MAKING AN IMPACT

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ABSTRACT

The paper describes how simulations have been used in several building projects to support the design of the buildings or special features of the buildings. The paper briefly describes the buildings, what the simulations have been used for, what impact the simulations have had on the final design and the process, which the simulations have been a part of. Finally, the gained experience is summarized.

INTRODUCTION

Buildings tend to get more and more complex. Previously, a building could be built on the basis of skills and experience. This is often no longer possible as too many processes occur in a building while at the same time comfort is a big issue. This leads to an increasing demand from building owners that the thermal behaviour and especially the comfort within the buildings are documented before the buildings are erected. Especially, smaller consulting firms experience problems here as they often do not have the necessary tools and skill to perform the often very detailed analysis of the thermal behaviour of the buildings. The Energy Division of the Danish Technological Institute has experienced an increasing demand from consultants, contractors and building owners of especially prestigious buildings to assist them by performing detailed analysis on the indoor climate in the buildings.

The paper will focus on the process and the resulting impact on the building design from simulations carried out in several Danish building projects mainly using the simulation program ESP-r (ESRU, 1996). The buildings are:

- OfficeVision – a fully glazed and natural ventilated office building with a special power envelope filtering the sunlight.
- A partly natural ventilated atrium at the Scandinavian headquarters of DaimlerChrysler.
- The Jewel - a natural ventilated office building.
- The headquarters of NCC (a large Scandinavian contractor) – a natural ventilated office building with large glazed facades and a central atrium.
- National and provincial archive of Denmark – large glazed facades and natural ventilation.
- Nokia office building with a large glazed facade, central atrium, two smaller atria and mixed natural and mechanical ventilation.

OFFICE VISION

OfficeVision was a research project with the aim of developing and testing a transparent high performance building envelope in the form of an office building that provides more energy that it consumes, which have an improved indoor visual climate and is more healthy to be in. The aim was further to develop an industrialized building system with transparent low-energy envelope which is competitive, to build a full-scale building and to test the performance of the building in an occupied environment (Moltke, 2000). Figure 1 shows the vision for the building.

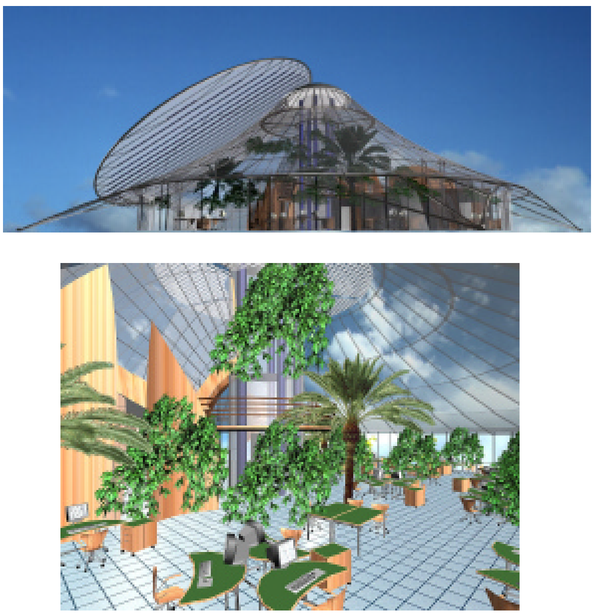

Figure 1 The vision of OfficeVision – to move the office to Bounty land

The walls and roof should consist of vacuum glazing with an overall U-value of >0.6 W/m²K. In order to decrease the direct solar gains, large parts of the glazing should be with a special purpose filtering mechanism without mowing parts (a lens system). This would allow diffuse sunlight to penetrate into the building while focusing the direct sunlight on strips of solar cells and thereby increase their performance.

The aim of the simulations was to calculate the energy demand and to investigate the indoor climate of the building and in this way support the design of the office building. The simulations of the thermal performance were an integrated part of the design process right from the start.

Several very different designs (developed by Moltke and Jeppesen, EnergyVision, Danish Technological Institute) were tried out for the building as shown in figures 1-4. The floor area of the building was 1000 m².

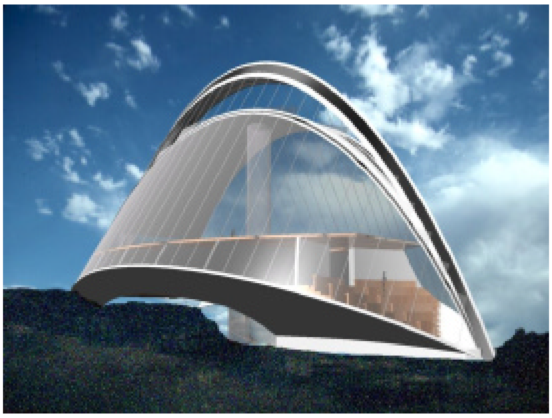

Figure 2. OfficeVision – the Bow.

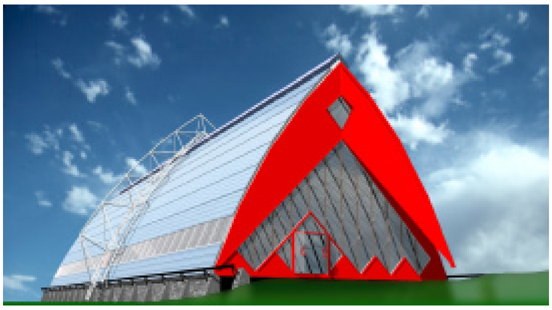

Figure 3. OfficeVision – the Toblerone.

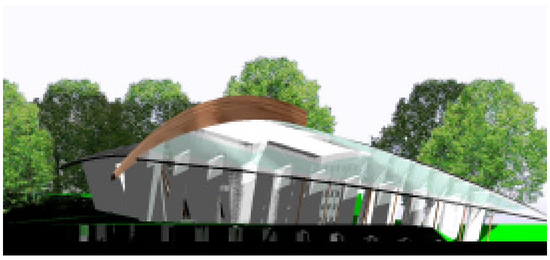

Figure 4. OfficeVision – the Ray.

The main conclusion from the simulations was (what could be expected) that it is difficult to obtain good thermal indoor climate in a fully-glazed building, even if the main part of the direct sunlight is not allowed to penetrate into the building and even if the U-value of the glazing is low.

During sunny days - even in the winter with ambient temperatures below zero degree - the building tends to overheat. Overheating of the air in the building was not the main problem as this may be eliminated by ventilation. The main problem is the radiation temperature of the glazing. Although only little sunlight slips through the glazing, it is still enough to increase the temperature of the internal glazing several degrees above the indoor air temperature as seen in figure 5. The reason for this is the small heat loss to the ambient due to the vacuum and during the summer a higher external surface temperature due to the heating up of the PV cells. Figure 5 shows a summer situation, but this problem occurs also during cold sunny winter days - internal surface temperatures above 35°C at an ambient temperature below -5°C.

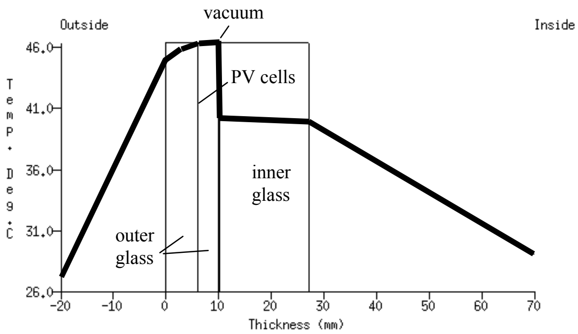

Figure 5. The temperature profile across a PV/lens/vacuum glazed roof during a summer situation (Moltke, 2000).

The simulations further pointed out that the ventilation system should be designed in order to prevent comfort problems (specially draught) on cold sunny days, as cooling of the building with ambient air is necessary in order to prevent overheating.

The project is stopped for the time being – not due to the results from the above-mentioned thermal simulations - although these simulations changed several important features of the building - but due to the fact that several necessary and important techniques are not evolved sufficiently today.

SCANDINAVIAN HEADQUATERS OF DAIMLERCHRYSLER

The Scandinavian headquarters of the DaimlerCrysler Corporation was erected in 1999 at Frederikskaj close to the centre of Copenhagen. The office building is approx. 9700 m^2. It was designed by the Danish architect company Dissing & Weitling a/s.

The building consists of traditional cell office blocks divided by 3 atria – the largest at the west end of the building. Whereas the cell offices are traditionally mechanically ventilated and air-conditioned in the summer, the large atrium was considered to be partly naturally ventilated – possibly with the use of a double-facade construction. The atrium functions as entrance and exhibition area and should be well conditioned.

Figure 6 The DaimlerCrysler building

ESP-r was used to investigate the thermal climate in the large atrium at the west facing end of the building. High temperatures in the summer were the main concern of the building owner and the consultants. Different natural and hybrid ventilation strategies were simulated with respect to location and size of window openings, how to take advantage of the double facades, etc. Also different types of glazing and controllable solar shading were investigated. The solar shading was located inside the double facade, with air movements on both sides of the shading.

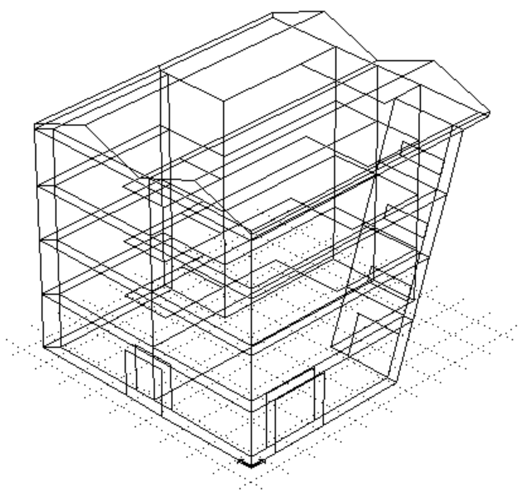

Figure 7 Wire frame of the ESP-r model

The use of simulations in the design process of the atrium had a large impact with respect to choice of window glazing, solar shading and ventilation rates (Jacobsen and Jensen, 1999). The first reports on the actual thermal climate inside the atria have been positive.

THE JEWEL

The objective of this research project was to compare costs and benefits for a "standard" office building and an "energy efficient and intelligent" office building. The aim was to design an office building with a 50% reduction of energy consumption within the same total economics.

The project was based on an actual building project in the development area of Ørestaden in Copenhagen. The building was designed by the Danish architect company Hvidt&Mølgaard A/S and should be build by the contractor NCC Denmark A/S. The building is not yet erected.

ESP-r simulations were used to estimate energy consumption and thermal indoor climate in the traditional office building as well as in the energy-efficient office building. It was essential that the thermal indoor climate in the energy-efficient building should be equally acceptable as in the traditional air-conditioned building.

Different features were used to obtain the goals for the energy efficient building: highly insulated constructions, natural ventilation, night cooling, special daylight windows, automated control of lighting, solar shading, low energy equipment, etc. Figure 8 shows a cross section of the energy-efficient building. Natural ventilation is provided by an airshaft though the building and by ventilation chimneys at the roof.

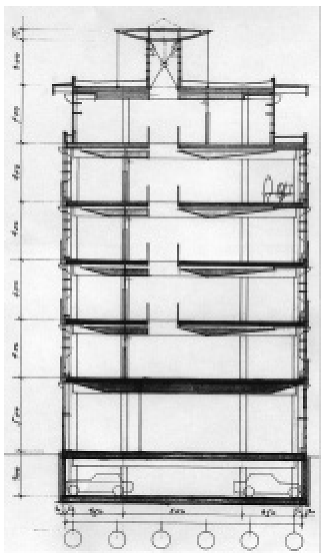

Figure 8 Cross section of the Jewel building.

The results showed that it is possible to design an office building with a 50% reduction of energy consumption with an equally acceptable indoor climate as well as the same total economics as a traditional office building. But the requirements to the building design as well as to the choice of constructions, glazing, equipment, ventilation strategy, etc. are stricter. (Jacobsen, 2000a).

HEADQUARTERS OF NCC

NCC Denmark A/S is the largest contractor company in Denmark. When they decided to erect a new headquarter north of Copenhagen, they wanted it to signal their ability to build innovative and energy-efficient buildings with focus on good indoor climate. This decision was partly based on the results from the above mentioned project – the Jewel. The building is being built when writing this.

The building is a large, highly glazed cubic building with a central atrium and open space offices. It is designed by the Danish architect company Schmidt, Hammer & Lassen. Natural ventilation with air intake from the facades and outlet in the top of the atrium is one of the key features of the building.

ESP-r simulations were used with focus on thermal climate in the building in the summer period. The simulations were used to investigate the effects of several features: window types and sizes, solar shading devises, ventilation flow rates, night cooling, thermal mass, etc. (Jacobsen, 2000b). A model of the central atrium of the building is shown in figure 9.

Figure 9 The atrium of the NCC headquarter.

The simulations started rather early in the design process. The person carrying out the simulations participated in several of the meetings where the design was developed. The simulations were as such performed based on requests by the design team leading to redesign which again lead to the need for new simulations.

The simulations have had a rather large impact on the final design of the building – especially with respect to window sizes, choice of glazing and solar shading. The simulations also had a major influence on the decision of not using assisting fans in the ventilation strategy.

THE NATIONAL AND PROVICIAL ARCHIVE OF DENMARK

The simulation work described here was carried out by one of the authors as her M.Sc. gradient thesis.

The building is rather complex as seen in figure 10. The building is designed by the German architect company Behnisch, Behnisch & Partner. Part of the public area is natural ventilated. The simulations were carried out in order to facilitate the design of natural ventilation with air intake through the facades (Overgaard, 2000a).

Figure 10. A model of the archive building.

The simulations were carried out very early in the design phase of the building at a stage where the major features of the building were not yet finally decided. Instead of making very detailed simulations on a very specific design, more general simulations were conducted and combined into a design tool as a set of curves, which the consultants also at a later stage could use to help the decision-making on the final design of the natural ventilation.

Several different tools were tried out in the project and compared – both very simple hand calculations, simple simulation tools and advanced simulation tools as ESP-r and CFD codes. The comparison showed that simple tools might be sufficient during the start of the design process where many important parameters of the building not yet are defined. Later in the design process, the advanced tools will often be superior especially if the building is complex, one of a kind or involves special non-standard features where the thermal performance is not well known.

NOKIA OFFICE

The simulations on this building were carried out on request by the consultant and the contractor in order to evaluate the maximum temperature at the top of the central atrium of the building.

The building has large glazed facades, a large central atrium and two smaller atria at the side of the building. The building is natural ventilated. The principle of the building is shown in figure 11. The building is designed by the Danish architect company Hvidt&Mølgaard.

The simulations confirmed that there is a risk of high operative temperatures in the top of the atrium mainly caused by high internal surface temperatures of the glazed roof of the central atrium. The simulations further showed that increasing the opening area in the top of the atrium could not solve the problem. The solution was shading devises not only on the central atrium, but also on the smaller atria at the sides. (Overgaard, 2000b).

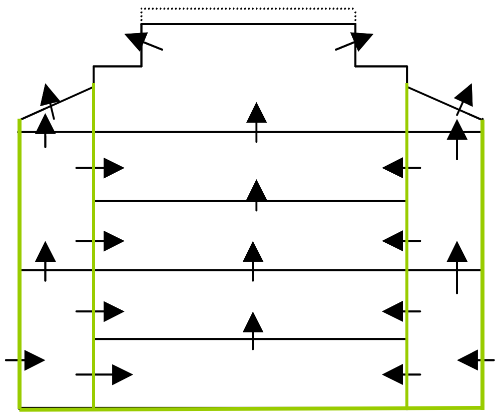

Figure 11. The ventilation principle of the Nokia office building.

GAINED EXPERIENCE

The experience gained from the simulations carried out in the above mentioned projects is:

There is an increasing request for detailed simulation of the thermal performance of especially prestigious (office) buildings. The reason for this is that these buildings often involve many non-standard features, which cannot be treated as "business as usual" by the contractors and the consultants. Natural ventilation is one feature where easy-to-use tools and rules-of-thumbs still are lacking. Increasing focus is further put on thermal comfort by building owners and users demanding that the contractor in advance proves that the building will function as intended.

The impact of the simulations on the design of a building is larger the earlier the simulations are introduced in the design face. On the other hand, it is more difficult to perform the simulations (especially the development of the model of the building), as much important information only will be present late in the design phace.

Simple tools may be sufficient early in the design phase, however, if it is believed that detailed and complex simulations may be necessary later on in the design phase it may be cost-effective to introduce the detailed simulation tool from the start.

ESP-r is a very detailed simulation tool with many features. However, it is often necessary to trick the program in order to allow for a more detailed representation of special features, which it is not possible to represent explicit by the program.

It is very important that the person performing the simulations is a skilled user of the specific program and has a major insight in the thermal processes occurring in building. Without this skill, the results of the simulations may easily be interpreted wrongly.

CONCLUSIONS

There is an increasing demand for detailed simulation of the thermal performance of office buildings in particular.

Detailed simulations have proved to be an efficient tool when designing and evaluating the design of complex buildings. Detailed simulations further make the contractor and the building owner more confident with the chosen design.

However, it is outmost important that the simulations are performed by a person who is a skilled user of the specific simulation program. The saying „rubbish in - rubbish out" is also true when simulating the thermal performance of buildings.

ACKNOWLEDGEMENTS

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