Indoor Climate of Large Glazed Spaces

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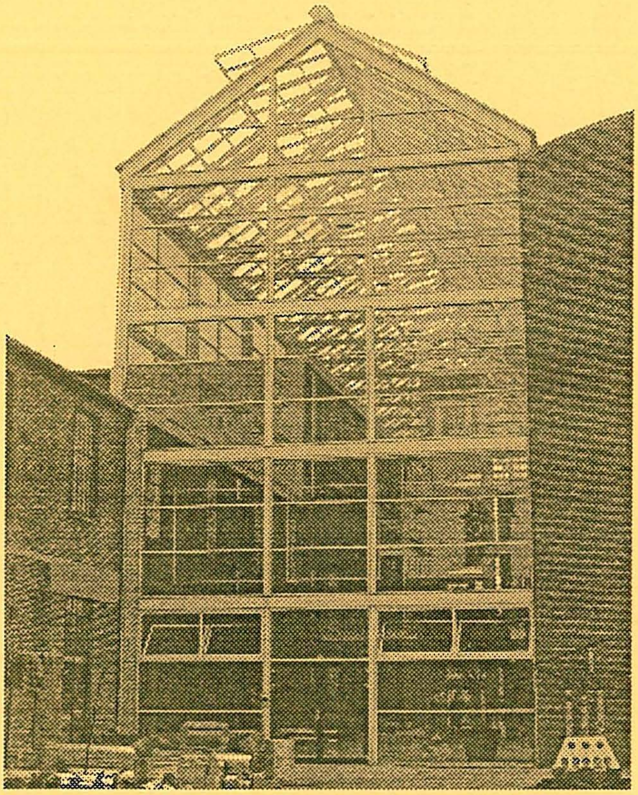

INDOOR ENVIRONMENTAL TECHNOLOGY
PAPER NO. 63

Presented at the 4th European Conference on Solar Energy in Architecture and Urban Planning, Berlin, Germany, March 1996

O. J. HENDRIKSEN, C. E. MADSEN, P. HEISELBERG & K. SVIDT
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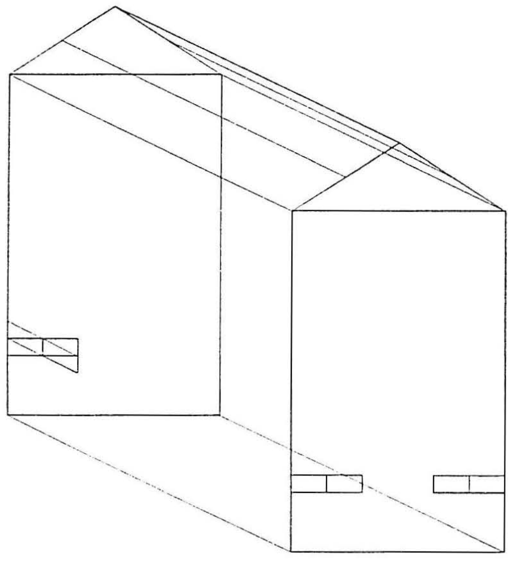
ABSTRACT: In recent years large glazed spaces has found increased use both in connection with renovation of buildings and as part of new buildings. One of the objectives is to add an architectural element, which combines indoor- and outdoor climate. In order to obtain a satisfying indoor climate it is cruicial at the design stage to be able to predict the performance regarding thermal comfort and energy consumption. This paper focus on the practical implementation of Computational Fluid Dynamics (CFD) and the relation to other simulation tools regarding indoor climate.
KEYWORDS: Natural ventilation, Computer simulation models, Atrium, Daylight evaluation, Thermal comfort

Project description

One of the important issues in design of large glazed spaces is determination of the air movements in the room and especially in the occupied zone.

This project is carried out as a case study, and comprises a monitoring programme and simulations using CFD for a natural ventilated atrium.

Furthermore the daylight conditions and the energy consumption for heating, ventilation and lighting will be analyzed in the project.



Outline of the atrium with openings

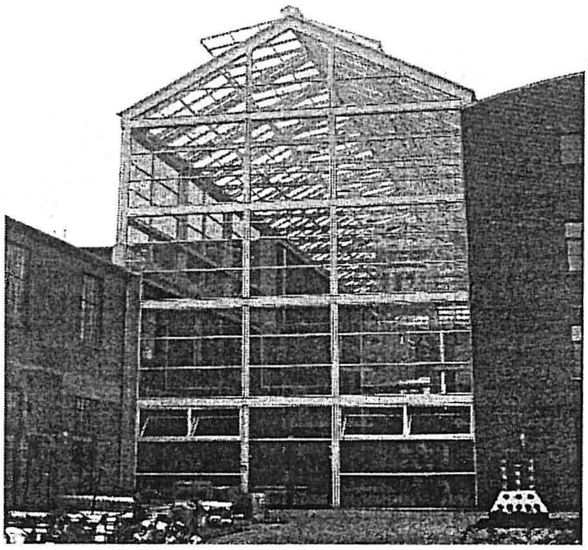
The monitoring programme consists of measurements of surface- and air temperatures for a six month period and detailed air flow measurements for two short-term periods during summer and winter conditions. The measurements are used as boundary conditions for CFD simulations, and for verification of the CFD models.

The programme FLOVENT has been used for the CFD analysis.

Building description

Sukkertoppen is an old sugar refinery in Copenhagen, which was redeveloped into a multi-media house in 1992. A new building was added south of the existing building, and the two buildings are coupled with a glazed atrium.

The purpose of the atrium is to reduce the space heating load of the buildings, and to improve the daylight conditions in the attached buildings. This atrium is used as circulation area and has no permanent occupation. The atrium is heated to 16-18°C during the winter season, and is naturally ventilated during summer season.



West end wall of the atrium Sukkertoppen.

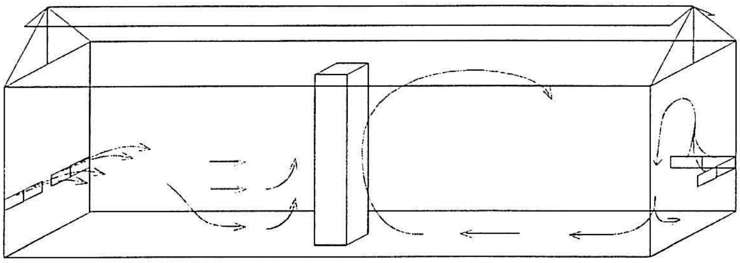
The dimensions of the atria is 10 x 18.5 x 58 meter. The openings are placed in the end walls and at the top of the roof.

All glazed surfaces facing the outdoor air are low-energy glazing with an U-value of 1.6 W/m²K.

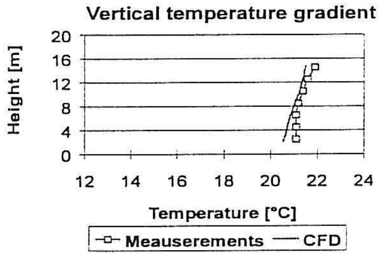
Indoor Climate

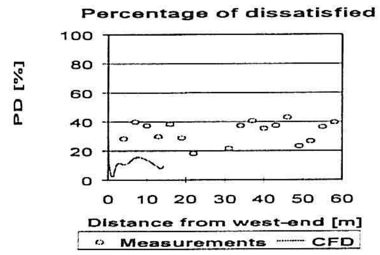
Summer

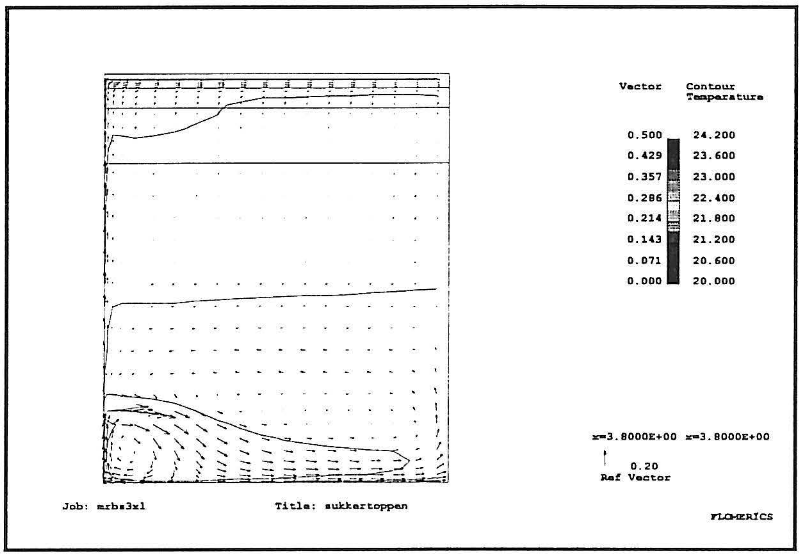
Natural ventilation with air supply through openings in end-walls, and outflow through the top of the roof. The airflow is characterized by moderate thermal stratification.



Ventilation rate: 46900 m3/h
Air change rate: 4.9 /h
Outdoor temperature: 20°C

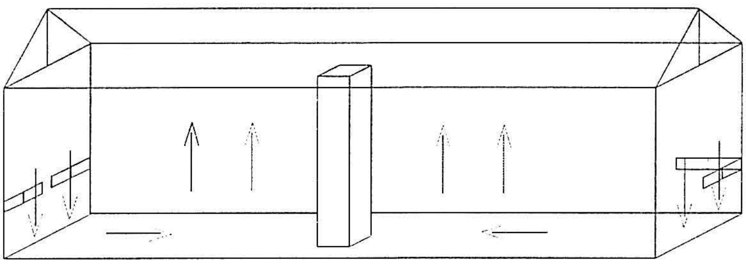




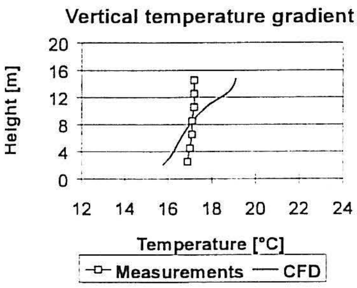


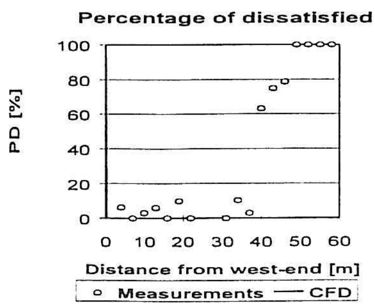
Winter

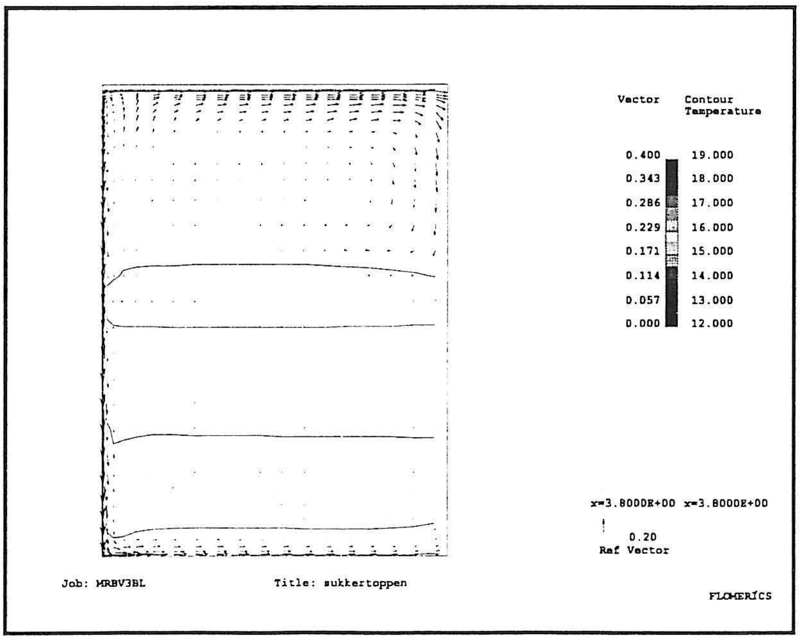
Infiltration through surfaces facing outdoor. The temperature measurements and a smoke test had shown mixed air, but the CFD model has a limited size, and lack of abilities to show the situation of mixed air due to infiltration.



Ventilation rate: 3350 m3/h
Air change rate: 0.35 /h
Outdoor temperature: 0°C

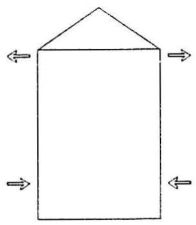


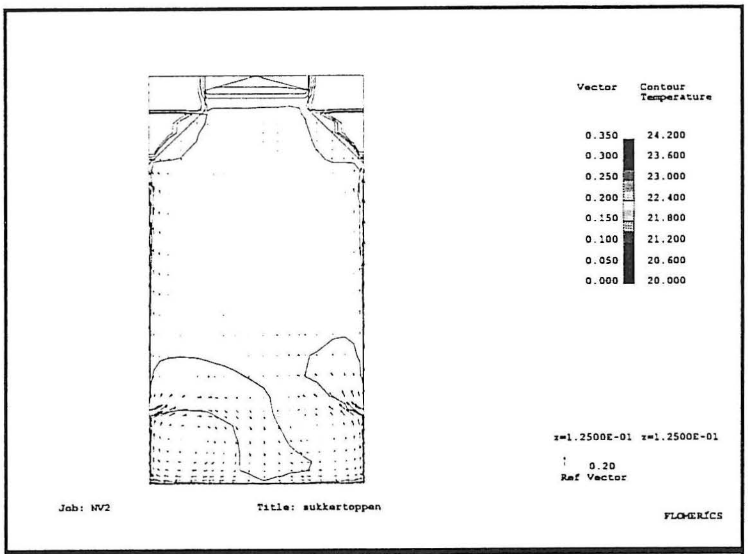




Natural ventilation

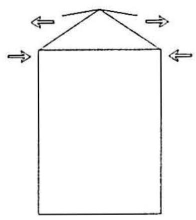
The capacity and the temperature conditions have been analyzed with CFD for three different configurations of natural ventilation at moderate summer conditions.

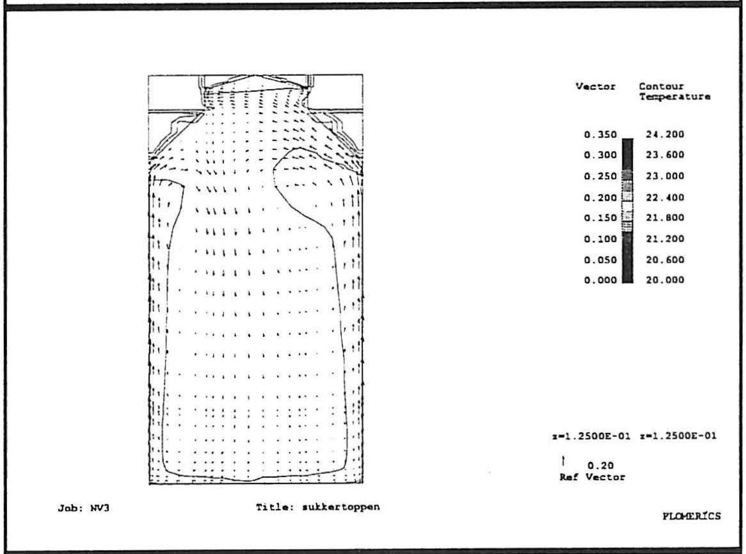




1. Openings in side walls

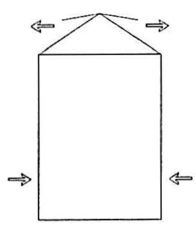
This configuration results in satisfying temperature conditions in the occupied zone, but leads to a high temperature gradient in the top of the atrium due to a pile of hot air.

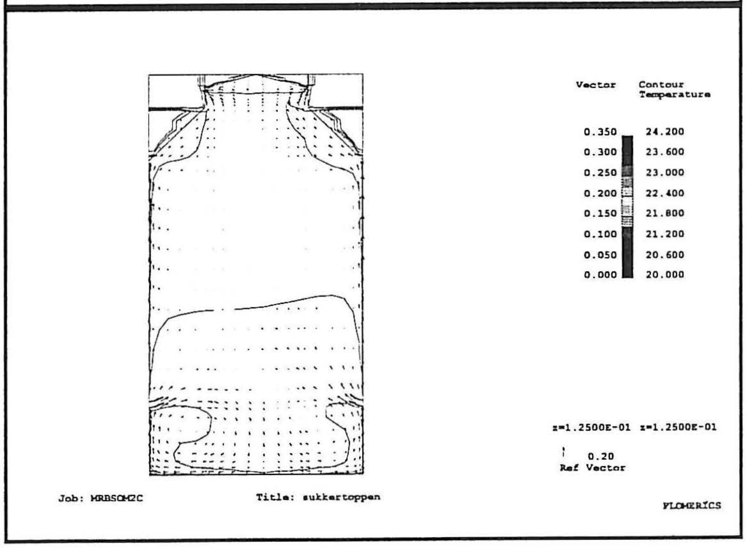




2. Openings in top of the roof and the of the side walls

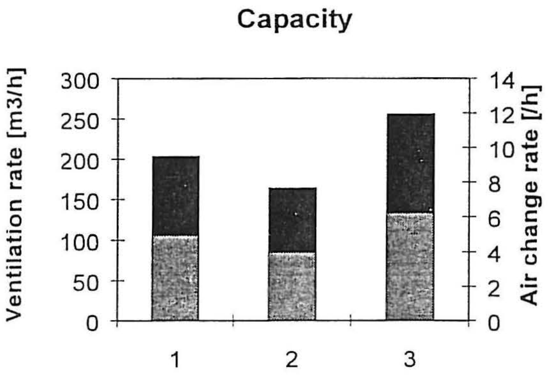
This configuration is characterized by the lowest ventilation rate and no temperature gradient, which indicates mixing of the air.

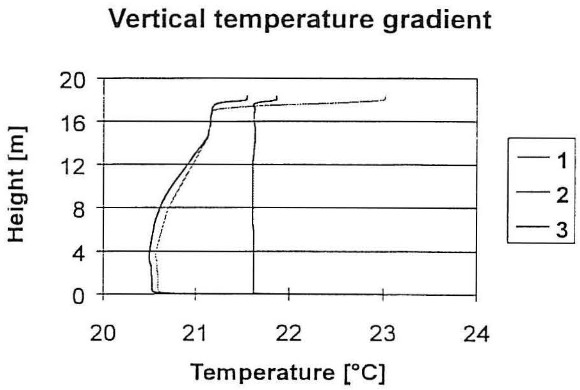




3. Openings in top of the roof and lower part of the side walls

This configuration has the largest distance between the openings, which results in the highest ventilation rate and the lowest temperatures.





Daylighting

In order to improve the daylight conditions in the adjacent rooms at the lower floors, the window area has been increased. This increased window area was possible due to the use of low-energy glazing at the surfaces facing the outdoor, and without an increased heating load for the building.

Calculations have shown that the daylight factor is reduced at the front of the room and increased towards the back of room. This is very advantageous since both the daylight availability deep in the room is increased and the contrast ratio is reduced.

Conclusion

- CFD is a powerful tool to predict or evaluate ventilation and indoor climate of large glazed spaces.
- The boundary conditions for the CFD simulations should be treated carefully in order to obtain useful results.
- The analysis of the indoor climate for the naturally ventilated atrium has shown that it is possible to obtain a satisfying indoor climate during the summer period. In the winter period the PD index is rather high at the end walls due to cold draught, especially by the east end-wall due to wind pressure.

Integration of simulation tools

An important part of the CFD analysis is to estimate the boundary conditions, in order to obtain useful results for ventilation and air flow.

Dynamic thermal simulation programmes can be used to determine the surface temperatures and the energy balance for a room, and the results can be transferrred to a CFD programme. Furthermore the air change rate calculated by CFD can be transferred back to the dynamic thermal simulation programme in order to improve the determination of the thermal performance and energy balance for the room.

Further information

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