Sustainable Comfort for retrofitting educational buildings

Richard Cantin, PhD
Nadine Adra, PhD
Gérard Guarracino, Prof

Ecole Nationale des Travaux Publics de l'Etat. Laboratoire des Sciences de l'Habitat.
Département Génie Civil et Bâtiment. URA CNRS 1652.
Rue Maurice Audin. 69518 Vaulx-en-Velin Cedex. FRANCE.
Phone :+33 4 72 04 70 31. Fax :+33 4 72 04 70 41.
richard.cantin@entpe.fr, nadine.adra@entpe.fr, gerard.guarracino@entpe.fr

1. INTRODUCTION

For historical and demographic reasons, in many European countries, an important part of educational buildings must be retrofitted in the next years. These retrofitting must be carried out in a context of reduction of greenhouse gas emissions and energy consumption.
In this context, the group of annex 36 of the International Energy Agency aims at promoting, for educational buildings, efficient measurements of retrofitting on energy level. In the same time, in France, an approach named HQE (High Environmental Quality) is developed as a specific action answering to the demand for green building and for integration of sustainable building concepts. In this way, the Rhône-Alpes authority leads actions for retrofitting educational buildings.
Among different targets for retrofitting, there are the improvement of comfort. Indeed, high and sustainable performances of indoor environment must be achieved with reducing energy consumption.
In this paper, special aspects of retrofitting educational buildings are set out, and comfort requirements are presented. Then, an assessment of comfort, in a study case, is exposed in order to present several sustainable comfort issues and decision makers constraints.

2. SPECIAL ASPECTS OF RETROFITTING EDUCATIONAL BUILDINGS

Because educational buildings are complicated structures, retrofitting design covers a broad and diverse range of activities and choices. Having a care for energy and environment questions in retrofitting does not mean buying and installing the latest or the most expensive equipment. Rather, it is a design philosophy that is focused on choices that improve the learning environment and save resources. Some choices stay essential.
Actually, educational buildings have many special aspects which should be considered in the design of retrofitting plans, hereafter some of these aspects are given:

- Educational building category includes different types: elementary school, high school, college or university, vocational school, kindergarten, training centres, etc.
- Educational buildings have different age, size, volume and can contain various space types with different set-point temperatures and activities. For instance, one of these may have intermittent heating, including: classrooms, libraries, offices, laboratories, dormitories, health care facilities, athletic facilities, auditoriums and others. This diversity of floor use creates both challenges and opportunities for implementing energy retrofitting projects of varying size and scope.
- A large diversity of material, construction (structure, facade, glazed wall, insulation, etc.), heating, ventilation and air conditioning systems, or solar and lighting systems, creates various issues which are strains on maintenance staffs.

- As educational buildings add space, the operation and maintenance of each addition is often different.
- Educational buildings sometimes use rooms, portable classrooms, or buildings which were not originally designed to service the unique requirements of educational buildings.
- Occupants are close together having four times as many occupants as office buildings for the same amount of floor space.

At the opposite of a new building, an existing educational building already have geographical constraints (site, orientation, etc.) and a technical, economical, social, environmental and architectural history which gives a framework for retrofitting.
For these numerous reasons, a broad and complete diagnosis of existing educational building is necessary before the retrofitting conception.

3. COMFORT REQUIREMENTS IN EDUCATIONAL BUILDINGS

Studies have indicated a correlation between the way educational buildings are designed, or retrofitted, and student performance. Studies were complicated by the highly systemic nature of education and the range of social, pedagogical and environmental variables involved. In fact, the educational process is strongly influenced by thermal, visual and acoustical comfort [High Performance Schools (c), 2001].

3.1. Thermal comfort

Thermal comfort is an important variable in student and teacher performance. Hot, stuffy rooms-and cold, draughty ones-reduce attention spans and limit productivity. They also waste energy, adding unnecessary cost to the energy bills.
Excessively high humidity levels can also contribute to mould. Thermal comfort is primarily a function of the temperature and relative humidity in a room, but air speed and the temperature surrounding surfaces also affect it [High Performance Schools (a), 2001].
Thermal comfort is strongly influenced by how a specific room is designed and by how effectively the Heating Ventilation Air Conditioning system can meet the specific needs of that room.

3.2. Visual comfort

Visual comfort means that lighting quality makes easier the visual tasks, such as reading and following classroom presentations. Students spend much of their day engaged in visual tasks-writing, reading printed material, reading from visual display terminals, or reading from blackboards, whiteboards and overheads. They must constantly adjust their vision from ‘heads up’ to ‘heads down’ position and back again. Inadequate lighting and/or glare can seriously affect a student’s ability to learn. On the other hand, a comfortable, productive visual environment will enhance the learning experience for both students and teachers [High Performance Schools (a), 2001].
Visual comfort results from a well designed, well integrated combination of natural and artificial lighting. Any strategy for enhancing the visual environment will therefore strongly affect the size and configuration of both these systems (for example type of windows, number, type and placement of light fixtures, etc.).

3.3. Acoustic comfort

Acoustic comfort means teachers and students can hear one another. When noise levels in the classroom are too high, students and teachers lose the ability to intelligibly understand each other. Typical sources are outdoor sounds (from vehicles and airplanes, for example), hallways (foot traffic and conversation), other classrooms (amplified sound systems and inadequate sound transmission loss), mechanical equipment (compressors, boilers and

ventilation systems), and even noise from inside the classroom itself (reverberation) [High Performance Schools (a), 2001].
Thus, acoustic comfort takes into account created sound barriers between classrooms and exterior sources of noise, mechanical rooms or equipment, noisy spaces within school, incorporated vibration isolators. It will reduce equipment noise and selected interior finishes which limit sound reverberation [Sustainable Schools Guidelines, 2001] .

Parameters	**Regulations or recommendations**
Temperature Winter/Summer	19°C<T<26°C (AICVF)
Relative Humidity	35%<HR<70% (AICVF)
Concentration CO_2	1000 ppm (OMS)
Illuminance tables	325 lux (AFE)
Illuminance blackboard	425 lux (AFE)
Noise	max 50/55 dB (A)

Table 1 Some comfort requirements for a classroom

3.4. Other aspects of comfort
In numerous countries, various recommendations about comfort parameters are proposed. A physical approach is given with numerical values defined with energy and environment considerations.
The interactions between thermal, visual and acoustic comfort, and even indoor air quality (ventilation), complicate the identification of a global comfort. For instance, if classrooms are cold in winter, or if the building is located, unprotected, on a noisy street or noisy HVAC systems, students and teachers will certainly perform as well. If unshaded windows create solar overheating, glare, or poor lighting results in eye strain, both students and teachers will be distracted. Students in classrooms that are quiet, well-lit, well isolated acoustically and properly ventilated will learn faster because they are more comfortable, can see and hear better, and are less distracted.
Moreover, in each existing educational building, it is possible to know occupants and experiment of maintenance staffs. Their physical and psychological appreciation about existing comfort, and also about structural and functional issues, let decision makers know their wishes and needs to define a retrofitting operation.

4. A STUDY CASE
4.1. Brief project description
One example of educational building, studied in the Region Rhône-Alpes, and integrated in case studies of annex 36 of IEA, is presented as an illustration (figures 1 & 2). The retrofitting project aimed to enlarge the built area and to retrofit spaces. The point is to unify teaching areas, to refurbish the general aspect of the building, and to correct comfort conditions. The final total floor area is 9000 m², with 600 pupils.
The oil furnace is replaced by a heat exchanger on the district heating service. Hot water is distributed to the rooms at a variable temperature depending on parts of the building. Ducts are insulated with 3 cm glasswool. Radiators with thermostatic valves contribute to the heat diffusion at a controlled temperature in the main part of the building. Domestic hot water is also produced by the heat exchanger through a interim storage.
For general classrooms, a minimum ventilation flow is provided by a mechanical ventilation. Additional needs are covered by a manual opening of the windows. Air inlets are located in the upper part of the windows and air outlets at the opposite wall. Fans running is temporised according to the occupation hours.

A Building Energy Management System is installed to manage heating, ventilation, alarms and maintenance.

Louise Labé secondary school is located near Lyon, built in the 1953 and retrofitted in 2000.

Figure 1: before refurbishment Figure 2: after refurbishment

Natural lighting is largely provided through highly glazed facade (ratio glazings/facade=0.79). Windows are equipped with roller blinds (ground floor) or outdoor screens (first floor) and horizontal solar protection as aluminium fins are installed on east, west and south facades. A zenithal lighting is provided in the workrooms of first floor by light-shelves.
In the classrooms, ceiling mounted luminaires with fluorescent tubes as blackboard lighting. In other rooms and corridors, ceiling inserted spots with fluocompact lamps, distributed on the corridors with time switches by the Building Management System.
Energy saving was not the main issue of this project but energy conservation for space heating should be achieved with a better insulation of the envelope and a better daylight in rooms.

4.2. Comfort assessment

People satisfaction regarding the comfort of the refurbished building was studied with an enquiry with provided questionnaires. The surveyed sample included teachers and students. Analysis of answers shows that:

- The results revealed some problems of low/high temperature linked to the control of the heating system. Level of temperature is good for 30% people, and acceptable for added 40%. Overheating problems are announced by 80% people in the afternoon and 50% in the morning, and 80% people have coolness feeling in the morning.
- Overall satisfaction noted about lighting, less than 30% have quoted sometimes a problem of insufficient lighting of blackboards or annoying glare.
- No problem were reported about the equipment, except some dissatisfaction relative to noise insulation between rooms or between rooms and circulation.
- Students complain about insufficient ventilation: sensation of enclosed space for 70% people, 80% feeling dusty and strong smell sometimes for 50% people.

Regarding the temperature recordings, made between the 13th and 20th March 2001, the set point temperature as designed are not fulfilled, especially set-back temperature is too high in the classrooms and the circulation.
A reduction of energy bill is achieved but the building management system is not efficiency used by maintenance staff who has not received a specific training on the energy and thermal management.
This study case gives an example of complex comfort constraints for the retrofitting educational building. Reaching a best level of comfort needs to control various parameters of the indoor environment.

Thus, if energy savings are carried out, a high level of comfort is not achieved. In 2001, others comfort studies in educational buildings of Rhône Alpes have shown this distinction between an energy consumption target and a comfort target.

5. SUSTAINABLE COMFORT CONSTRAINTS

In this study case, comfort requirements and results for retrofitting educational buildings can be defined by numerous parameters. Mainly, they give a numerical level of performance (temperature in wintertime and summertime, asymmetric radiation, surface temperature of floor, ventilation rates, illuminance, reverberation time, indoor air quality, etc.). These values are often numerical and static, but comfort cannot be considered as a static target for retrofitting educational buildings.

If sustainable concepts are integrated in a retrofitting educational building, comfort has to be the higher and the better for the lifecycle of building. So, time and dynamic parameters must be integrated in the comfort target.

Several factors must be taking into account. The historical life of the existing building shows a various comfort during the lifecycle of building. The comfort requirements and recommendations, and the indoor perception, are not the same originally and some decades later. The ageing of building and components exist, and population of occupants also move.

Physical and psychological factors for each occupants, teachers, pupils or students, are not static. For instance, activities and clothes influence the comfort perception. Even if specific indicators are developed, like the PMV (Percentage Mean Value), it is always difficult to integrate the own physical or psychological adaptation of an occupant in its thermal, visual and acoustic environment. The comfort for occupants integrates dynamic parameters.

Moreover, climatic conditions have impacts on buildings and occupants behaviour. Natural cycles (day and night, seasons, etc.) are sources of dynamic environmental constraints. Occupants stay sensitive to their natural environment and do not accept to live in artificial environment for a long time.

In fact, when the decision makers have to define sustainable comfort, they have to take into account different important choices:

- to propose a retrofitting project with a high level of educational conditions
- to reduce energy consumption for reducing exploitation cost of building (for example, minus 20%)
- to have the higher level of comfort (wintertime, summertime)
- to have a sustainable building and so a sustainable comfort.

Several interactions between possible choices exist and each target depends on the other. The result of retrofitting are linked by level of performance of each target (figure 3).

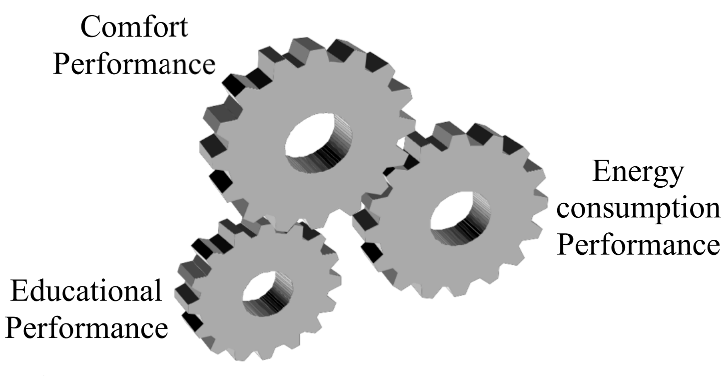

Figure 3 Interactions between performance targets

Thus, designers and engineers have to consider qualitative and quantitative, static and dynamic comfort targets for retrofitting. Their actions have to achieve the higher level of comfort for answering to the needs of future occupants. But these choices are complex to make because of opposite constraints:

- What is the best combination between thermal, visual and acoustic constraints?
- Is the higher level of comfort, the lower energy consumption?
- Does a limited financial budget for retrofitting allow to integrate an efficient maintenance management system?
- Does existing building allow to propose satisfied and sustainable comfort solutions?

A strong opposition between the high level of comfort and the low energy consumption is not necessarily in favour of sustainable comfort. The challenge for decision makers is to find a balance between these different requirements.

6. CONCLUSION

Poor thermal, lighting and acoustic quality can become barriers to education. Retrofitting educational buildings must remove these barriers, allowing teachers and students to work in the best possible conditions. In this way, stakes about a large retrofitting education buildings stock overtakes aim of reduction of energy consumption. A high level of comfort is not necessarily sustainable comfort.

Even if this reduction of consumption allows decision makers to limit the financial costs of exploitation, sustainable comfort needs to take into account occupants and the lifecycle of building.

The choices for decision makers are complex. They need to deal with global and interactive approach in order to integrate occupants perceptions and behaviour. To reach the best indoor environment quality building, equipment and occupants have to be considered.

Quantitative and static assessment of comfort, as explained in high environmental quality, have to be associated to qualitative and dynamic constraints integrating physical and psychological perception of indoor environment.

In this way, a reduction of comfort cannot be synonym of a reduction of greenhouse gas emission. Thus, a sustainable comfort could deal with relevant aims of energy consumption management during all the lifecycle of building.

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