505: Sick Building Syndrome in a University Building – An Educational Survey

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Abstract

Sick Building Syndrome (SBS) was identified and defined some 30 years ago and has been investigated since then, yet recently designed and constructed buildings seem to disregard both the phenomenon and the significant body of work that documents it. A Post Occupancy Evaluation (POE) study was undertaken in one such university building in Israel, combining offices and laboratories. A review of plans and building shows basic flaws in decision-making and design, and lack of POE. Many of the problems identified by a simple walk-through are indicative of the design flaws, yet seem to have gone unnoticed by architect and owner alike. Furthermore, the design of the specific building and its details prevent rather than encourage it to take advantage of its location in an arid environment, a fact that promotes excess energy usage without necessarily providing a comfortable indoor environment. The results of measurements, surveys and interviews presented here are the outcome of an educational exercise undertaken with a group of graduate students.

Keywords: architectural design, energy, hot-arid climate, indoor environment quality, thermal comfort

1. Introduction

Health and well-being of building occupants are directly dependent on and affected by architectural design, which defines to a great extent the Indoor Environment Quality (IEQ), Indoor Air Quality (IAQ), and the thermal, visual and acoustic comfort of occupants, in turn affecting their productivity. Faulty design leads to Sick Building Syndrome (SBS) and Building Related Illness (BRI), causing discomfort, displeasure, sickness and related absenteeism [1,2]. These were first identified in the late 1970s following the first oil crisis and subsequent rise in fuel prices, which led to attempts to air-tighten buildings in order to conserve energy. As a result, many building types, and especially office, hotel, public and educational buildings became totally dependant on artificial HVAC systems not just for their internal conditioning but also for the provision of outdoor (often mistakenly branded “fresh”) air, i.e. oxygen. Dependence on such systems allowed a parallel change in the plan depth of the building, since windows were not necessary any more for outdoor air supply or for lighting, the latter achieved by extensive artificial lighting systems [3].

IAQ in such buildings tends to be problematic, and this is an understatement. The continuous use of poorly maintained mechanical HVAC systems and the attempt to lower operation costs carry with it them the unavoidable concentration of dust, mold, and bacteria, as well as the circulation of such together with odors, smoke, allergens, pathogens and poisons from one part of the system to another. *Legionella pneumophila, Penicillium* and *Stachybotrys chartarum* are but a limited sample of a long inventory of these [3]. Independent studies of HVAC-operated buildings have shown that SBS occurrence is by far higher in such as opposed to naturally ventilated, free-running buildings [4,5].

IAQ is assessed according to various parameters, among them thermal [6], visual [7] and acoustic comfort [8], pollutants concentration (such as benzenes and forlmaldehyde), Volatile Organic Compounds (VOCs), gases including CO, SOx, NOx and O3, and odors [9].

It is common to identify SBS with various symptoms or combinations of these, which often point to the sources of the problems. Such symptoms include inflammation of eyes and respiratory system, headaches and tiredness, inability to concentrate, nausea etc [10]. The disappearance of these symptoms after occupants leave the building, or during weekends and vacation (when complaints relate to workplaces) is typical of SBS and differentiates it from similar symptoms resulting from different reasons. As a result of such symptoms workers leave frequently their workstation, are often absent from work, and their productivity drops. Such low productivity, sick leave, and absenteeism have significant economic implications [11], and possible lawsuits for compensation demanded due to long-term ill-health effects can reach significant sums.

SBS symptoms can be often identified through poor thermal and visual comfort. It is not uncommon for such symptoms to be the result of psychologically induced discomfort, a function of perceived comfort and perceived control of one’s immediate environment. These may result from the physical properties and characteristics of a building and its details, such as lack of eye contact with the outdoors, and lack of openable windows [12,13]. There are differences and variations between different gender and age groups, but a growing body of knowledge points to the fact that well-being and productivity are improved when personal control over one's immediate environment is restored [14,15].

Most of the already published research in this field deals with buildings in high latitude cold regions [13] or hot and humid ones [6]. However, little information exists on hot arid regions, and this survey aims at beginning a discourse in this direction, stemming from the belief that unless POE is established as one of the necessary building-related disciplines, new buildings will eventually become unoccupiable due to their IAQ problems, total dependence on HVAC and other artificial IEQ control systems, and rising energy prices.

2. A hot-arid case study

It is usually assumed that buildings in hot-arid regions should be airtight and air-conditioned, especially if they are office buildings or research facilities. This assumption cancels *a priori* the possibility of free-running buildings, or even the possibility of partially naturally ventilated and conditioned buildings. The implications of this are economic, operational, and functional.

The building surveyed and presented in this paper is a university building, housing offices, labs and assorted facilities. It is located on the main campus of the Ben-Gurion University in Beer-Sheva (31.15ºN, 34.48ºE, 270m above MSL, 45km from the Mediterranean coast), capital of the Israeli southern Negev Desert. Its construction completed in Oct.2000, it is among the latest generation of university facilities aiming at upgrading not just working conditions, but also the university image. The specific building was chosen because of certain complaints that were made by its users, but can easily be considered indicative of many similar facilities in Israel and abroad.

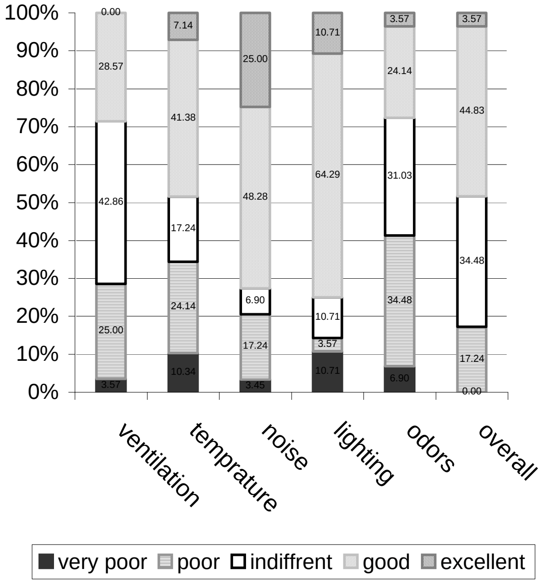

Fig 1. Comfort levels of ventilation, temperature, noise, lighting, odors and overall comfort

The building is an L-shaped plan, which, together with an adjacent building by the same architect and of similar design and function, enclose a long and narrow courtyard. The eastern, shorter (4 storeys and basement level) wing includes offices in the eastern side, with labs and meeting rooms in the western side of it. The southern wing (5 storeys and basement level) houses labs in its southern part and faculty offices in its northern part. Materials include exposed concrete walls, aluminium window frames and significant parts of the facades fully glazed. Most windows in labs and administrative staff offices are non-openable. Fenestration exists in all orientations, but it is important to note the many windows in the eastern façade are designed so that they face north-east.

3. Methods

It is often claimed that a well-prepared questionnaire may provide some 80% of the information needed in a POE study. Since this survey was conducted as part of an educational module on modern bioclimatic design, students were referred to various standard questionnaires and were asked to prepare drafts, which were discussed in class and merged into the one used during the survey. This included registration of indoor climate data, observations, and rating by the interviewees of various parameters on a five-degree scale, from "very poor" to "very good". An additional tool often disregarded as "not scientific" is a "walk-through", a critical observation of various building and design parameters and problems expressed physically and behaviourally (such as *ad hoc* alterations in working spaces).

All of these were coupled with spot measurements of air temperature, relative humidity, light intensity and noise, all taken at the workstation of each one of the interviewees, in order to compare visual and thermal quality perception of the occupants with the monitored data.

Interviews were conducted in laboratories, administrative and faculty offices on three typical storeys and the basement level. A total of 29 occupants (16 male and 13 female), appr. 50% of the daily average number of occupants, participated. The survey was conducted in Dec.2005.

4. Results

28% of the interviewees complained about the ventilation; 42% were indifferent to it, but 40% of the interviewees found the odors condition to be "poor" and "very poor". 41% found the temperature "good", and lighting was considered "good" by 64%. The overall building IEQ was considered "good" and "excellent" by 48% of the

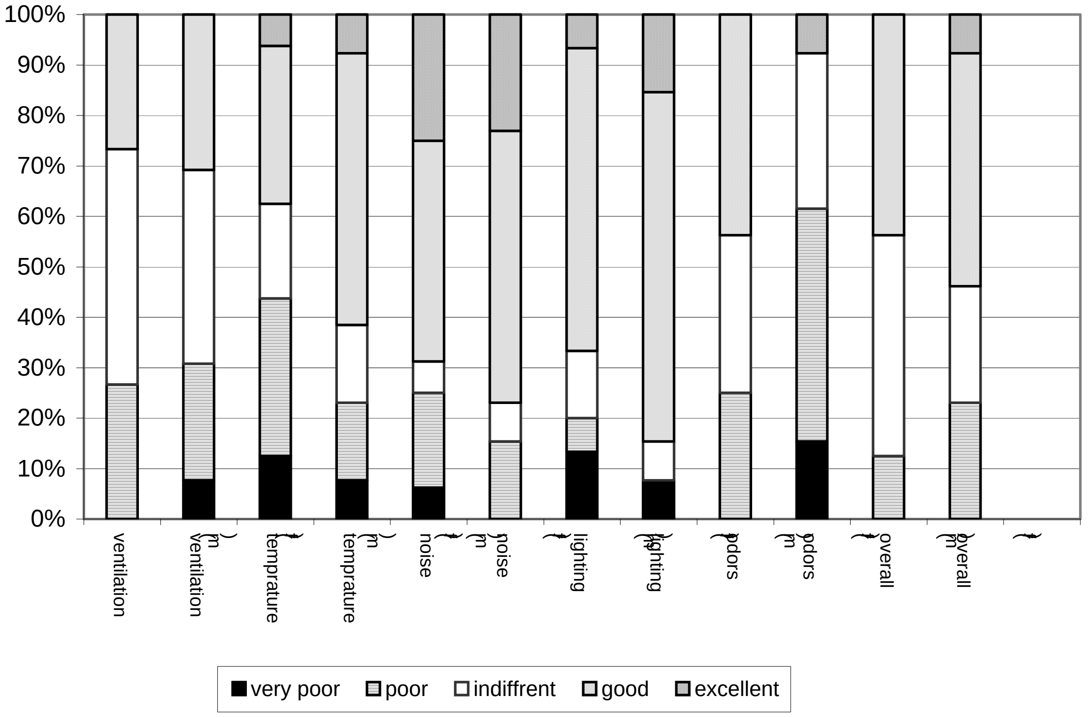

Fig 2. Comfort assessment of male and female interviewees

interviewees (Fig.1). 37% of male interviewees considered temperature to be “good” or “excellent”; the same assessment increases to 60% with female interviewees. Lighting is also considered “good” to “excellent” by 56% of male interviewees and by 84% of female interviewees. The difference between genders is especially pronounced in the assessment of odors: 56% of male interviewees rate this parameter as indifferent or below, compared to 92% of female interviewees (Fig.2). In general, in private – faculty – offices, answers indicating good levels are higher than in non-private –administrative staff – offices, and in laboratories, with an exception in lighting levels, with “good” and “excellent” levels being lower in private offices (20% difference). The biggest discrepancy was identified in overall comfort levels: in private offices 69% rated conditions as “good” and “excellent”, whereas in the rest of the spaces this assessment drops to 31% (Fig. 3-4).

Forgiveness Factor (indicating the ratio of the overall comfort score to the average of the individual overall air quality, temperature, noise, and lighting scores; with a factor >1 deemed more forgiving and <1 less forgiving) was calculated for male and female interviewees and for private and non-private rooms, and laboratories. According to the results, female occupants tend to be less forgiving than male. People working in laboratories are the least forgiving whereas those working in private offices seem to be more forgiving.

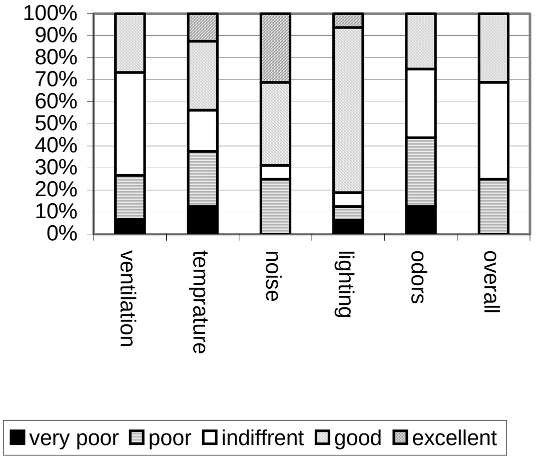

Fig 3. Comfort assessment of in non-private rooms and in laboratories

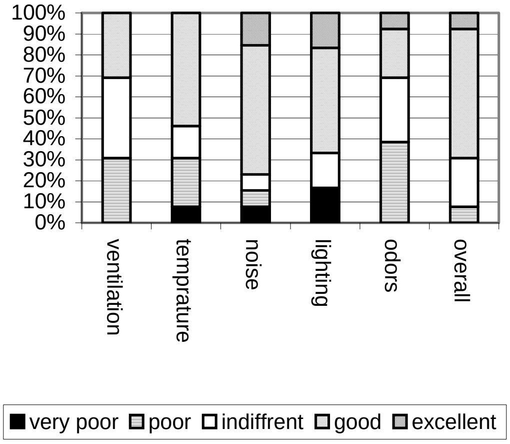

Fig 4. Comfort assessment of in private rooms

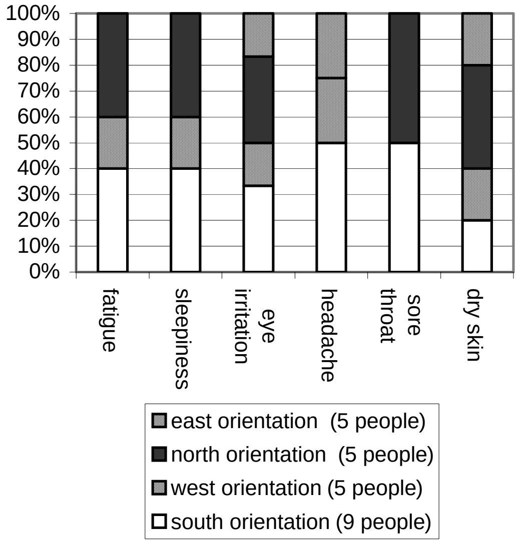

Fig 5. SBS symptoms according to space location horizontally (façade orientation)

Table 1. Forgiveness Factor

Female	0.957997
Male	1.051085
Laboratories	0.894832
Non-private off.	1.047774
Private off.	1.153412

5. Discussion

Despite the relatively small number of interviewees, the results may be considered indicative and representative of the general relation of occupants toward their working environment. The interviewees included senior and junior academic, as well as technical and administrative staff, and research students (master's and doctoral), thus spanning ages between late 20s and late 50s. A walk-through that preceded the measurements and surveys indicated air quality problems, not least due to visible mould concentration on HVAC outlets and return air openings, moisture-caused patches on acoustic ceilings, and condensation-induced mould on aluminium window frames, indicating lack of thermal brakes. These were referred to in the interviews held with the building occupants. A general discontent was indicated by the IAQ, and anecdotic evidence was mentioned, including the fact that since the building was occupied two senior staff members died of cancer (no evidence was produced to suggest any relation between the two, and the time frame seems to make such a connection impossible, but the fact that building occupants make this connection indicates there is certain discontent with the building, creating psychological problems, to say the least).

To this general perception contribute additional parameters. For one, the central HVAC system leaves little room for individual control. The air temperature measured in most spaces during the survey ranged between 22-25ºC. Considering the fact the survey was undertaken in December, and the ambient temperature was less than 13ºC, it seems that the building is overheated, causing unnecessary energy use and expenditures, while causing relative discomfort in most spaces. Using the adaptive model algorithm presented by Nicol and Humphreys [16] for free-running buildings (as opposed to ASHRAE standards):

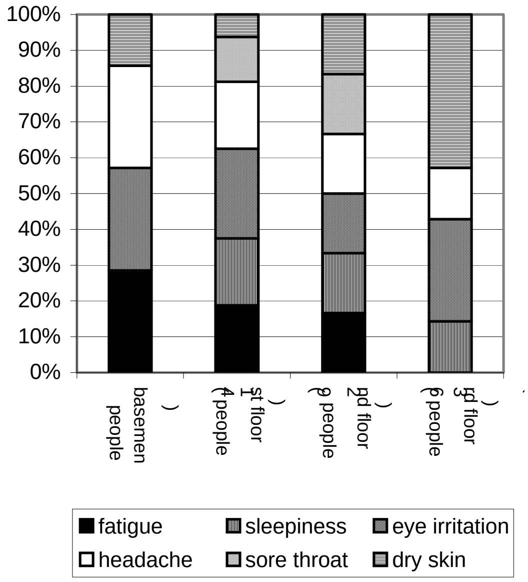

Fig 6. SBS symptoms according to space location vertically (storeys).

$$T_c=13.5+0.54T_o$$

where T_c is the calculated comfort temperature and T_o is the monthly ambient average, the comfort temperatures for the months of December (the month of the survey) (T_{oDec}=13.8), January (T_{oJan}=11.2) and February (T_{oFeb}=12.6), usually the coldest months of the year, would be 20.9, 19.55 and 20.30 respectively. These are between 3-5ºC lower than the measured indoor temperatures. This means that unnecessary energy is invested to heat indoor spaces to uncomfortably high temperatures, as reported by the people present during monitoring. This may also explain the discrepancy between male and female occupants, the latter usually preferring higher air temperatures.

Similarly, relative humidity measured indoors was in the range of 20%, which may be considered low for indoor spaces, and seems to be in accordance with complaints of eye, nose, throat and skin irritation, as well as headaches.

A significant amount of the windows in the labs, all of them south facing, were covered with paper sheets, cardboard and other makeshift shading devices. Subsequent visits have shown the situation has not change. These windows are mostly narrow and tall. The external fixed shading devices provide very little shading, esp. in winter when the sun is low and in the southern part of the sky dome, entering the lab space from appr.

09:00 to 15:00. Offices, esp. those of the secretarial staff, are located in the eastern wing of the building, and have large east-facing windows, with no external shading. Glare is one of the major problems in these spaces, and the repeated attempts to treat them (Venetian and rolling blinds) indicate the need for solutions integral to the design process, explicitly lacking here.

The overall fenestration issue is also of interest. Certain working and office spaces have been located on lower levels, some of them being partly underground in relation to the building access way, but having high windows exposing them to the passers-by. Users of such spaces were observed to show signs of uneasiness, often peeking towards the windows. Similarly, several offices have fully glazed facades, floor to ceiling, thus resembling an exposed fishbowl or terrarium, jeopardizing privacy. In all such spaces female employees adopted a sideways sitting posture visible from outside the building, with the lower part of the body rotated in relation to the torso. Such posture was almost dictated by the furniture arrangement in the room if one wears a skirt, and seemed to be more than uneasy or uncomfortable. Though no direct complaints were registered, it is assumed that such working conditions have a negative influence on the overall time spent by the occupants in such spaces.

High levels of odors were observed in the laboratory spaces despite the existence and use of chemical hoods, but no measurements of VOCs were made during the survey. However, a senior faculty member working in the building had monitored VOCs in it during the first occupation stages, and stated in a private communiqué (March 22, 2005) that “odor problems in the building are common, well-known to everyone in the university, the administration knows what the problem is, but nobody wants to do anything about it.” His comments refer to the ventilation system of the building drawing air for the chemical hoods through the building corridors, office spaces and eventually other lab spaces in which the hood ventilation is not operated at the same time. Additionally, exhaust chimneys on the roof (inc. those of the lab hoods) seem to be positioned upwind from the outdoor air intake openings, thus reintroducing air exhausted from the labs back to the building’s ventilation system.

6. Conclusions

It is obvious that certain design features of the building were based on basic lack of understanding of the environmental parameters vis-à-vis the specific building’s functional needs. Such are the windows in both lab and office spaces, obviously designed for aesthetic reasons, but causing glare and overheating, as well as lack of privacy. It is also obvious that various design decisions were not made on the base a full consideration of all the parameters. Such is the location of outdoor air intake on the roof - high above traffic pollution level, but close to indoor air outlets. It is the claim of this paper that unless POE is established as a standard procedure following the commissioning of buildings, the change of design practices so much needed to adapt buildings for energy conservation at a time of climatic uncertainty cannot be achieved. In climatic regions such as the one described here, where free-running buildings can operate with little or no conventional energy input for significant parts of the year, this may be regarded as a major design flaw.

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