I

INDUSTRY CORNER

ALBERTSLUND LIBRARY, DENMARK: OPTIMIZATION OF INDOOR DAYLIGHT AND THERMAL CLIMATE CONDITIONS AND USE OF FAN-ASSISTED NATURAL VENTILATION IN A PUBLIC LIBRARY

Bruno Nielsen,[1] Henrik Sørensen,[2] Rasmus Pedersen,[3] and Frans Drewniak[4]

INTRODUCTION

The theme for the renovation of Albertslund Library has been to create a markedly bright library that is open to its surroundings and environment. The overall objective is to satisfy the needs of the staff at the library and users in all age groups and from all social stratums. Further, the goal is to have a building which is optimized in terms of indoor daylight and thermal conditions, use of natural ventilation for saving energy in terms of cooling, and electricity for fan assistance and artificial light.

The innovative elements in the project are a result of co-operative work by Esbensen Consulting Engineers A/S and Henning Larsens Tegnestue. Project meetings early in the design process between the architects and engineers has resulted in a success for integration of several innovative and effective energy elements, thus saving valuable time and reducing costs.

This paper will describe the different technologies used in the project, and the detailed and specialized simulations carried out in the design process will be discussed with special focus on daylight. The building was completed in spring 2004.

1. RENOVATION OF THE ALBERTSLUND LIBRARY

Albertslund Library is part of "Albertslund Huset," which was finished in the beginning of the 1970s before the energy crisis. It is a two-storey building that—in addition to the library—comprises municipal administration, and cinema and music venues. The municipality of Albertslund decided that "Albertslund Huset" should undergo a thorough renovation, mostly due to mould problems and subsequent problems with its indoor climate.

A totally new building volume replaces the first floor and the old library. The new library is designed as one large and bright space that opens up towards the surroundings. The children's section is situated in a protruding part of the south façade with a view to the tall trees, and the reference library faces the town hall and a lake to the north through large glass panels. The renovation of Albertslund library includes the roof construction and façade and creates new possibilities for improving the indoor daylight and thermal climate conditions. Furthermore, the new library is

FIGURE 1. The main library seen from the north.

1. Esbensen Consulting Engineers, Vesterbrogade 124 B, DK-1620 Copenhagen V, Denmark. Tel.: +45 33 26 73 08, fax: +45 33 26 73 01. email: b.nielsen@esbensen.dk, www.esbensen.dk
2. Esbensen Consulting Engineers.
3. Henning Larsens Tegnestue, Vesterbrogade 76, DK-1620 Copenhagen V, Denmark. Tel.: +45 82 33 30 00, fax: +45 82 33 30 99. email: rasmus.pedersen@hlt.dk, www.hlt.dk
4. Henning Larsens Tegnestue.

FIGURE 2. Skylights, seen from northeast.

characterized by large open spaces and high rooms, which enable the use of natural ventilation.

The continuous skylight in the characteristic serrated roof assures dispersion of daylight into the entire deep volume. Furthermore, it constitutes an important element in establishing natural ventilation.

An essential demand from the building owner was to have a green building with improved indoor thermal and daylight conditions with these improvements achieved in a simple and cost-effective way. It was important that the engineers and architects had a close, cooperative way of working and that the way improvements could be reached was indeed considered from the very beginning of the project.

The result is a building that has improved the indoor daylight and thermal climate conditions substantially with an innovative design of skylights using the integrated design process.

2. INDOOR DAYLIGHT CONDITIONS

The new library is constructed with high façade windows and through-going skylights, which assure a high level of daylight and a good daylight distribution in the library. The aim was to obtain a high level of daylight and good daylight distribution without glare problems and at the same time reduce the internal heat load from the sun.

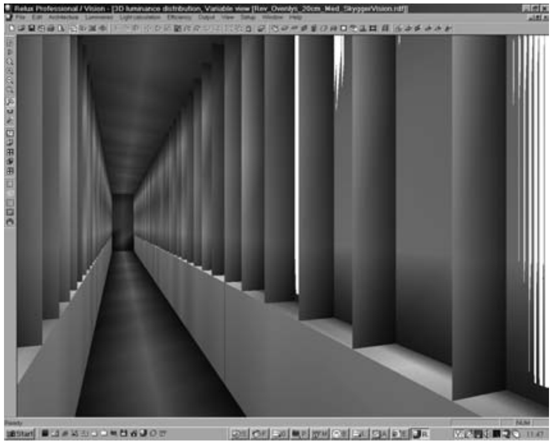
For this purpose the light planning software Relux Professional/Vision was used. The calculation is based on a version of Radiance that has been revised by Relux.

2.1. Skylights

For reducing the internal heat load from the sun and overcoming possible glare problems, the skylights have been developed with integrated constructive solar shading, as seen in Figure 3.

The depth of the constructive solar shading (fins) is 200 mm at intervals of 500 mm has been consid-

FIGURE 3. Skylight with constructive solar shading (brown) as modeled in Relux. Seen from the gable of the skylight.



ered carefully with Relux. The advantages of the constructive solar shading are:

- Part of the skylight construction
- Permanent solar shading
- Permanent glare shading
- No mechanical parts
- No repairs and maintenance
- Contributes to an optimized daylight distribution in the library
- Gives a special ray of solar radiation into the library, see Figure 10

In Figure 4, a picture of the skylight as constructed on site is shown.

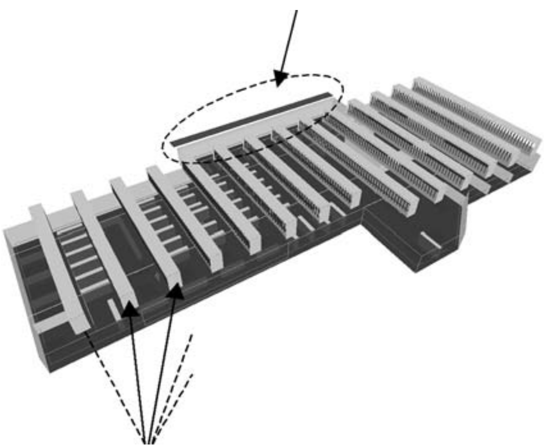
2.2. Main Library

After the dimensions of the skylights and the constructive solar shading were found with Relux, a building model for the whole library was made in Relux, including all skylights with fins and all inventories in the library. In Figure 5, the model is seen from northeast with the children's section facing south.

The model was simulated with an overcast CIE sky. The long simulation time (6 days) due to all the fins in the skylights, limited the mesh that was set to 0.5 meters. After completing the simulation, it is possible to have a walk-through of the library and get a feeling of the daylight conditions. Thereby, it is

FIGURE 4. Skylight with constructive solar shading (gray) as constructed, seen from the floor and up into the skylight.

FIGURE 5. Model of the library made in Relux Professional/Vision seen from northeast with skylights including all fins working as constructive solar shading.



possible to optimize the indoor daylight conditions and place the permanent working spaces and inventory so the daylight is used where it is needed the most and avoid glare problems.

Figure 6 shows the simulated daylight conditions in lux for the whole library on an overcast CIE sky in a plane 0.85m above the floor. The lux level is 0 – 600 lux.

From Figure 6, it can be seen that the daylight level is at a sufficient level, exceeding 200 lux (daylight factor = 2), in most of the library. The public section of the library especially has a daylight level above 200 lux. It is also interesting to note that the daylight level is higher between the skylights than right underneath them. The bookshelves are situated right between the skylights thus taking advantage of the high level of daylight there. The higher level of daylight between the skylights can also be seen in Figure 7, where the actual daylight distribution on a sunny day is shown.

FIGURE 6. Simulated daylight conditions for the whole library on an overcast CIE sky in a plane 0.85 m above the floor (lux).

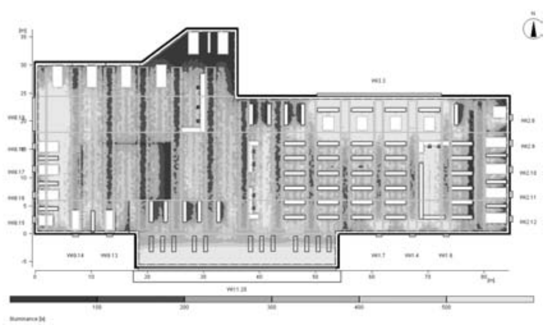


FIGURE 7. Actual daylight conditions inside the library. Note the higher level of daylight between the skylights.

Figure 8 shows the simulated daylight distribution in the library seen from the west end of the library with the children's section on the right on an overcast CIE sky expressed from 10 cd/m^2 to 50 cd/m^2.

In Figures 9 and 10, the actual daylight conditions on a sunny day are shown for the almost finished library.

The traces of sun on the floor and façade from the skylights and due to the constructive solar shading, give a finishing touch to the daylight distribution. The traces of sun also move relatively fast so the traces have moved from one side of each skylight to the other during a span of a couple of hours. Furthermore, the number of hours the sun traces appear each day is highest during summer and goes to zero during wintertime.

FIGURE 8. Simulated daylight distribution, seen from the west with the children's section on the right (cd/m^2).

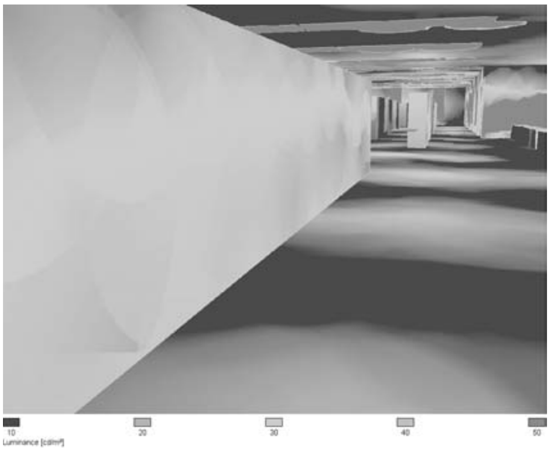


FIGURE 9. Actual daylight distribution, from west with children's section to the right.

FIGURE 10. Actual daylight distribution, seen from the middle of the library to the north. Note the traces of sun on the floor and façade.

2.3. Conclusion

From detailed simulations carried out for the library, constructive solar shading in the skylights has been developed. The constructive solar shading has a depth of 200 mm and is placed every 500 mm on each side of each skylight. The constructive solar shading contributes to an optimized daylight distribution inside the library and at the same time decreases the level of solar radiation into the library thus increasing the level of thermal and visual comfort.

Furthermore, the level of daylight and daylight distribution has been optimized with simulations. After construction the level and distribution of daylight met our expectations. Glare problems have been avoided by the constructive solar shading in the skylights, a solar curtain in the children's section, and by using the daylight simulations to optimize the inventory plan.

3. NATURAL VENTILATION

Today, in well-insulated buildings, ventilation and cooling may account for about 50% of the energy requirements, and a well-controlled and energy efficient ventilation system is prerequisite for low energy consumption for the building.

The ventilation system for Albertslund Library is based upon natural driven forces caused by the temperature difference and the differential pressure between indoors and outdoors. The natural ventilation system is fan assisted for assuring a comfortable indoor thermal climate on sunny days and days with rain and high gusting winds.

The success of the hybrid ventilation system depends on utilizing the benefits of natural ventilation and that the design of the system is integrated from the start and in subsequent design stages. This was precisely the case for Albertslund Library.

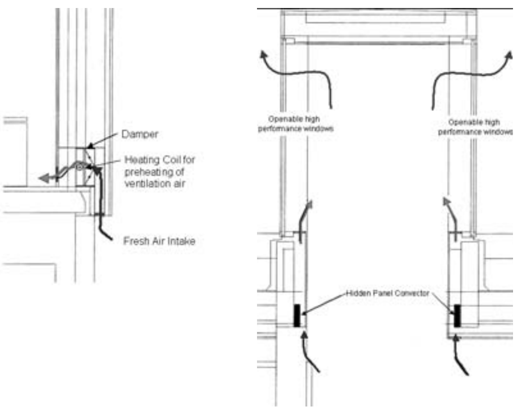
3.1. Design

The design of the new library is characterized by big open areas and a high room height, which gives a good possibility to use the building for fresh air distribution and gaining good air quality. Renovation of the façade and installation of skylights make the building highly suitable for natural ventilation by using the façades as fresh air intakes and removing the exit air through the skylights. Thereby, the building will act as a ventilation duct for distributing the fresh air inside the library. The fresh air is then distributed by displacement.

Fresh air intakes are situated along the façade between the façade windows. A convector is integrated in the intake for preheating of the fresh air, as seen in Figure 11. The fresh air intakes are controlled with a damper in each intake, and all are connected and controlled by the BMS; see Figure 3.

The exit air is ventilated to the outside through openable windows in the skylights; see Figure 11. The openable high performance windows are regulated by wind direction, indoor temperatures, indoor CO_2 level and rain by the BMS. In both sides of each skylight hidden panel convectors are installed for avoiding cold draughts and to contribute to space heating of the library.

FIGURE 11. Sketches of the fresh air intake on the left and the skylight on the right.



The size of the openable area in the skylights is dimensioned after a demand of rate of air change of 3 h^{-1} (24 000 m^3) found from the internal heat and CO_2 load. The program ContamW 2.0 has been used for dimensioning the size of the openable area in the intake and exit. It has been found that the openable area needed in the intake is minimum 7 m^2 and that 20 m^2 of openable area is needed in the skylights for exit. Here the openable area has been downwind prioritized.

3.2. Heating Season

During the heating season the air change is kept at a minimum by regulating the damper in the fresh air intake and thereby the amount of fresh air after the CO_2 level during opening hours. The natural driven forces will keep the CO_2 at a satisfying level during the heating season. A convector integrated in the fresh air intake assures that the temperature of the minimum incoming fresh air is 18°C so that cold draught is avoided. Fan assistance is used when the openable windows are shut because of high winds or rain. Furthermore, openable high performance windows are used in the façade with user control for removal of excess heat during summer.

3.3. Summer

Outside the heating season the natural ventilation system is controlled as during the heating season. However, the dampers in the fresh air intakes and the openable windows are regulated by the indoor temperature during opening hours. When needed, the natural ventilation system will also be active during the night with a lower setpoint for indoor temperature than during the opening hours, thus cooling the library. Preheating of the ventilation air is shut off outside the heating season.

During very hot and sunny days where the natural ventilation cannot keep the indoor temperature at a satisfying level, the fans that are installed in the gable of every 2nd skylight will kick in.

4. INDOOR THERMAL CLIMATE

The indoor thermal climate conditions are primarily dependent on the internal heating load from people, equipment, artificial light and the sun. The indoor thermal climate is regulated by ventilation and night cooling of the building by using the internal mass of the library, e.g., concrete floor and books.

For reducing the internal heat load as much as possible and thus reducing the number of hours the fans need to assist the natural ventilation, integrated blinds are used in the façade windows, and the artificial lighting is subdued/shut off as per the level of daylight.

The indoor thermal climate has been simulated with the thermal simulation program BSim2002 (BuildingSimulation 2002), which is a computer based calculation program for simulation and analysis of the indoor climate and energy consumption in buildings. By constructing a detailed mathematical model of the structure, it is possible to simulate a large number of indoor climate and energy parameters. This is done taking into consideration the dynamic interaction between the outdoor climate and miscellaneous design of structures, installations, and running situations.

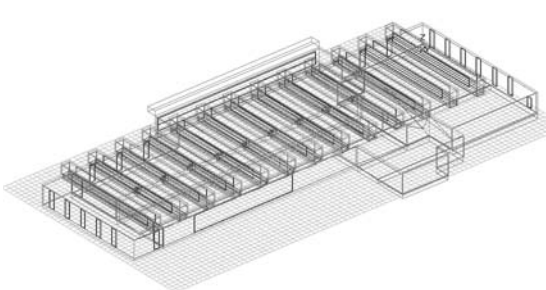
4.1. The Model

Based upon the construction details derived from, among others, the daylight simulations and the natural ventilation system, the following building model was made in BSim2002 that corresponds closely to the actual conditions.

The library is divided into 4 sections, children's section (south), north section, east section, and a west section that is closed and has its own mechanical ventilation system with cooling. The west section is the administrative area for the library, while the rest of the library is public.

The most important elements in this simulation are the ventilation system, the internal mass from all the books, and the internal heating load from the artificial lighting system due to the high demand of lighting level on the bookshelves and wishes for artificial light by the architects.

FIGURE 12. BSim2002 model of Albertslund Library with skylights and all fins. Seen from northeast.



4.2. Natural Ventilation System

The ventilation system is a natural ventilation system with fan assistance. The minimum temperature of the intake air is 18°C, and the amount of fresh air is regulated by the CO_2 level during the heating season and by the indoor temperature outside the heating season. There is no cooling coil in the ventilation system. The air change is set to a maximum of 1 h^{-1} during the heating season and 5 h^{-1} outside the heating season. The high rate of air change, 5 h^{-1}, during the summer is kept by the assisting fans. The low rate of air change during the heating season and the fact that it is controlled by the level of CO_2 decreases the energy demand for space heating and ventilation. During summertime, when needed, night cooling is initiated and with fan assistance if needed. The internal mass from all the books acts as a good buffer and has been taken into account in the simulations.

4.3. Artificial Lighting System

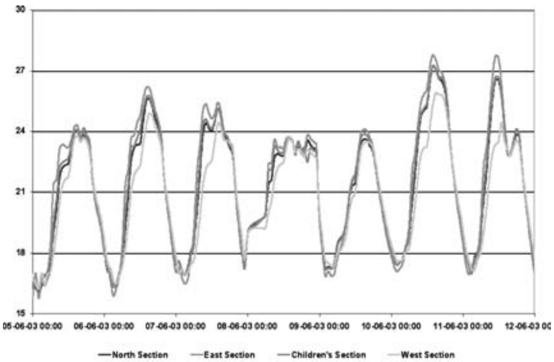
The high demands for level of lighting on the bookshelves and the architects wishes for the artificial lighting system causes the heating load from artificial light to be much higher than the heating load from people and equipment. The overall internal heating load is high and will give high indoor temperatures outside the heating season. An effective way to overcome this problem is to control the artificial lighting system, especially that on the bookshelves in such a way that they are shut off or subdued most of the time outside the heating season.

Daylight simulations showed that it is possible to shut off most artificial light about 65% of the opening hours if controlled by the level of daylight at minimum 200 lux. In the BSim2002 model of Albertslund Library the artificial light at the bookshelves is subdued and shut off most of the time during summer as found in the daylight simulations.

4.4. Indoor Thermal Climate

From the simulations made with BSim2002 the following indoor temperatures in different parts of the library have been found during opening hours. Fig-

FIGURE 13. Indoor mean operative temperatures for all sections of the library during a warm and sunny week, June 5th–June 11th.



ure 13 shows the mean indoor operative temperature during opening hours for the different sections of the library during a warm and sunny week.

Figure 13 shows that the indoor temperatures are at a satisfying level in the summer. Table 1 shows the annual number of hours the mean indoor operative temperature exceeds 26°C and 27°C, respectively, for all sections in the library.

4.5. Conclusion

According to Danish guidelines for indoor thermal climate in offices, DS474, the annual number of hours during the opening hours for a whole year should not exceed 100 hours above 26°C and 25 hours above 27°C and the maximal indoor temperature should not exceed 30°C. Table 1 and Figure 13 show that these guidelines are held for Albertslund Library. Furthermore, Table 1 shows that the amount of hours with overtemperatures are low. The east section of the library has a high internal heating load per m^2 and only one skylight for exit, thus getting higher indoor temperatures than the rest of the library. Overall it can be concluded that the indoor thermal climatic conditions for Albertslund Library are satisfying.

TABLE 1. Annual number of hours the mean indoor operative temperature exceeds 26°C and 27°C, respectively.

	T > 26°C (hours)	T > 26°C (hours)	T_{max} (°C)
Children's section (south)	22	9	29.2
Library, north	20	8	28.4
Library, east	38	18	30.7
Library, west	2	0	26.5

5. CONCLUSIONS

Based on the detailed simulation work that has been carried out during the design phase, the following overall conclusion can be made:

5.1. Daylight Conditions

From detailed simulations carried out for the library, constructive solar shading in the skylights has been developed. The constructive solar shading has a depth of 200 mm and is placed every 500 mm on each side of each skylight. The constructive solar shading contributes to the daylight distribution inside the library and at the same time decreases the level of solar radiation into the library thus increasing the level of comfort.

Furthermore, the level of daylight and daylight distribution has been optimized with simulations, and after construction the level and distribution of daylight meet our expectations. Glare problems have been avoided by using the simulations to optimize the inventory plan, the constructive solar shading in the skylights, and a solar curtain in the children's section.

5.2. Natural Ventilation

The shape of the library with open space and high room height, together with the renovation of the façade and installation of skylights, make Albertslund Library highly suitable for natural ventilation by using the façades as fresh air intakes and removal of the exit air through the skylights. Thereby, the building will act as a ventilation duct for distributing the fresh air inside the library. The fresh air is then distributed by displacement.

Fresh air intakes are situated along the façade between the façade windows. A convector is integrated in the intake for preheating of the fresh air. The fresh air intakes are controlled with a damper in each intake, which is connected to the BMS.

The minimum temperature of the intake air is 18°C, and the amount of fresh air is controlled by the CO_2 level during the heating season and by the indoor temperature outside the heating season. The openable areas in the intake and exit are dimensioned after a rate of air change of 3 h^{-1} thus keeping the CO_2 level at a satisfying level.

5.3. Indoor Thermal Climate

The indoor thermal climate of Albertslund Library has been simulated with the thermal simulation program BSim2002 (BuildingSimulation 2002), which is a computer based calculation program for simulation and analysis of the indoor climate and energy consumption in buildings.

According to Danish guidelines for indoor thermal climate in offices, DS474, the annual number of hours during the opening hours for a whole year should not exceed 100 above 26°C and 25 above 27°C. Simulations with BSim2002 verified that these guidelines are held for Albertslund Library and that the indoor thermal climate overall is satisfying.

ALBERTSLUND LIBRARY PROJECT LIST

Frans Drewniak, project architect
Rasmus Pedersen, architect
Klavs Holm Madsen, architect
Magrethe Rask Pedersen, architect
Jeppe Mosen Bjerg, architect
Claus Simonsen, architect
Henrik Vuust, architect
Lars Steffensen, partner, architect

HLT HENNING LARSENS TEGNESTUE A/S
+45 82 33 30 00 (+45 27 15 02 18)
http://www.hlt.dk