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Creating Healthy and Energy Eficient Buildings : Lessons learned from the HOPE Project

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Creating Healthy And Energy-Efficient Buildings: Lessons Learned From The Hope Project

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ABSTRACT

Within the European research project HOPE, 97 apartment buildings and 67 office buildings - of which approximately 75% have been designed to be energy-efficient, and half of them are indeed - were investigated using checklists addressing the building characteristics and questionnaires to the occupants asking their perceived comfort (thermal visual, acoustical and indoor air quality) and health (sick building syndrome and allergies). The analysis of the collected data, together with experience gained from former projects and literature lead us to present guidelines for creating healthy and energy-efficient buildings. These guidelines are presented together with the rationale and facts on which they are based.

INDEX TERMS

Buildings, indoor environment, field study, guidelines.

INTRODUCTION

The salient features of high quality buildings include indoor air quality (IAQ), thermal comfort, visual and acoustic characteristics, as well as low impact on the environment. Within the HOPE research project, the following definition has been adopted *(Bluyssen et al., 2003)*:

A healthy and energy-efficient building does not cause or aggravate illnesses in the building occupants, assures a high level of comfort to the building's occupants in the performance of the designated activities for which the building has been intended and designed, and minimises the use of non-renewable energy, taking into account available technology including life cycle energy costs.

In some case, especially when appropriate studies are not performed, there may be a conflict between strategies to reduce energy use and to create healthy buildings. However, studies and existing high performance buildings show that it is possible to realise healthy, comfortable and energy efficient buildings, named below High Quality or HQ buildings.

RESEARCH METHODS

A multi-disciplinary study was performed in 164 buildings (97 apartment buildings and 67 office buildings) of which approximately 75% have been designed to be energy-efficient, and 50% proved to be so. This investigation has been carried out in nine European countries. Three kinds of screening methods were used*(Bluyssen et al., 2003)*; which are listed in another paper in this conference(Roulet et al., 2005). These studies provided data supporting the guidelines presented below.

Collected data (about 420 figures in each office buildings and 550 in apartment buildings) are interpreted using basic statistics: splitting buildings into groups and looking at significant differences between means for various characteristics, looking at significant correlations between variables in the building populations (Johner et al., 2005), and using a multicriteria analysis method to sort the best and the worst buildings for their performance in perceived comfort, declared health and energy use (Roulet et al., 2005).

RESULTS

From the observations and measurement performed within the HOPE project, a series of recommendations for improving the performance of new and existing buildings are published in a report. This report is organised according to main issues such as indoor air quality, thermal comfort, etc. It is written in a positive, performance based way to address designers, architects, and decision makers. The document (in English) delivered as a draft in February 2005 will be later published in several languages by HOPE participants. Its content is as follows:

Introduction

After having given a definition of high quality building, the introduction presents the reasons for increasing the number of high quality buildings, and presents the work performed within the HOPE project.

Overall design

Most of the best buildings investigated within the HOPE project were indeed designed to be HQ buildings. The intentions of the building owner and of the designer have the greatest influence on the quality of the building. This chapter emphasises two important design principles for HQ buildings:

(a) prefer, as far as possible, passive (architectural) to active (technological) ways to ensure comfort in buildings and

(b) design for the building user. In particular, the user should be able to adapt his indoor environment to his needs.

Layout of occupied space

There is a strong correlation between the occupant's well being and the layout, the decoration and the cleanliness as perceived by the occupant.

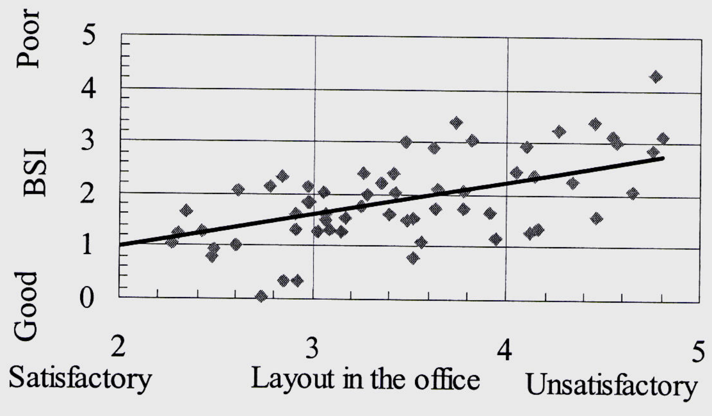

***Figure 1**: There is a strong correlation between the BSI and the layout as perceived by the occupant. BSI gives the average number of symptoms per occupant.*

Surveys also give (again) evidence that open offices are, in general, less healthy and noisier than cellular ones (**Figure 2**). As could be expected, the lack of privacy increases with the number of occupants of the same room. In other words, special care should be given to occupant's well being in open offices.

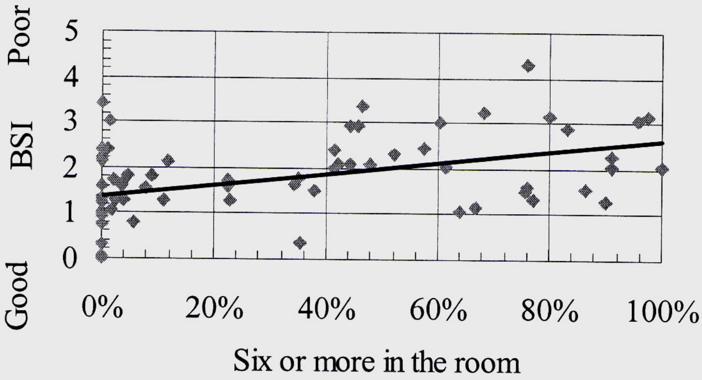

***Figure 2**: Correlation of BSI with the percentage of occupants in the building having six or more neighbours in the same room.*

Ensuring thermal comfort

This chapter presents passive ways to improve thermal comfort, in particular by making use of passive solar gains in winter, passive cooling in summer, and pre-heating or cooling air using heat recovery or underground heat exchangers. Emphasis is given to efficient solar protection, since there is now a tendency to design fully glazed buildings without efficient solar protections. Too high temperatures (hot) in summer decreases the perceived productivity as shown in Figure 3

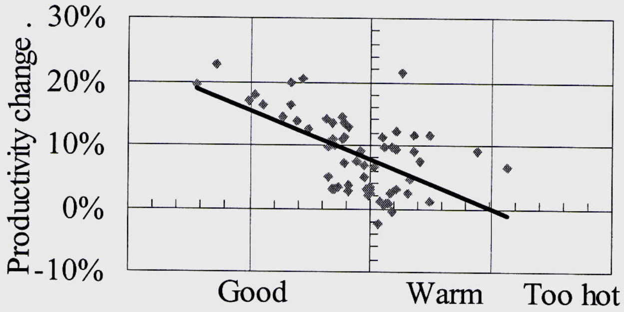

Figure 3: Perceived productivity and temperature in summer.

Good air quality

Most of the audited buildings had nearby potential sources of pollution such as busy road (69%), car parking (59%) or attached garage (24%). These do not seem to have a clear negative effect on occupant's well being. However, in the measurements carried out in the detailed field investigations, the presence of VOCs or dust was shown to be present in several buildings close to pollution sources and in which appropriate measures were not taken.

As seen in the AIRLESS project (Bluyssen et al., 2003), most pollution sources are internal, some of them in the air handling system. The recommendations published by the AIRLESS project to reduce them together with improving the energy performance are given. It can be seen, from the HOPE audit results, that these recommendations seem very efficient, as shown in **Table 1**

Advantages and inconveniences of mechanical and natural ventilation systems are presented, together with some evidence that occupants prefer natural ventilation wherever possible, as shown in **Table 2**. It can also be seen that, on the average, the energy performance do not differ significantly among buildings with these different ventilation strategies, even if, in principle, mechanical ventilation could save energy with heat recovery.

***Table 1**: BSI, perceived IAQ and comfort as well as energy use in buildings equipped with mechanical ventilation or air conditioning fulfilling or not fulfilling the AIRLESS recommendations.*

		Residential buildings				Office buildings			
		Yes	Partly	No	P	Yes	Partly	No	P
Ventilation	Number	3	10	4		12	10	7	
	BSI	0.55	1.85	1.2	0.5%	1.6	1.9	2.6	1%
	IAQ	2.34	3.12	2.73	0.4%	3.3	3.9	4.4	0.01%
	Comfort	2.3	2.8	2.6	2%	3	3.4	3.6	0.1%
	kWh/m²	109	202	238	NS	275	190	211	NS
Heating & Cooling	Number	3	8	3		9	10	8	
	BSI	0.54	1.88	1.33	2%	1.7	1.7	2.7	0.2%
	IAQ	2.29	3.11	2.86	2%	3.4	3.8	4.3	0.6%
	Comfort	2.3	2.8	2.7	9%	3	3.3	3.6	4%
	kWh/m²	109	205	292	2%	276	198	207	NS

P is the probability that the differences result from chance. NS means that the difference is not significant.

***Table 2**: BSI, perceived IAQ and comfort as well as energy use in residential buildings ventilated with various systems.*

	BSI	IAQ	Comfort	kWh/m²
Natural	0.78	2.85	2.96	157
Mechanical	1.47	2.96	3.12	206
Hybrid	1.00	2.65	2.99	141
P	0.21%	NS	NS	NS

Lighting and noise

Principles of day lighting are presented, together with basic principles of efficient artificial lighting design. Ways of protecting the occupant's against outdoor and indoor sources of noise and to improve the acoustical ambiance are given, together with HOPE results showing the effectiveness of some of these measures.

Energy and well being

Half of the buildings audited within the HOPE project were chosen for being designed to have a good energy performance. The annual total delivered energy use divided by the gross heated floor was used as an indicator of the energy performance. Other indicators such as final energy use per heated floor area, per person, per building volume, etc. could be used. The conclusions will not change much by using these other indicators.

Figure 4 shows the frequency and cumulated distributions of the energy performance indicators in the audited homes and office buildings. It should be noticed that these distributions are not representative of the European building stock, since the sample is biased by the selection of low energy buildings for half of them. The median value for apartment buildings is 140 kWh/m² and 200 kWh/m² for office buildings. Significant differences are found between the two groups of buildings that use less or more than these median values. Some of these differences are reported in **Table 3**.

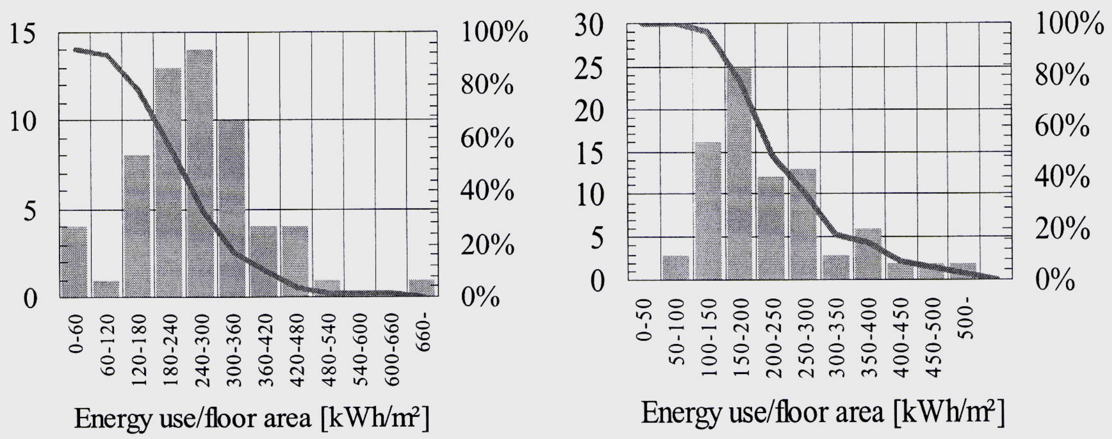

***Figure 4**: Distribution of the energy performance indicators in apartment buildings (left) and office buildings (right)*

***Table 3**: Some differences between "low" and "high" energy buildings in the HOPE sample. The difference is considered as significant if P< 5%*

Characteristics	Mean values for "low" energy	Mean values for "high" energy	P
BSI in apartment buildings	0.98	0.86	16%
BSI in office buildings	1.95	2.11	2%
Comfort overall in offices in Summer (1-7 scale)	3.21	3.47	2%
Comfort overall in offices in winter (1-7 scale)	3.08	3.26	6%
How comfortable is your home? (1-7 scale)	2.97	3.22	0.2%

On the average, low energy buildings are perceived as more comfortable than other buildings. Also low energy office buildings seem healthier than high energy ones. The same difference is not observed on apartment buildings, where there are slightly more symptoms in low energy buildings. This difference is however not significant. There are of course healthy and comfortable buildings that use much energy, and also low energy buildings that are neither healthy nor comfortable. However, there are, within the HOPE building sample, several low energy buildings that are also perceived as healthy and comfortable (Roulet et al., 2005).

It should also be noticed that perceived health does not give a full insight in the "healthiness" of a building. Some building characteristics (presence of asbestos or radon, VOC, etc) could be dangerous fro health but not lead to SBS. Within the HOPE project a method for such a health hazard assessment has been developed. This health hazard assessment tries to give a hint if a given hazard is present or possibly present (Maroni et al., 2005).

Problems observed in audited buildings (Do's and don'ts).

In this chapter, the problems observed in audited buildings are listed, together with their possible consequences on energy use, comfort and health, as well as ways to fix these problems.

DISCUSSION

There are many publications in the literature providing guidelines to improve the indoor environment quality and the energy performance (Maroni et al., 1995; Roulet, 2004; Seppänen et al., 2002)). The 50 pages booklet presented here differs from these by giving statistical evidences supporting the guidelines. These evidences are, strictly speaking, valid only for the type of buildings audited within the HOPE project. However, most of the recommendations given in the booklet are well known, and could as well be valid for other types of buildings on other continents.

CONCLUSION AND IMPLICATIONS

Healthy and comfortable buildings do not necessarily require much energy, and can have a limited impact on the environment. Smart managers, architects and engineers construct and operate buildings in a way that both good indoor environment and low energy consumption can be achieved. Good design is essential to achieve these objectives. By contrast, expensive measures to improve the indoor environment are sometimes counterproductive: even when technical requirements (temperature, air flow rates, etc.) are met, occupants do not feel well.

The EU Directive on energy performance in buildings (Council, 2002) requires that "*The measures further to improve the energy performance of buildings should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness. They should not contravene other essential requirements concerning buildings such as accessibility, prudence and the intended use of the building.*" Energy savings should not be achieved to the expense of poor indoor environment, since this is not only at the opposite of the purpose of buildings, but would also result in a bad perception, and may generate unexpected waste.

The existence of buildings that are healthy, comfortable and have a good energy performance, as well as the better comfort and health shown on the average by low energy buildings shows that the apparent conflict between comfort and energy use does not, in fact, exist.

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