The energy performance of glazed office buildings with double skin facades - BESTFACADE

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ABSTRACT

Many modern office buildings have highly glazed facades. Their energy efficiency and indoor climate is, however, being questioned. Therefore more and more of these buildings are being built with double skin facades, which can provide improvements: a thermal buffer zone, energy savings, wind protection with open windows, fire protection, aesthetics, solar preheating of ventilation air, sound protection, nocturnal cooling and a site for incorporation of PV cells. However not all modern double skin facades perform well.
A project BESTFACADE, was therefore partially (50 %) financed by the European Commission to promote well-performing concepts of double skin facades. The paper summarizes the best practice guidelines.

1. 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 on the other hand often have a higher use of electricity than older office buildings, which is due to a higher energy use for ventilation, cooling, lighting and office equipment.
Especially since the nineties office buildings with glazed facades have been built. The increased use of glazed facades has been enabled thanks to the development of façade construction technology and physical properties of glass during the last decade. There has been and is a growing interest among clients to build and among architects to design glazed double skin facades. The purpose of these double skin facades has often 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. Other improvements, which can be provided are: energy savings, wind protection with open windows, fire protection, aesthetics, solar preheating of ventilation air, sound protection, nocturnal cooling and a site for incorporation of PV cells.
Commercial buildings with integrated double skin facades can be very energy efficient buildings with all the good qualities listed above. However not all double skin facades built in the last years perform well. Far from it, in most cases large air conditioning systems have to compensate for summer overheating problems and the energy consumption badly exceeds the intended heating energy savings. Therefore the architectural trend has in many cases unnecessarily resulted in a step backwards regarding energy efficiency and the possible use of passive solar energy.
Therefore the European Commission partially (50 %) financed a project, BESTFACADE, to promote the concept of well-performing double skin facades. A best practice guideline for double skin facades has been created (Blomsterberg 2007). It is based on a survey of double skin facades in Europe (Streicher 2005). Information on built examples of double skin facades in European office buildings has been collected, investigated and assessed. A simple calculation method for national guidelines to estimate the energy demand and comfort parameters has been developed (Erhorn 2007). It will be presented to the relevant CEN committees and could be integrated into the assessment methods of the EPBD (energy performance of buildings directive of the European Commission). Energy related benchmarks and a certification method for double skin facades have been outlined as well (Matos 2007).
In many countries the level of knowledge on double skin facades (especially advantages/-disadvantages and costs) is insufficient for all target groups, apart from some educational/research institutions (Santamouris 2007). It was also concluded that there are many existing buildings with double skin facades, but very few of them are documented with regard to energy and environmental performance. The best practice guideline aim to fulfil this knowledge gap and is summarized below.

2. METHODS

The best practice guidelines aims at offering, information supporting in the design, choice, implementation and management of energy efficient and healthy office buildings (retrofitting and new construction) with double skin facades. The target group is governmental bodies, standardization, decision makers, clients/-developers, architects, engineers, HVAC managers, and facility managers. The guideline consists of three parts:
Part 1 Fundamentals: The purpose is to provide to the targeted audience common basic scientific, technical

and economic knowledge on double skin facades. The following aspects are dealt with: architecture, technology, glazing, façade construction and costs.

Part 2 Applications: The purpose is to provide the targeted audience with detailed practical information in order to design, choose, manage, use and maintain first of all double skin facades but also buildings with double skin facades (case studies - good examples of technical solutions and buildings; potential advantages and disadvantages with double skin facades, situations where double skin facades can be appropriate, impacts of double skin facades). Other aspects dealt with are: performance specifications, and predicted performance.

Part 3 Tools: General information on tools, review of simulation tools and existing standards. The simple calculation method is described.

3. RESULTS

3.1 Fundamentals

A glazed office building is here defined as a building where at least one façade has a window area more than 2/3 of the façade area. No other building material has during the last two decades experienced such an innovative increase as glass. It has evolved into a high-tech product that in its right use can create slender and bold constructions. Architecturally an airy, transparent and light building is created, where the access to daylight is higher than in more traditionally built office buildings. The idea is often to create a building with openness and to give an impression of the future. The complete transparency also shows a corporate will of communication and openness towards society outside. If the traditional façade gives the architect a freedom of expression, the double-glazed facade and the design of its building demands collaboration with engineers and suppliers. This cooperation will affect the architecture in many ways.

The daylight and its positive effects on humans have always been a main ingredient in architecture. However, careful planning is necessary for a glazed facade with the amount of light that is allowed into the building. If glass architecture is to survive it must limit its influence on energy losses by new innovative solutions.

A ventilated double skin facade can be defined as a traditional single facade doubled inside or outside by a second, essentially glazed facade. Each of these two facades is commonly called a skin (hence the widely-used name "ventilated double-skin facade"). A ventilated cavity - having a width which can range from 10 centimetres at the narrowest to 2 meters for the widest accessible cavities - is located between these two skins. The cavity can be ventilated with natural, mechanical or hybrid ventilation. The double skin façade can be classified as follows:

- Ventilated double window
- Facade partitioned per storey with juxtaposed modules
- Facade partitioned per storey - corridor type
- Shaft-box façade
- Multi-storey façade
- Multi-storey louver façade

The application is often new construction, but can also be refurbishment.

The choice of the glass type for the interior and exterior panes depends on the typology of the facade. In case of a facade ventilated with outdoor air, an insulating pane (=thermal break) is usually placed at the interior side and a single glazing at the exterior side. In case of a facade ventilated with indoor air, the insulating pane is usually placed at the exterior side, the single glazing at the interior side.

The shading device is placed inside the cavity for protective reasons. Often a venetian blind is used. The characteristics and position of the blind influence the physical behaviour of the cavity because the blind absorbs and reflects radiant energy. Thus, the selection of the shading device should be made considering the proper combination between the pane type, the cavity geometry and the ventilation strategy.

Openings in the external and internal skin and sometimes fans allow the ventilation of the cavity.

The choice of the proper pane type and shading device is crucial for the function of the double skin facade system. Different panes can influence the air temperature and thus the flow in case of a naturally ventilated cavity. The geometry (mainly width and height of the cavity) and the properties of the blinds (absorbance, reflectance and transmittance) may also affect the type of air flow in the cavity. When designing a double skin facade it is important to determine type, size and positioning of interior and exterior openings of the cavity since these parameters influence the type of air flow and the air velocity and thus the temperatures in the cavity (more important in high-rise buildings).

The daylight availability is a very contradictory aspect for double skin façades. If, on one side, the additional pane (outer skin) combined with the framing of the exterior surface and shading equipment are responsible for a reduction by 10 up to 20 % of the light transmission compared to traditional façades, on the other side, the higher surface of glass to wall façade ratio compensate it so that, ordinarily, the total daylight access is higher in double skin facade buildings than in buildings with traditional facades.

This high daylight access for the building, combined with an intelligent lighting control system dealing with daylight and presence detection, may lead to very important energy savings in use of electricity for lighting

(up to 50 %). However this high daylight availability can cause glare problems and be responsible for visual discomfort. To avoid any glare problems (direct and indirect glare), special attention has to be paid to the material of the indoor surface and the control of daylight.
All buildings must be made sustainable i.e. a building must have a small as possible impact on the environment during its life time. Products are to be judged from a life cycle perspective, where attention must be paid to all impacts on the environment during the entire life cycle. A building will change during its life span and besides it consists of several different components with different life spans. Usually the structural parts such as the facade system have a longer life span than many other parts of the building e.g. the ventilation system.
An important factor when choosing a facade system is the costs of the façade and the entire building. Today usually the investment cost and not the life cycle cost is considered. Only taking into account the investment cost often results in a facade system and a building that just fulfils the requirements of the building code at the lowest investment costs. A glazed double skin façade is usually more expensive than a single skin, at least considering the investment cost. Justification of its inclusion in a building design is however seldom based on energy efficiency and associated cost savings. Qualitative benefits of solar control, moderated surface temperatures, noise reduction, reduced glare, reduced heating/cooling demand, aesthetic purity and increased daylighting are generally seen only as intangible 'bonus' benefits.
Preferably the cost of the entire building is taken into consideration, in order to avoid sub optimisation. A well designed double skin facades can result in lower operating cost (mainly lower energy costs compared with a glazed single skin façade) for the building in question. The cleaning costs for the façade can be higher.
The great challenge for a glazed office building (single and double skin) is to optimise energy use, use of daylight, visual and thermal comfort at a reasonable investment and life cycle cost. Office buildings with glazed facades risk having having a higher use of energy for cooling and heating than an office with a traditional façade. A traditional glazed façade increases the risk for an unsatisfying thermal comfort close to the façade and glare further inside the building. A double skin façade will lower these risks. Glazed buildings (single and double skin) require more planning and have less tolerance for design and construction errors.
Double skin façade can provide: a thermal buffer zone, energy savings, wind protection with open windows, fire protection, aesthetics, solar preheating of ventilation air, sound protection, nocturnal cooling and a site for incorporation of PV cells.

3.2 Applications

In order to arrive at a glazed double skin façade office building with a reasonable energy use, good thermal and visual comfort the following actions are required during the building process (Blomsterberg 2006):
- 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 the first year of operation.
- energy and indoor climate simulations are carried out starting already during the brief phase and then being refined during the building process.
- 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.
- good cooperation between designers to ensure a well performing system: architecture, HVAC, structural engineering, electrical engineering and building physics.
- 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 double skin facade based on analysis of the entire building, to avoid sub optimisation.

Applying performance specifications to double skin façade systems and buildings with these facades provide a more flexible and less rigid approach to facade system and building design and operation whereby targets are set which must be met in order for the facade system and the building to perform as required. This approach also facilitates the implementation of innovative systems. The performance specifications for the double skin façade has to include:

Building physics

- Influence of climate on inner and outer skin: The double skin façade must be designed for sufficient tightness against climate influence i.e. requirements on wind load, air tightness, water tightness etc. have to be specified.
- If natural ventilation: The cavity of the double skin façade must designed for natural ventilation e.g. by specifying certain air flows for different boundary conditions
- Energy conservation and thermal comfort: The double skin façade has to fulfil certain requirements on thermal (U-value) and total solar transmittance (g).
- Sound insulation: The double skin façade has to fulfil certain requirements regarding sound attenuation.
- Fire protection: The double skin façade has to fulfil certain requirements regarding spread of fire between fire cells etc.
- Light: The double skin has to fulfil certain requirements regarding daylight i.e. to ensure visual comfort.

Technology
- System – method of production: Loads and tolerances.
- Material in outer and inner skin: Durability and need of maintenance
- Glazing: The glazing has to fulfil certain requirements on thermal (U-value), total solar transmittance (g-value) and daylight transmittance etc.
- Safety: Personal safety
- Shading devices: The shading devices has to fulfil certain requirements on solar transmittance etc.
- Air cavity: Geometry, openings, ventilation
- Cleaning and service devices
- Costs

Building process planning

Operation and maintenance

The eight determining areas of influence for highly glazed buildings (Brunner 2001), which buildings with double skin facades usually are:
- Comfort/daylight: PMV (predicted mean vote)/PPD (predicted percentage dissatisfied)/ daylight quality, asymmetry/ cold air
- Internal gains: Equipment/artificial lighting, persons
- Ventilation/cooling: Air quality, removal of loads
- Energy use: Heating, cooling
- Thermal mass: Floor/ceiling, walls/-furniture
- Solar shading: type/location/material, operation/control
- Glazing: area, U-value/g-value incl. and excl. solar shading, surface temperature, daylight transmittance
- Boundary conditions: Size/orientation, use/outdoor climate

How to succeed during design, some remarks:
- The internal gains must be minimized.
- Increasing the glazed area results in increased risk and lowered tolerance for errors.
- Corner rooms with two glazed facades should be avoided.
- U- , g- and τ_V -values have to be chosen correctly. These values do of course depend upon many factors e.g. the climate, the size and shape of the building, the size, type and orientation of the glazed areas and the geometry and ventilation of the cavity of the double skin facade. A thorough analysis is required to determine these values. A low g-value (total solar transmittance) is mostly needed during warm sunny days. Typically the window U-value should be lower than 0.9 W/m²K for a highly glazed façade (in a cold climate, where space heating is needed). The daylight transmittance (τ_V) should be higher than 50 %. The g-value for the combination of glazing and solar shading should be less than 0.1 for a façade facing south, east or west.

To ensure optimal operation of a building with a double skin facade, the following is crucial:
- The design and implementation of an intelligent control system for the double skin facade and the installations of the building
- The design and implementation of a usable and user friendly building energy management system (BEMS).

3.3 Energy and indoor climate tools

The modelling of ventilated double skin facades or a building with a double skin façade is a complex task. The choice of the most appropriate software for simulation depends on the objective of the simulations. For the pre-design the simple calculation method developed within the BESTFACADE project can be used to make a first decision concerning type of façade and to make an energy performance certificate. There are tools for simulation of the double skin façade and there are building energy simulation programs capable of simulating a ventilated double skin façade e.g. TRNSYS, EnergyPlus, ESP-r, TAS and IDA ICE. During the detailed design the role of simulation is important and simulation represents the only method to predict the yearly energy consumption of and to dimension a building equipped with a ventilated double skin façade and to assess the impact of different control systems and control strategies on the building performance.

4. CONCLUSIONS

There is a high interest to design and build glazed office buildings with double skin facades. The buildings can be high-rise and low-rise, mainly office buildings. The buildings usually have highly glazed facades. The application is often new construction, but can also be refurbishment of existing facades.

If the starting point is a glazed building, then with proper design adding a second skin can result in energy savings (heating and cooling) and improved thermal and visual comfort, improved sound attenuation and protected “exterior” solar shading. However, the double skin facades are often more expensive than single skin facades. The additional investment costs can be compensated for by a reduction in use of energy. For a building, which is not highly glazed and with a high level of thermal insulation, the energy user for heating and cooling is likely to be lower, than for a highly glazed building with a double skin facade.

In order to ensure a well performing, in terms of energy use and indoor climate, building with a double skin façade, simulations of the double skin facade and building are necessary.

The best practice guidelines for double skin facades provide information supporting in the choice, design, implementation and management of office buildings with double skin facades. Using the guideline designers and investors can avoid application of non relevant concepts of double skin facades performing worse than traditional facades. The investor confidence concerning operating performance, investment and maintenance costs can be increased.

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