BUILDING SIMULATION IN APPLICATION

Developing concepts for low energy buildings through a co-operation between architect and engineer

Integral interdisciplinary planning of buildings - a fairy tale or practicable?
an experience report of 3 years of application in around 30 projects

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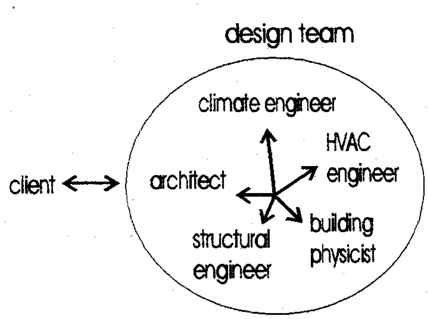
ABSTRACT

Even at the beginning of the concept and planning phase for low energy buildings co-operation between architect and different engineers is mandatory. In particular, the climate engineer supports the architect by developing an energy concept for a building. Thus, even in the design phase this new discipline of engineering makes sure that the influences of the climate, of an active or passive use of solar radiation, of zoning and all aspects concerning the thermal behaviour of a building are taken into account. With a dynamic simulation program like TRNSYS the concept is checked for the whole year (winter and summer) and optimized by the design team.

Fig.1: Design Team



STARTING POINT

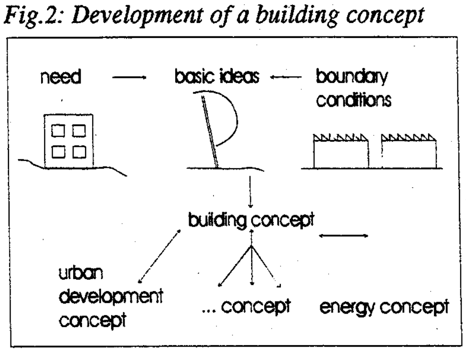
Usually the client - being private or municipal - orders the design of a building. Even in the early stage of the planning phase the co-operation between the architect and the engineers of the different fields should begin, however this is still an exception. In most cases the "other" branches of engineering (building physics, HVAC, structure, climate) are only incorporated after the conclusion of the building design.

The design process in a real team means developing an interdisciplinary concept for the various fields - like the urban development or the energy concept - which all form the building concept.

PRACTICAL EXPERIENCE

For 3 years of experience the engineers of TRANSSOLAR have applied this way of action in about 30 building projects. This activity can be seen as a practical application of the results of the IEA research program, Task XI, Passive and Hybrid Solar Commercial Buildings. The following article describes the way of action and the results up to the completed building but also shows the problems and difficulties.

Fig.2: Development of a building concept



DEVELOPMENT OF A NEW OFFICE BUILDING

AIM

The primary goal in the development of DATAPEC's new office building was to create work places with optimized thermal and visual comfort and to minimize the investment costs for ventilation and cooling systems. The design and construction of the building in combination with the ventilation system was meant to avoid the investments for an air conditioning system. The central atrium was designed to function as "a centre providing freshness and coolness in summer." Thus the building should function entirely on its own and not act only as an envelope.

The design team consisting of architect, structual engineer, HVAC engineer, building physicist and climate engineer should realise these aims. The climate engineer - a branch of engineering that has developed only recently - gives advice in the field of construction wherever climate plays a role and uses the new planning instruments like simulation programs. This interdisciplinary activity is very important since today building components often have to perform additional functions like "load-bearing" and "air conducting", for example.

REQUIREMENTS

In persuing the above mentioned goals it must be considered that most of the work places at DATAPEC (a company distributing hard- and software for large administration offices) have at least 2 computers. Therefore artifical lighting, glare problems, as well as internal gains of nearly 300 Watts per work place have to be considered in the design.

Measurements in the client's old office showed that most enmployees felt comfortable with a lighting level of ~ 100 Lux which was realized by taping opaque foils onto the windows. 30 Lux was felt to be even more comfortable, as opposed to the standard regulations of work places demanding 300 - 500 Lux at desk level.

Commonly constructed buildings that use artificial lighting all day have high internal gains, leading to an overheating of the rooms. This requires the installation of a cooling system. In addition, the room depths (8 - 12 m) prohibit the use of one-sided window ventilation (according to the ventilation regulations).

BASIC CONCEPT

It was the basic idea to give the building components several functions.

For instance:

- atrium: air and light duct, offering a climate between office room and outdoor
- floor: air duct and thermal storage as well as load-bearing structure
- facade: passive shading device and recreation area

Building shape:

Through these measures investment cost could be reduced. In addition the circle shape of the atrium with intermediate climate anticipates the general shape of the building - a circle. Thus the external facade area is minimized. This has two advantages: less erection costs, less heat losses. Moreover the glazing area is small compared to commonly used building designs (structural glazing etc.), again this has two advantages: less heat losses in winter, less heat gains in summer.

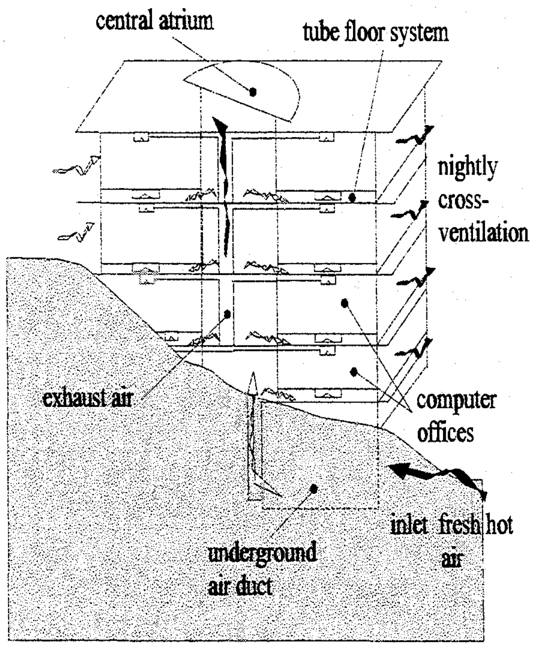
Daylighting:

Deep balconies and the overhang roof are used as fixed sun protection and prevent direct light coming into the work places. Therefore the problem of glare is reduced and a strong contrast can be avoided – which are important aspects for computer work areas. At the same time the structure with the core atrium provides lighting on both sides – i.e. indirect through the atrium – leading to an uniform illumination level.

Building services:

A local air supply is necessary for an entire room depths of up to 12 m. This is done by elements for fresh air which are placed below the fitted carpet. The ceilings have a thickness of 30 cm due to static and building physic reasons. Tubes with 10 cm diameter were put into the neutral zone of the ceilings. This method has no negative influence on the structural behaviour. These tubes are used - within some limits - as ducts for fresh air and electric services. They are positioned nearly radial round the atrium.

SUMMER VENTILATION CONCEPT



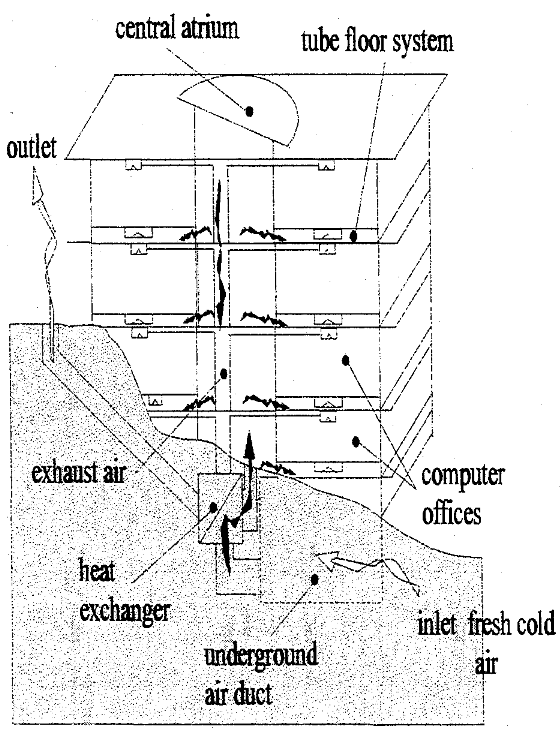
at day:

- solar gains of the atrium are blocked by an internal shading device. At top level warm air is collected and vented off by flaps.
- the overhang roof and large outstanding balconies serve as shading device for the windows on the south east to south west sides of the building.
- fresh air, pre-cooled by using an underground air duct is blown into the atrium.
- ventilators bring fresh air from the atrium through the double floor which is ventilated at night as well.
- exhaust air is directly expelled above roof.

at night:

- the atrium has a cross ventilation through ventilation flaps at floor and roof level
- cool air at night is conducted - naturally or supported mechanically - through the office zones and the double floor to activate the building mass as cold storage

WINTER VENTILATION CONCEPT



- cold fresh air is pre-heated by underground air ducts.

- warm air from the offices is used in a central heat recovery for pre-heating the fresh air coming from the underground air duct and going into the atrium
  (post-heating is possible).

- the air is sucked from the atrium into the double floor. By source ventilation it will be supplied to the offices.

- large wall heating elements allow a further room air conditioning.

Air ventilation:

Fresh air comes in through a concrete duct below ground level. Thus the air will be precooled in summer and preheated in winter by the earth. After passing the concrete duct and the heat exchanger of the heat recovery system the air is blown by ventilator into the central atrium. The atrium serves as manifold for the in-tube ventilators. These small ventilators suck the air from the atrium and blow it through the carpet into the office rooms. After use the exhaust air is collected under the ceiling and sucked by exhaust ventilators to the recovery system. After transferring the heat, the air is expelled on the roof.

INTEGRATED PLANNING

This concept was developed in discussions together with the architects and engineers in the fields of HVAC, building physics, structural and climate engineering and then settled with the client who worked very actively with the design team.

Nevertheless the client and the HVAC engineers had to be convinced of the ventilation system at first. To this end a scale-1:1-model of the air tubes in the floor was built, tested and demonstrated. Thus noise level, air flow rate and draught problems could be investigated in detail. The final product was accepted by all members of the design team and - most important - also by the client.

PREDESIGN WITH COMPUTER TOOLS

Parallel computer simulations were conducted to verify the expected thermal behavior of the building. Since effects like heat and cold storage in parts of the building are necessary functions, dynamic building load simulations were carried out. In the described project, the program package TRNSYS [1] was used because it allows to specify system components like ventilator and the heat exchange to underground duct in addition to a building simulation (with a cross ventilated floor). The engineer can also define any control strategy for shading, lighting and ventilation up to cross ventilation with fresh air at night.

The profiles of the various air temperatures in the rooms of the building allow to examine the function of the proposed concept and to make corrections. From this information guidelines for the architect and HVAC engineer can be obtained. The structural engineers must judge the influences of changing temperatures of the ceilings.

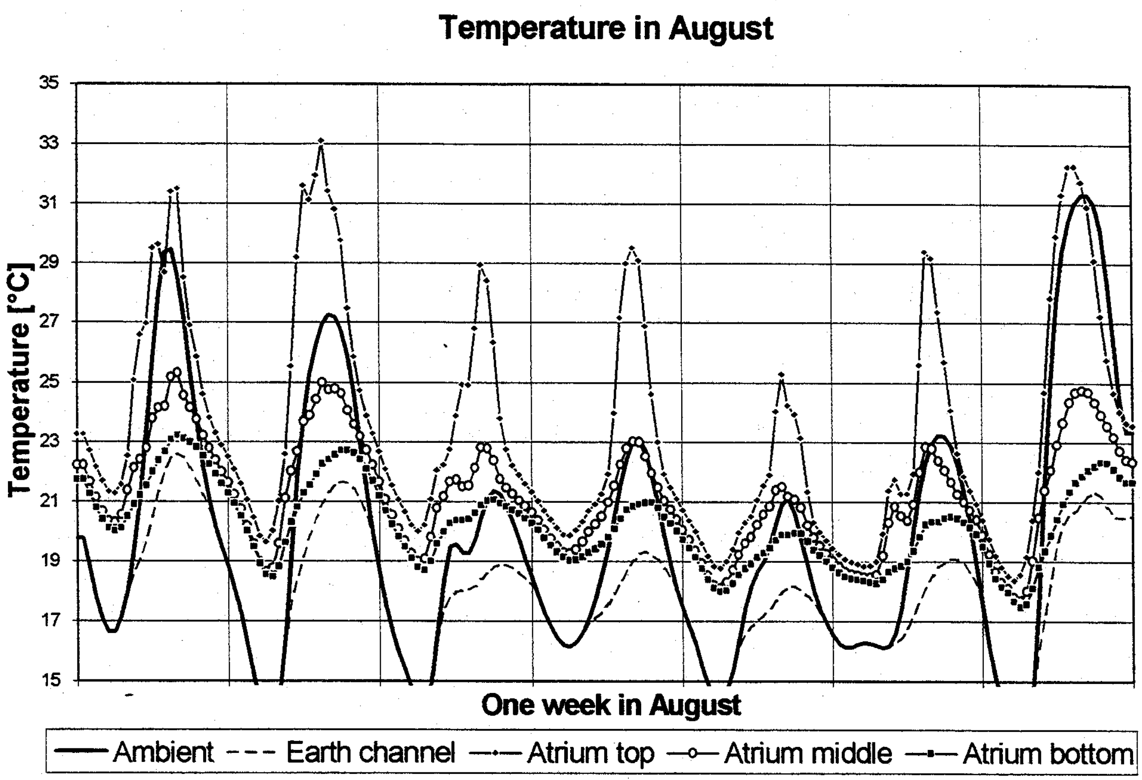
The daylight simulations were carried out with the program package ADELINE which has an interface to the thermal simulation package TRNSYS. Thus internal gains by electric light that depend on the amount of daylight can be considered and strategies for minimizing internal gains can be validated. The resulting heating- and cooling-demand show the client the future operating costs and allow a description of the economy of different building components (like glazing, insulation, ventilation).

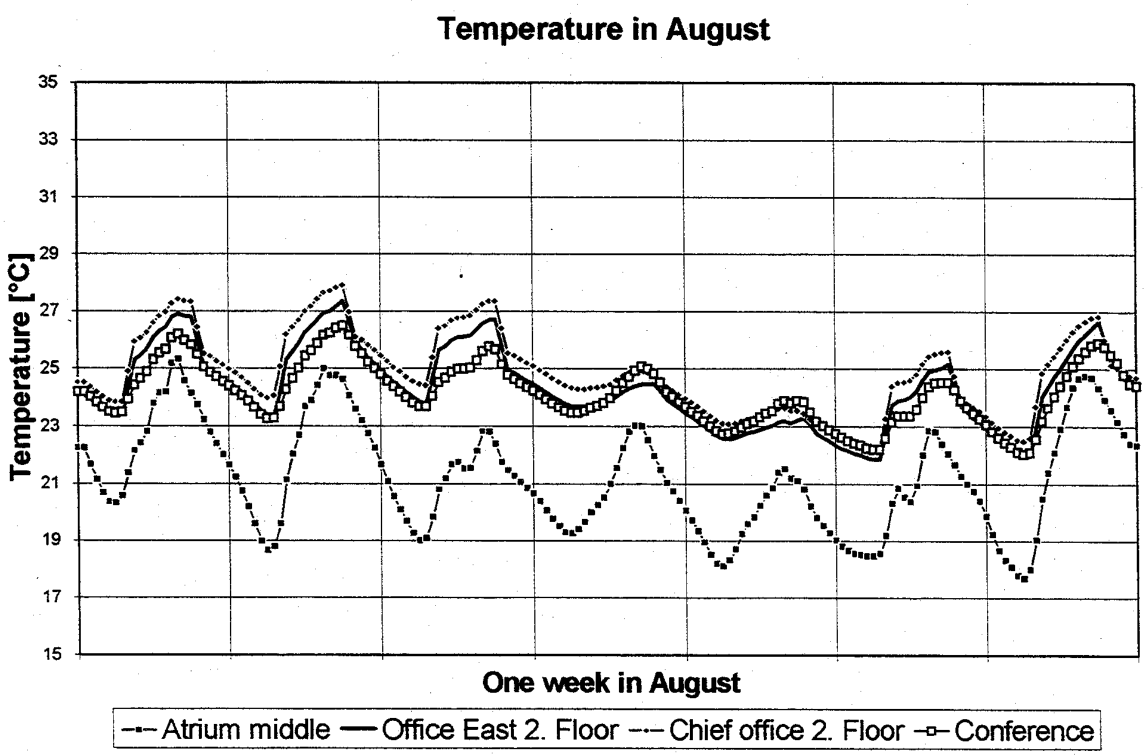
FINE-TUNING OF THE BUILDING DESIGN

After approving the draft building concept all members of the design team had to draw consequences for their own work area. The structural engineer, for instance, had to integrate the tube into the floors, i.e. into the iron support structure. The HVAC had to redesign the ventilation system etc. Since all planners had to consider technical and economic limits a real optimization process was conducted by all.

The minimization of the external surfaces and the insulation level of opaque walls (14 cm mineral wool), roof (16 cm foam-glass) and transparent building parts (windows U-value 1,3 W/m^{2}K) result in a heating load of 25 kWh/m^{2}a. This low value (30% below the actual regulation) is achieved by the building envelope, heat recovery of the exhausted air and to a smaller extent by increased internal gains. The heating period of the office building of DATAPEC is reduced to 6 months. The concept of double-use (building parts are used for air conducting) has a significant effect on the costs associated with the ventilation system (see economic consequences).

Fig.3/4: Profiles of the air temperature in August





REALIZATION

During the erection phase a lot of details for the new system components had to be considered. Since the components were unknown to the building people, there were many questions to answer. However this ensured a correct implementation of all new components.

Thus, after conclusion of the erection phase, the new system components (underground air duct, tubed floor) worked very well. At commissioning difficulties occured only with well-known components.

ECONOMICS

For HVAC the first estimation excluding cooling was 1.100.000 DM. The final total costs were 700.000 DM. However changes of the structural construction, underground air duct, tubed ceiling and increased planning requirements reduced the total investment savings for the client to 250.000 DM.

Although the investment costs were reduced, the design team's salary was not reduced as it would be demanded by engineering regulations. This was only possible since it was agreed before the start of the design phase, that the planning engineer would benefit, if the investment costs were below standard level. Ultimately the investment costs for heating, venting and air conditioning are only 5% of the total erection costs.

In addition the client benefits every year from reduced operating costs of the building which are now about 20.000 DM (at the actual energy price level)

DESIGN TEAM:

Architects: Kauffmann Theilig und Partner, Stuttgart. Project leader: W.Kergaßner

Structural planner: H. Steinhilber, Pfefferkorn und Partner, Stuttgart

HVAC: Engineering office Schreiber, Ulm

Electric: Heldt, Stuttgart

Building physic: Engineering office Horstmann, Altensteig

Climate concept: TRANSSOLAR Energietechnik GmbH, Stuttgart

REFERENCES

[1] M. Schuler, P. Voit, Th. Lechner, Simulationsprogramm TRNSYS, S. 10-12, Sonnenenergie 5/94

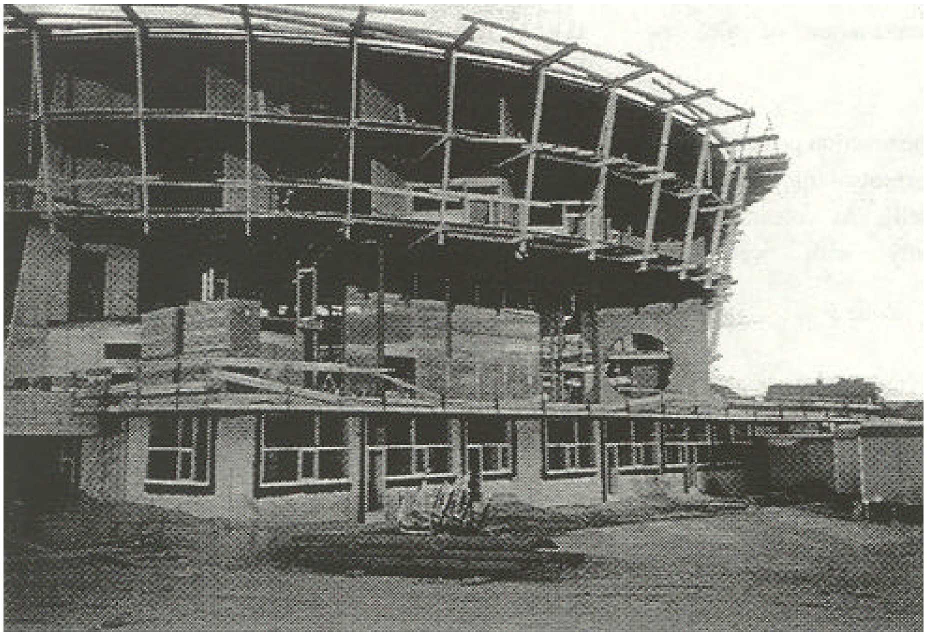
[2] M. Schuler, Kühlbedarf statt Heizwärmebedarf ?, Bundesbaublatt 3/94, Bundesanzeiger Verlag Bonn

[3] M. Schuler, Sonnenkollektoren zur thermischen Nutzung der Sonnenenergie, S. 725-728, Detail - Zeitschrift für Architektur und Baudetail, Heft 6/93

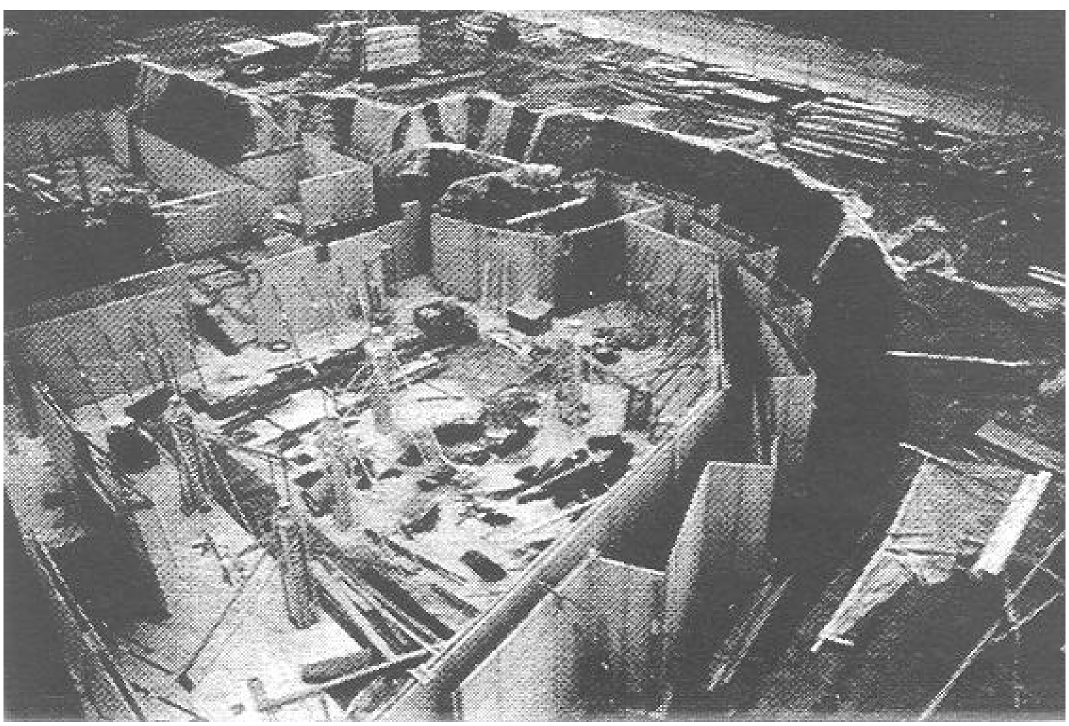
[4] M. Schuler, Gesamtenergiekonzept in Niedrigenergiegebäuden, S 119-120, Bund deutscher Baumeister, Architekten und Ingenieure, Landesnachrichten R-P/Saar 3/95

[5] M. Schuler: Entwicklung von Niedrigenergiegebäude-Konzepten in der Zusammenarbeit zwischen Architekt und Ingenieur, AIT - Die Zeitschrift für Architektur, Sonderheft "Intelligente Architektur 4/95, S. 68 - 71

View from south west with overhang roof and thermally seperated balconies (passive shading device).



Underground air duct in the foundation area (slope wall).



Atrium with intake air ducts and ventilation openings

Inserted ceiling shuttered with armouring and intake supply ducts (ventilation, electronic data processing)