Architectural education for sustainable design A proposal for improving indoor environment quality

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ABSTRACT: Buildings should be comfortable and healthy. They are a shelter for their occupants and should not be a source of problems. The architect widely influences the indoor environment quality by his design,. Ensuring a good indoor environment through appropriate architectural measures is one of the stakes of sustainable architecture. For that purpose and for several reasons, constructive measures are preferred to technical ones.

It is proposed, either through lectures, conferences or, better, by integrating this issue into workshop activity, to make students in architecture aware of the issue, to show them the sources and effects of various contaminants, including the conditions favourable to the growth of unhealthy micro-organisms. Emphasis should be given on the influence that design options have on indoor environment quality, addressing their positive or negative effects on thermal comfort, air quality, lighting, noise protection and acoustic comfort.

This paper presents the stakes and aims of such education, together with four years experience in this issue at the EPFL.

Keywords: buildings, comfort, well-being, architecture, education

1 INTRODUCTION

Building design should ensure a good indoor environment to its occupants. Vitruvius, the often-quoted Roman architect, said that architecture should be based on three qualities:

- Firmitas (or soliditas), solidity of construction;
- Voluptas (or venustas), that can be translated by aesthetic, and, last but not least
- Commoditas (or utilitas), adaptation to use. He recommends, “Laying the building out so ingeniously that nothing could hinder its use.”

There could be other objectives, such as:

- prestige, image;
- low cost;
- energy saving;
- real estate business, speculation;

but ‘adaptation to use’, which includes indoor environment quality (IEQ) must be one of the main objectives, since it is one of the very purposes of buildings. A sculpture should be solid and beautiful, but a building must be, in addition, adapted to its use.

The notion of sustainable development requires that buildings should be designed, built and maintained taking account of environmental, economic, and social stakes. This implies, in addition to good indoor environment quality and health that the building should also have (among others) a low energy use to reduce the load on the environment, an aesthetics appreciated by society. and a cost affordable by owners and tenants. A building cannot be good if it fails any of these criteria.

In some cases, especially when no appropriate studies are performed, there may be a conflict between aesthetics, cost, strategies to reduce energy use and ways to ensure good IEQ. However, recent studies and existing high quality buildings clearly show that it is possible to design buildings that are beautiful, healthy, comfortable, affordable *and* energy performing [1]. These buildings are the result of a conscious design keeping constantly the three objectives of sustainable development in mind. It is not by chance that most of the apartment and office buildings fulfilling best the criteria defined in the European research project HOPE (Health Optimisation Protocol for Energy-efficient Buildings) were designed that way [1, 2].

Since the issues of cost should be handled by the market, the aesthetics by the architects and energy performance by regulations, we will mostly support, in this paper, that ensuring a good indoor environment is one of the objectives of sustainable architecture.

2 HOW TO GET GOOD IEQ

2.1 Requirements

Good IEQ means good comfort and good health for the occupants. Within the HOPE research project [3], the following definition has been adopted (the original definition includes energy efficiency):

A healthy 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.

Comfort includes thermal comfort, good indoor air quality, comfortable lighting, protection against noise, and good internal acoustics. A new draft European standard provides detailed information on these requirements [4].

It is well known that errors in design, construction or maintenance may cause occupant's sickness [5, 6]. Many of these errors are known [7-11] and can be easily avoided. It is more difficult to clearly state what, in a building, makes that occupants are healthier than in another one. From examples of good and poor buildings, several ways for achieving an improved IEQ can be however outlined.

2.2 Ways for achieving improved IEQ

Basic recommendations that could be given to reach good IEQ are:

- Think about IEQ, together with other architectural issues, all the time from the earliest design stage to commissioning and exploitation.
- Prefer passive methods to active ones wherever possible
- Think about user comfort, needs and behaviour
- Adapt the building to its environment.

2.2.1 Thinking about IEQ

When designing a new building or planning a refurbishment, each decision restricts the freedom for the next ones. Therefore, it is important to take all aspects (including IEQ) in consideration at the earliest design stage. It is much more difficult and always more expensive to correct the effects of an imperfect decision later. A later decision however may also destroy the beset early intentions. For example, using a toxic paint for the latest finishes can make (and did in a few cases) the building uninhabitable and poor maintenance may strongly reduce the healthiness of a building. Therefore, good IEQ requires permanent care.

2.2.2 Passive and active ways to ensure IEQ

The passive way to ensure IEQ includes architectural and constructive measures that naturally provide a better indoor environment quality without or with much less energy use. Examples are:

- Improving winter thermal comfort with thermal insulation, passive solar gains, thermal inertia, and controlled natural ventilation[1]
- Improving summer thermal comfort with thermal insulation, solar protection systems, thermal inertia, and appropriate natural ventilation
- Ensuring indoor air quality by using low-emitting materials and controlled ventilation
- Providing controlled daylighting by mobile solar protection or variable transparency glazing
- Protecting from outdoor noise with acoustic insulation
- Adjusting the reverberation time for comfortable indoor acoustics

Passive means are often cheap, use very little or no energy, and are much less susceptible to break down than active means. However, they often depend on meteorological conditions and therefore cannot always fulfil the objectives. They need to be adapted to the location. The architect needs to take more issues and parameters into account to optimise the design. Furthermore, additional studies are often necessary to avoid a design error that may have dramatic consequences.

The active (or technological) way to ensure IEQ allows reaching the objectives by mechanical actions, using energy for complementing the passive measures or even for compensating low building performance. Examples are:

- Heating boilers and radiators for winter comfort
- Artificial cooling by air conditioning or radiant panels for summer comfort.
- Mechanical ventilation
- Artificial lighting
- Actively diffusing background music to cover the ambient noise.
- Active acoustic correction.

Active ways, when appropriately designed, built and maintained, are perfectly adapted to the needs. Flexible and relatively independent on meteorological conditions, they allow correcting architectural errors. However, the required technology is often expensive, uses much energy and may break down. Furthermore active means require careful maintenance. The fact that they allow correcting architectural ‘errors’ can also be considered as a disadvantage….

Passive ways are preferred because of their reliability, for most of them, their low cost and their energy effectiveness, but they cannot always fulfil the comfort objectives. Therefore, the appropriate strategy is to use them as much as reasonably possible and to compensate for their insufficiencies with active systems, which will then be smaller. This strategy often allows more freedom in choosing the type and location of active systems.

2.2.3 Think about user comfort and needs

The occupant of a building expects that the building provides an acceptable indoor environment, according to his wishes and needs. As shown in Figure 1 resulting from the HOPE European audit [12], occupants like to have some control on their environment and even require such a control to adapt the indoor environment to their personal needs.

This correlation is not an exception: perceived indoor air quality, lighting, glare and noise are correlated with the corresponding perceived control on ventilation, lighting, solar protection and noise.

The control an occupant has over his environment not only affects his perceived comfort, but is linked in some way with his well being: occupants having no control on their environment present, on the average,

[1] Natural ventilation can be controlled by installing (automatically or manually) adjustable vents in an airtight building envelope.

more sick building symptoms than those having full control [12].

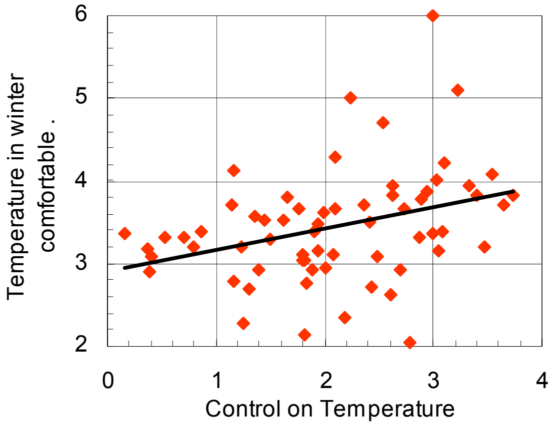

Figure 1: Correlation between the perception of occupant regarding their control of the temperature and their overall winter comfort. Both scales go from 0 (no control, no comfort) to 7 (full control, perfect comfort)

Where the environment cannot be modified by designed means, and when users are dissatisfied with a particular aspect of their comfort, they find a way to reduce this dissatisfaction, sometimes by hindering the measures taken to ensure good IEQ. Known examples are taping air inlets when they are draughty (suppressing ventilation), bringing in electrical heaters when the temperature is too cold, opening the window in winter instead of putting the (non existent) thermostat down; or simply absenteeism when the working conditions are too poor.

Therefore, the building design as well as the system must take into account the user's needs and wishes, and allow him to adapt its environmental conditions to his needs as much as possible.

Automatic control systems are installed for improving comfort and saving energy. When well designed and installed, such systems are very efficient in ensuring stable indoor conditions and using energy systems efficiently. However, users often complain about indoor climate if they cannot adapt it to their wishes, and engineers are afraid that leaving this to users may increase the energy use or even perturb the energy systems. [13] has shown that using control systems that adapt themselves to user wishes considerably improves the acceptability of the automatic control by users with a very slight increase of energy use.

2.2.4 *Adaptation to the environment*

The outdoor environmental characteristics (temperature, solar radiation, wind, dust, pollution, noise, etc.) change with the location of the building. Therefore, a design that is well adapted in a place may be completely unsuitable for another one: Bedouin tents, igloos, tropical huts, all well adapted to their environment, cannot be used elsewhere. This is also valid for contemporary building design: it is of course possible to compensate for environmental changes using active techniques, but this often decreases the indoor environment quality and always increases the energy use.

Adaptation of the building to the environment includes the following:

- Adaptation to climate: appropriate thermal insulation, solar protection systems and ventilation openings. An acceptable architecture should ensure that the building is, without any heating or cooling, *at least as comfortable as the external environment* [14]. In many cases, it is easy to do better by passive means. Figure 2 shows the evolution of external temperature through the year, as well as the comfort range and internal free-running temperatures in a well adapted and a poorly adapted building. A poorly insulated building without appropriate solar protection will be too cold in winter ant too hot in summer or will have long heating and cooling seasons. A well designed building may have no cooling in many temperate climates and a shorter heating season.
- Adaptation to noise: improve acoustic insulation in noisy areas, for example by using a double skin, and installing mechanical ventilation with sound barriers.
- Adaptation to pollution: locate air intake as far as possible from pollution sources, install mechanical ventilation with appropriate filters and ensure appropriate maintenance.

The latter two are also issues in town design or adaptation of the environment to buildings: the various areas should be arranged in the town so that it is possible to locate residential buildings or rest houses in quiet and clean places.

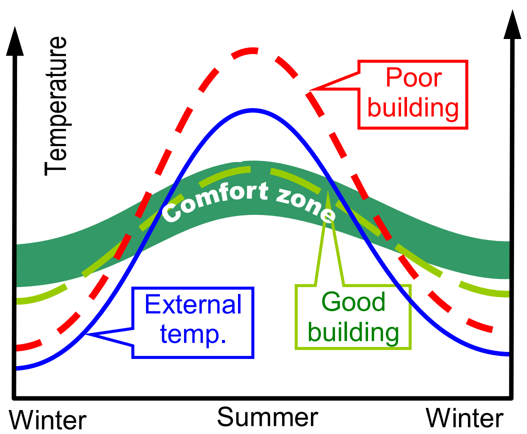

Figure 2: A good building should be, without any heating or cooling, **at least as comfortable** as the external environment

Nevertheless, it should be mentioned that clothing is the most natural first step for temperature control. A building management has justified air conditioning because full formal dress was mandatory in the company. Allowing clothing adaptation in buildings certainly improves comfort and may save much energy!

3 THE ARCHITECT AND IEQ

3.1 The Situation

Assuming that a building should be comfortable, using the strategy mentioned above - which is to privilege passive measures – leads to a coherent design. This is supported by the following facts:

- Passive means are completely controlled by the building design, hence mastered by the architect.
- Understanding the basic principles of good IEQ and building physics allows the architect to "play" with them and to have a choice between the many ways to improve the well being of inhabitants, together with a sound aesthetics and a low impact on the environment
- The architect takes part in the design from the earliest phases, and therefore has the best position to take the most important decisions.

Some architects prefer to concentrate just on the aesthetic design and the distribution of spaces, leaving up to the engineers the care of indoor climate. This looks convenient in the short term, because the number of problems to be solved is reduced at a first glance, and the building project looks easier to design. IEQ is then ensured by active technology, whose power is calculated by specialised engineers to comply with the building design and applied according to known technology.

This strategy has however strong disadvantages. First, the risk of major problems occurring in the buildings is increased because powerful technology may have to fight against a building whose design amplifies the loads resulting from the climate. In many of such high tech buildings, occupants complain about poor IEQ [15], even when all standards are met.

Using this strategy, the architect completely loses control over the technology which, in the worst cases, may decrease the aesthetic quality of a building (think about cooling towers or the indoor space occupied by large ventilation ducts).

3.2 Architectural Education and IEQ

Trying to make future architects aware of IEQ issues, a lecture was created 4 years ago at the EPFL. The lecture notes are now published in a book [10]. This lecture does not give architectural advice, but provides enough common knowledge in building sciences and technology to help architects in solving the problems they may face with indoor environment, or better, to avoid these problems.

At a pedagogical level the course aims to:

- Make students aware of the problem
- Teach the sources and effects of various contaminants, and the conditions favourable to the growth of micro-organisms.
- Review the comfort and health conditions, and teach means to fulfil them.
- Teach some appropriate methods for solving conflicts between contradictory requirements.
- Present some building diagnosis methods.

Its content is split in two parts: The first part presents today's status of IEQ in buildings, the various hazards encountered in buildings and the comfort requirements. Chapters are:

- Utility and use of inhabited buildings
- Indoor environment quality as observed today in buildings. The sick building syndrome.
- The sources and effects of various pollutants and micro-organisms.
- Comfort conditions and inhabitants needs.

The second part proposes solutions to IEQ problems or ways to avoid problems and improve IEQ:

- How to ensure thermal comfort?
- How to ensure indoor air quality?
- How to avoid moisture and mould problems?
- How to ensure good lighting?
- How to ensure a nice acoustic environment?
- Which are the available diagnosis methods when facing a problem?

The students following this optional lecture are mostly interested and often ask why this is not given to a larger audience. They are asked, at the end of the two semester cycle, to present a short report on a topic in relation to IEQ, such as a study of the causes of problems encountered in a building and proposals for fixing them, a bibliographic survey of a specific pollutant such as asbestos, radon, electromagnetic fields, a study of a famous architect with emphasis on his way to handle IEQ, etc. It can as well be the integration of IEQ issues in their semester architecture project.

3.3 Proposal

Such a lecture is useful, but is unfortunately disconnected from the main teaching tool for architects, which is the design workshop. Indeed, IEQ should be integrated, together with architecture, structure, materials and environmental impact in workshop teaching, where students learn how to develop a project. Only this can make students used to simultaneously consider all issues of sustainable architecture.

4 CONCLUSION

Beautiful, healthy and comfortable buildings that also have a limited impact on the environment exist. Smart managers, architects and engineers design, construct and operate buildings in a way that all requirements of sustainable architecture can be achieved. The very existence of such buildings proves that the apparent conflict between these issues need not in fact exist, since it can be overridden by careful design, construction and operation.

Experience shows that passive design strongly helps in reaching these goals. By contrast, expensive technical measures to improve the indoor environment of a poorly designed building are sometimes counterproductive: even when technical requirements (temperature, airflow rates, etc.) are met, occupants may not feel well.

The EU Directive 89/106 (1989) considers good "*hygiene, health and environment*" as well as "*energy economy and heat retention*" as essential requirements. The more recent directive on energy performance in buildings [16] 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."* Building design 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.

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