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