ENERGY SAVINGS AND INDOOR AIR QUALITY IN RETROFITTING OF EDUCATIONAL BUILDINGS

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ABSTRACT

A significant part of existing educational buildings have to be retrofit in the next years in France. The economical, environmental and social requirements have increased with the international targets of reduction of greenhouse emission and sustainable development. Thus, retrofit scenarios have to reduce energy consumption and have to maintain a high quality of indoor environment.
However, various studies showed that measurements of energy savings, combined with an improvement of indoor air quality, are rarely applied in retrofitting, because of a lack of knowledge of decision makers conecrning the potential improvements.
In order to improve knowledge of these decision makers and for best results in retrofitting, we have studied performance in retrofitting of several existing educational buildings, in Rhône Alpes area. In particular, we have investigated energy savings (building envelop and systems) and indoor air quality (ventilation, pollutants) aspects in these case studies. Diagnosis, monitoring data and questionnaires have allowed to characterize the quality of indoor air and energy savings of each building. With these studies, we have identified complex constraints for high perfrmance goals in retrofitting of educational buildings.
In this paper, the results about five retrofitting of existing educational buildings are presented. They show quantitative and qualitative performance about indoor air quality and energy savings. Then, the significant difficulties for decision makers are exposed in order to improve the future elaboration of retrofit scenarios in educational buildings sector.

KEYWORDS

Retrofitting, school, energy, indoor air quality, case studies

INTRODUCTION

Numerous existing educational buildings have to be retrofit in the next years in France for historical and demographical reasons. The economical, environmental and social requirements have increased with the international targets of reduction of greenhouse emission and sustainable development. Thus, retrofit scenarios of educational buildings have to reduce energy consumption and have to maintain a high quality of indoor environment.
However, energy savings and indoor air quality are not optimized in retrofitting because of a lack of knowledge of decision makers concerning the potential improvements. In order to improve the knowledge of decision makers and for best results in retrofitting of educational buildings, we have studied performance in 5 case studies, in Rhône Alpes Area. We have investigated energy savings and indoor air quality aspects in two retrofitted schools, in one school before and after retrofitting, and in two schools before retrofitting. Diagnosis,

monitoring data and questionnaires have allowed to characterize the constraints to optimize the energy savings and the indoor air quality in retrofitting of educational buildings.
In this paper, we will describe and will present the results of the 5 case studies in France, and we will show main quantitative and qualitative performance about energy savings and indoor air quality in retrofitting of these 5 educational buildings. Then, significant difficulties for decision makers will be exposed in order to improve future elaboration of retrofit scenarios in educational buildings sector.

CASE STUDIES DESCRIPTION

Five educational buildings have been studied: two after retrofitting, one during and two before retrofitting. They are in 5 different sites in the Rhône Alpes Area and their main features are described in table 1:

TABLE 1
Main characteristics of 5 case studies

Educational Buildings	Louise Labé	Léon Gambetta	Danielle Casanova	Gaspard Monge	Hippolyte Carnot
City	Lyon	Bourgoin Jallieu	Givors	Chambéry	Roanne
Latitude	45°4N	45,6°N	45,75°N	46°N	46,1°N
Altitude	200 m	255 m	150 m	270 m	280 m
Year of construction	1953	1930	1965	1969	1900/1962
Year of retrofitting	2000	1995	2003	Study in progress	Study in progress
Total floor area	9000 m²	9200 m²	3900 m²	33000 m²	11700 m²
Number of pupils	600	540	350	1800	1200

The basic temperature is -9°C (RT, 2000) and these 5 schools are in the winter climate "H1" (colder climate in France) and in summer climate area "Ec" (moderate climate).
The typology of educational buildings show strong similar features when the educational have been built in the same period. For the 5 case studies, the building envelops and existing heating, ventilation, cooling and lighting systems before retrofitting have been investigated.

TABLE 2
Technical retrofit technologies in the 5 case studies

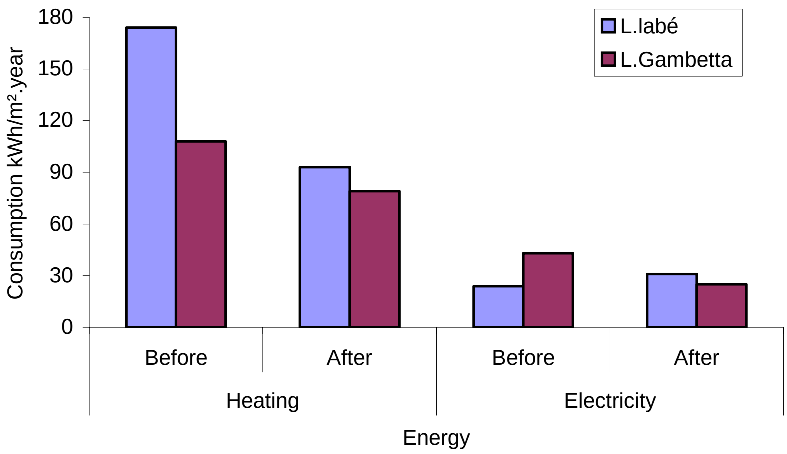
Educational Buildings / Technologies	Louise Labé	Léon Gambetta	Danielle Casanova	Gaspard Monge	Hippolyte Carnot
Insulation	●	●	●	●	●
Low emissivity windows	●	●	●	●	●
Atria		●			
Heating systems	●	●	●	●	●
Insulation of pipes	●	●	●	●	●
Natural ventilation	●		●	●	●
Mechanical ventilation	●		●	●	●
Ventilation with heat recovery				●	
Demanded controled ventilation			●	●	
Fixed shading	●	●		●	●
Movable shading			●	●	●
Building Management System	●	●	●	●	●

The diagnosis and analysis of these 5 case studies have been made with the methodological approach of the annex 36 (IEA Annex36, 2003). In these 5 case studies, the different technical retrofit measures were usual. The decision makers did not have specific knowledge about quantitative and qualitative performance of energy savings and indoors air quality in educational buildings.

ENERGY SAVINGS AND INDOOR AIR QUALITY FEATURES

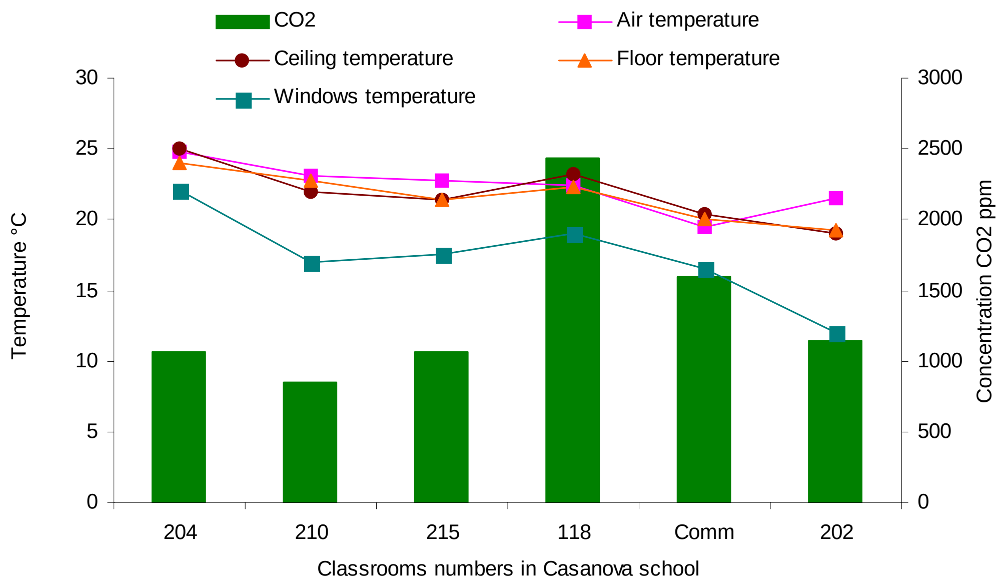
In order to identify energy savings and indoor air quality features in these 5 case studies, we have followed the 4 first levels of energy certification procedure for educational buildings (Adra et al, 2002). This approach integrated the first level of global energy performance, a second level of indoor environmental quality, then two levels with diagnosis and calculation.
The energy consumption has decreased (Figure 1), but complementary diagnosis allows to precise energy and indoor air quality features.

FIGURE 1
Energy savings before and after retrofitting



- In Labe school, after retrofitting, regarding the temperature, the set point design temperature as designed are not fulfilled, especially the set-back temperature seems to be too high in the classrooms and the corridors. The building is largely glass, which improves daylight penetration but causes some comfort problems due to summer overheating. The relative humidity, about 30% in spring, is too low. Problems of strong smells were reported by the surveyed people. The CO_2 concentration, recorded in some classrooms, showed that levels specified for comfort were exceed during lessons. The Building Management System is not totally used and there are not efficient ventilation strategy in the different spaces.
- In Gambetta school, after retrofitting, regarding the temperature in spring, the set point temperature as designed are not fulfilled, especially set-back temperature seems to be too high in the classrooms (between 20°C and 24,5°C). The relative humidity is acceptable in the classrooms (between 40% and 60%). Problems of indoor air quality have been reported by 50% of the surveyed people for the toilets, and by 41% for the gym and the changing rooms.
- In Casanova school, during the indoor comfort diagnosis and monitoring made in november/december 2003, the retrofitting works were just finished, and the BMS was not yet commissionned. Regarding the air temperature recordings, the indoor temperature in Casanova school is a bit high (average 23°C). The air temperature was high in cumputerized classrooms (25°C) and the relative humidity was inferior to 40%. High asymetric radiations (more than 10°C) have been measured in some classrooms between the north windows and the indoor vertical walls.

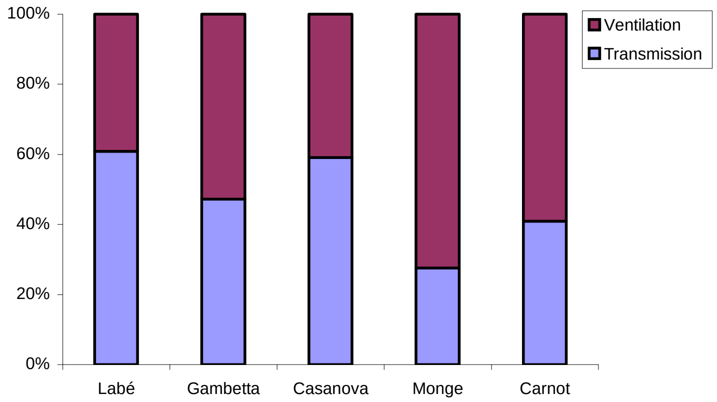
FIGURE 2
Indoor comfort indicators in Casanova School after retrofitting



High levels of CO_2 concentration have been measured in some unoccupied classrooms (more than 1000 ppm). The ventilation systems was stopped or worked with very low air flow. In some classrooms, manual systems for Ventilation Mechanical Control were not used by the teachers or the pupils.

In the five educational buildings, each ventilation strategy is a strong link between energy savings and indoor air quality. The energy losses for each school has been calculated (RT, 2000). The distribution between energy losses by ventilation systems and by envelop transmission shows the significant part of the ventilation in the energy savings (figure 3).

FIGURE 3
Distribution of energy losses in 5 educational buildings



In average, 50% of energy savings depend on the ventilation strategies in retrofitting of educational buildings. However, in these 5 educational buildings, a simple interaction has not been established only between indoor air quality, mechanical ventilation technologies and energy savings. This diagnosis has shown that it is necessary to consider others parameters like, for instance, the occupants' behaviour, the openings of windows being quite frequent in these 5 educational buildings.

DIFFICULTIES IN RETROFITTING OF EDUCATIONAL BUILDINGS

This study shows other sources of difficulties and the frequency of each difficulty among these 5 case studies, given in the following table.

TABLE 3
Sources of difficulties in retrofitting of five educational buildings

Five Educational buildings	L.Labé	L.Gambetta	D.Casanova	G.Monge	H.Carnot	Frequency of each difficulty
Year of retrofitting	**2001**	**1995**	**2003**	**In progress**	**In progress**	
Wall insulation		•		•	•	3
Windows	•	•	•	•		4
Ground floor on underfloor space	•	•	•	•	•	5
Covered playgroung roof	•			•	•	3
Roof	•		•		•	3
Summer overheating	•	•	•	•	•	5
Asymmetric radiation	•	•	•		•	4
Ventilation	•		•		•	3
Lighting	•		•	•	•	4

Detailed investigations provide complementary explanation about the encountered difficulties and others parameters to take into account in retrofitting of schools. For instance, contrary to the other projects, the retrofitting of existing envelop in Gambetta school, was very light and not optimized. In particular, there was not insulation for the whole envelop, but only one change of the HVAC systems, and a reduction of heating volumes with the installation of false ceilings in the several classrooms.

In all case studies, the weakness of thermal performance of existing windows before retrofitting was known and all the projects envisaged a change of the windows. However, the solutions were weak with the sight of the requirements of the french thermal regulation (RT, 2000), adapted for new buildings, or the case studies in other countries (IEA Annex 36, 2003). The energy losses, through windows transmission, represented between 25% and 54 % of the total losses by transmission in the 5 studied cases.

The roofs did not represent the most important losses by transmission. However the weaknesses of the vertical walls were not systematically considered. For instance, only the extension part of the Gambetta school has been insulated. Moreover, it appears that the gables insulation were sometimes forgotten (Casanova, Monge, Carnot).

All the case studies took into account air flows by mechanical ventilation lower than the required flows (18m3/h.person). A complementary ventilation flow was often planned by openings of windows. Thus, in the 5 case studies, the efficency of HVAC systems was not optimized and depended on several parameters such as the air infiltration, the ventilation strategies, the occupancy of classrooms, and the opening or not of windows.

These new systems, brought with retrofitting, seemed difficult to use for the occupants in some schools. The analysis of the information collected by the systems was not systematically made.

The retrofitting of educational buildings was often carried out with important extensions. This increased in floor areas and the unoccupied classrooms were heated like the others all the days. The planning of occupation of the classrooms was not coordinated with the HVAC systems.

CONCLUSION

The case studies presentation has shown that technical retrofit measures are similar for the educational buildings. However, the synthesis of the encountered difficulties, and their frequency in the 5 educational buildings, has shown the complexity for getting a high energy and indoor air quality performances in a retrofitting project. Many various qualitative and quantitative parameters, and their interactions, have to be take into account.
The energy needs can be fully different with a retrofitted educational building. With new pedagological targets in the schools, and a new building envelop, a significant reduction of energy can be get. A new envelop building needed to consider a new design of the HVAC systems, with often new energy sources.
Moreover, the indoor air quality was not sufficient in numerous classrooms in spite of mechanical ventilation systems. The openings of windows had to be take into account in an educational building. In this case, the hybrid ventilation strategies seemed to be interesting solutions in retrofitting.
The BMS installations were not completely well operated by users. The high occupant loads and the transient occupancy were design parameters in retrofitting of schools. The behaviour of occupants had to be considered in the ventilation strategies.
To take full advantage of new HVAC systems, the operating staff must be able to read all the indicators of the building facilities, and to adjust and control technical parameters (HVAC). Efficient operation of a BMS requires training according to the user 's needs.
These 5 case studies have shown that difficulties, are closely linked to find best retrofit measures. There are many interactions between the building envelop, the HVAC systems and the occupants. A retrofit measure for an educational building needs always to take into account complex interactions between the different components of the existing building.

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REFERENCES

ADEME, AICVF. 1993. Programmer, concevoir, gérer des bâtiments d'enseignement à hautes performances énergétiques, Ed, PYC.
Adra, N. Cantin, R. Guarracino, G. 2003. Indoor Air Quality in retrofitting educational buildings. Conference AIVC BETEC. Washington DC, USA.
Adra, N. Cantin, R. Guarracino, G. 2002. Energy certification procedure for educational buildings. Conference EPIC 2002 AIVC. Lyon.
Cantin, R. Adra, N, Guarracino, G. 2002. Sustainable comfort for retrofitting educational buildings. Sustainable buildings 2002, International conference. Oslo, Norway.
CHPS. 2001. High Performance Schools, Best Practices Manual, The collaboration for High performance schools. Vol. I, II and III: design, planning and criteria.
Daisey, Joan M. and William J. Angell. 1999. Indoor Air Quality, ventilation and health symptoms in schools: an analysis of existing information. The 8th international conference on Indoor Air Quality and Climate. Vol 2.
IEA Annex 36 ECBCS. Retrofitting in educational buildings - Energy Concept Adviser for technical retrofit measures. 2003. www.annex36.bizland.com
RT. 2000. French Thermal Regulation. Arrêté du 29 novembre 2000 relatif aux caractéristiques thermiques des bâtiments - Règles de calcul.