Sick building transformed into a feelgoodbuilding

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ABSTRACT
As part of a graduation project, a typical 'sick' office building was subject to a retrofit R&D programme. It concerned a typical 1975 building with a sealed façade and a central climate control system with induction units. An interview of the some of the people working in the building showed that many suffer from SBS symptoms.

A survey and measurements were carried out to find causes for the building related symptoms. It was shown that both inadequate design and maintenance of façade and building service systems played an important role. A combination of measures was defined to improve the quality of the indoor environment. This list of required adjustments was taken as the basis for a total redesign of the building, its façade and its HVAC system.

The redesign needed to meet several requirements:

1. guarantee a healthy and comfortable work environment;
2. be environmentally friendly (energy and materials);
3. meet functional requirements of the organization occupying the building;
4. facilitate simple and easy maintenance (aimed at low cost).

The overall goal of the study was to find out if with a specific design a notorious sick building can be transformed into a healthy, comfortable but also energy/material and cost-efficient building.

INDEX TERMS
Renovation; Office building; Sustainability; Occupational health; Integration

INTRODUCTION
In the 1970s, many office buildings were constructed that nowadays could be described as 'sick'. They are either in need of a renovation or will eventually be abandoned and demolished. For keeping these buildings occupied in the future, it is essential to 'get rid of the SBS symptoms'. It will be even more effective to turn them into real feelgoodbuildings that people actually enjoy using.

One of the many examples of a 'sick building' is the main office of the Municipal Health Service Rotterdam in the Netherlands (see Figure 1). It is a typical building from the 1970s bearing influence of the energy crisis. It has a sealed façade and central climate control system with induction units.

Figure 1 Building of the Municipal Health Service Rotterdam, Netherlands.

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METHOD

Prior to the start of this project, the indoor environmental quality (IEQ) in the building was investigated according to a standard procedure (Boerstra and Leyten, 2000). A questionnaire among the people working in the building showed that a significant number of workers suffered from SBS symptoms. A survey of both the building and its building service systems and measurements revealed the main causes for the IEQ complaints in the building.

As part of a graduate programme, this building became the subject of a retrofit R&D programme that aimed at creating a more sustainable and more healthy ‘feelgoodbuilding’. The shortcomings in the present design as found during the IEQ investigation formed the fundamental for the redesign of both the building’s façade and the HVAC systems.

Various steps in the programme involved: (a) interviews with occupants; (b) finding the shortcomings in the design that created the SBS symptoms and the relatively high environmental load (partly by (c) pointing out the shortcomings with the highest priority; (d) Determination of healthy and sustainable measures; (e) creating several design solutions with these measures; (f) consideration of several solutions; and (g) creating a design proposition.

The redesign needed to meet several requirements. Not only should it guarantee a healthy and comfortable work environment, but it should also be environmentally friendly.

RESULTS

Research

The origin of the SBS symptoms was established by an investigation conducted prior to the research project (Raue *et al*., 2001). A survey of the building and its HVAC system showed that the building had 11 out of 16 known SBS risk factors (Boerstra *et al*., 1999, see Table 1). The highest priority for the redesign resulted from Raue *et al.* (2001) and addressed the design of both façade and building service systems.

Table 1 SBS risk factors present before and after the (planned) renovation (redesign)

	Risk factor	Before redesign	After redesign
1	Large number of workers per room (>4)	×	–
2	Lack of environmental control	×	–
3	Mechanical cooling	×	×
4	Humidification	×	–
5	Recirculation	–	–
6	Rotary Heat Exchangers	–	–
7	Copiers and printers close to workstations	×	–
8	Carpets and other fleecy materials	×	–
9	No separate smoking rooms	×	–
10	Central air inlets close to exhaust	–	–
11	Internal duct lining (insulation)	×	–
12	Absence of radiant heating	×	–
13	Change of building function	–	–
14	High internal heat load	×	×
15	High external heat load	×	–
16	Lightweight thermal properties	–	–

Interviews with occupants—amongst other things—showed that the organizational lay-out of the building gave functional problems. A problem was that the public part of the building was not located well (‘relatively far into the building’). As a result, many doors had to be locked all the time in order to keep strangers out of the offices. Another problem was that too little floorspace was available. Therefore, as an additional redesign requirement, it was decided that the renovated building should meet the spatial–functional requirements of the organization better.

A computer analysis (Hulsman and Dobbelsteen, 2003) on the environmental load of the existing building was conducted. This method used was based on van den Dobbelsteen *et al.* (2002). The results showed a high level of energy use due to heating and lighting. The analysis also showed that redesign could have a big impact on the environmental effect of the materials used. Thus, minimizing energy use and materials were also defined as important renovation themes.

The additional literature study resulted in a list of design measures that could improve the quality of the indoor environment and the sustainability of the building. This list was organized by distinguishing between health, sustainability and comfort. The main themes were: thermal comfort, air quality, light and view, acoustics, radiation, energy, materials, flexibility and lay-out. Extra emphasis was placed on the themes: air quality, light and energy. In the 'design-measures list', several measures were presented at distinct building levels (scales). These scales were: building, floor, room, detail and control. An example of this list regarding indoor air quality and the control of pollutants transfer is presented in Table 2. Such a list was made for every theme.

Table 2 Example from list of design measures for the health theme Air Quality with focus on controlling the transfer of pollutants to occupants

Building scale	Lay-out	Façade	HVAC	Interior finishing
Building	Temperature zoning		When necessary use safe/clean humidifiers	
Floor	Temperature zoning			
Room	Prevent high air temperatures from occurring		Heating and cooling by radiation	
Detail		Background ventilation at minimum 30–40 m^3/hp	Background ventilation at minimum 30–40 m^3/hp	
		Provide flush ventilation	Provide flush ventilation	
Control	Personal contribution	Personal contribution	Personal contribution	Create direct view for occupants on devices of personal control
		Demand controlled	Demand controlled	
		Maintain temperature in winter in case of sitting work at 20–21°C		

The design measure lists were used as a basis for a redesign of the building, its façade and its HVAC system. The different themes occasionally demanded conflicting solutions. For example, energy use prefers a minimal air change rate. In relation to air quality, this is not acceptable. In addition, other contradictions occurred—in relation to air quality, it is preferred to use a natural system for air inlet. The surroundings of the building do not allow this for the lower levels, however. The noise and air pollution levels are too high due to a nearby street with heavy traffic. In case of conflicts, the solution preferred from a health and comfort point of view was given priority.

Design
Within the possibilities of the existing bearing structure, a healthy and comfortable work environment was created by changing lay-out, façade and HVAC design. The redesign is based on simple but efficient systems that give the occupants freedom for personal control without causing chaos. Table 1 (right column) shows the origin of some adjustments; aimed at minimizing the number of SBS risk factors. Other adjustments followed the results of the 'design measures lists'. As mentioned before, special attention was given to the themes: light and view, air quality and energy use.

Building Lay-out
The new (renovated) building was better adjusted to its surroundings and to the occupying organization (see Figure 2). Public spaces were located near the main entrance, causing a more cohesive zoning of the public and personal spaces. This functional zoning also resulted in allowing functional temperature differences within the building. Further, a link with the surroundings was created by tuning the functional lay-out indoors to the sound and air pollution levels outdoors. This made it possible to open the façade at the upper levels and the backside of the building allowing for natural ventilation 'where possible'. Extra floor space was created by rearranging the workspaces and minimizing the floor space for building services.

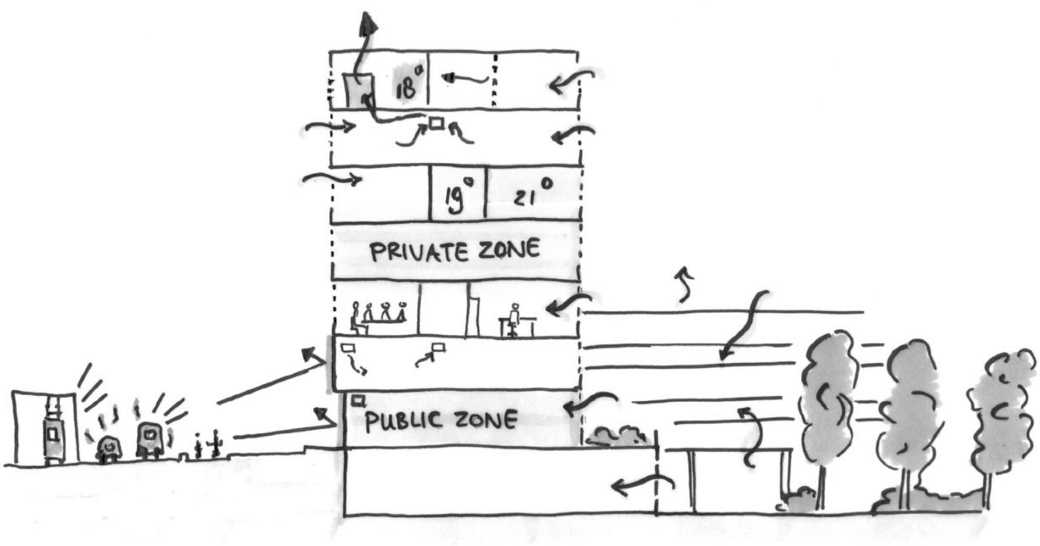

Figure 2 Relation between the building, its surroundings and the organizational lay-out, in the new, renovated situation.

Façade Design
The façade (Figure 3) plays an important role in both climate control and energy use. Next to insulation, a daylight strategy is introduced. This results in high and equally divided luminance levels inside. It is realized by introducing a light shelf that reduces luminance levels in front of the façade. Also, reflective surfaces are created to increase luminance levels around the window and prevent glare. For comfort and personal influence, louvers are integrated. Louvers are needed for sun protection but also for decreasing luminance levels in the office. The view is guaranteed by keeping the parapet at a maximum level of 90 cm. This daylight strategy is based on both comfort and energy use. Artificial lighting is thus restricted to a minimum.

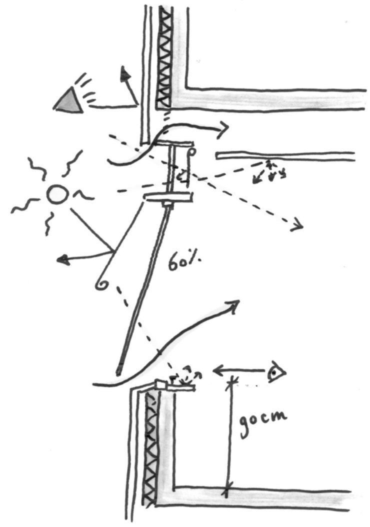

Figure 3 Façade design with daylight devices.

HVAC Design
The building is located in the centre of Rotterdam, which means the front side of the building has to deal with high sound and air pollution levels from the adjacent street. Natural ventilation has a high priority in creating healthy buildings but is not possible on the lower levels of this particular building. The upper levels, however, use a hybrid ventilation system with a natural air inlet and mechanical outlet. The air inlets provide for the right amount of background air and are demand responsive. For flush ventilation, the operable windows can be used. In the façade design, measures are taken to prevent draught and sound exposure (see Figure 4). The air is guided into the room by means of a special climate panel and mixed with the room air before it enters the work zone.

Heating and cooling is minimized by using the thermal mass of the building. This implicates the use of open ceilings. An open suspended ceiling was equipped with a low temperature heating and high temperature cooling system in order to heat both the incoming air and the workspace. A heat pump connected with an aquifer will provide for the green energy used for cooling and heating.

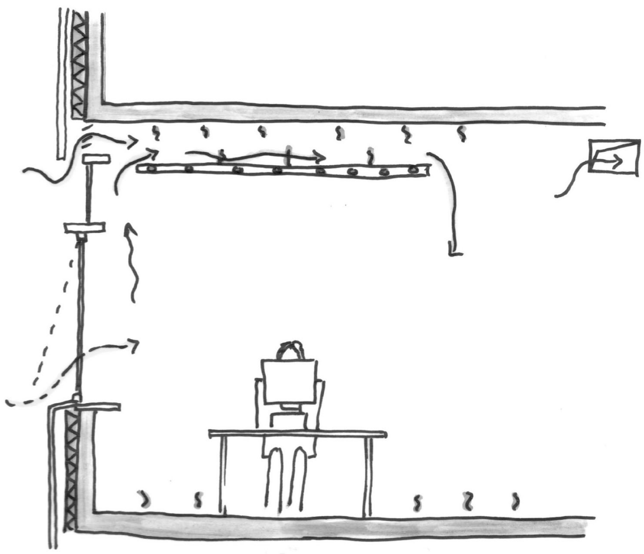

Figure 4 HVAC system of upper floors; use of thermal mass, natural air inlet and climate panel.

Personal Control
For maintenance and occupant comfort, the façade and HVAC system are kept simple but efficient. It has to be clear to the occupants what to do to create one's best comfort level. A building control system will have the overall control, but the

occupants can have their way by changing the ventilation rate, temperature, the shading system or the luminance levels.

DISCUSSION

An R&D programme for turning a ‘sick’ building into a ‘feel-good’ building is presented. It showed several design measures that individually have been proven in other projects/studies to contribute to health, comfort and sustainability. It also showed these measures can be joined into a design solution for an existing building structure. This study, however, did not result in a real-life design and this proposal for a feel-good-building was not actually built and tested. Therefore, it cannot be concluded that this study resulted in designing a feelgoodbuilding. Furthermore, in real life, there are more concerns than just health, comfort and environmental issues. Potentially, this study can hand out pointers and design aspects that can be included in a real-life design.

CONCLUSION AND IMPLICATIONS

As part of a graduation project, a typical ‘sick’ office building was subjected to a retrofit R&D programme. The origins of the SBS symptoms and relatively high environmental load were determined. A combination of measures was defined to improve the quality of the indoor environment and the environmental load. This list of required adjustments was taken as the basis for a total redesign of the building, its façade and its HVAC system. The overall goal of the study was to find out if with a specific design a notorious sick building can be transformed into a healthy, comfortable but also energy/material and cost efficient building. Potentially, this study can hand out pointers and design aspects that can be included in a real-life design for a sustainable feelgoodbuilding.

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REFERENCES

Boerstra, A.C. and Leyten, J.L. (2000). Investigation of IEQ. *Proceedings of Healthy Buildings 2000*, Espoo, Finland, Vol. 1, pp. 35–40.

Boerstra, A.C., Leyten, J.L. and Kurvers, S.R. (1999). Diagnosing problem buildings: the risk factor approach II. *Proceedings of the International Conference on Indoor Air Quality and Climate—Indoor Air ‘99*, Edinburgh, Vol. 2, pp. 278–282.

Hulsman, L.P. and Dobbelsteen, A. (2003). Environmental load of the Municipal Health Service Rotterdam (unpublished; in Dutch).

Raue, A.K., Gelton, C.J., Verlinde, M.J.H. *et al.* (2001). Indoor Environmental Quality Research on the Municipal Health Service Rotterdam, Rotterdam, The Netherlands (unpublished; in Dutch).

van den Dobbelsteen, A.A.J.F., van der Linden, A.C. and Ravesloot, C.M. (2002). Defining the reference for environmental performance. *Proceedings of International Conference on Advances in Building Technology*, Oxford, UK, Vol. II, pp. 1509–1516.