"REFURBISHING OF THE VENTILATION SYSTEM IN A SCHOOL"

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ABSTRACT

This project aims to demonstrate via a refurbishing operation, how a mechanical ventilation system can both provide a good indoor air quality and limit the energy consumption due to air renewal. The field of this operation concerns the improvement of indoor air quality for sensitive people as young children in classrooms, associated to a rational use of energy by the ventilation systems. Several series of measurements have been carried out before and after the refurbishing of the ventilation system to investigate the performances of the systems installed, evaluate the feeling of the occupants, and compare with the previous situation. The results obtained show a real improvement of the indoor air quality and also a possibility for energy savings up to 70% due to the use of demand control ventilation.

KEYWORDS

School, Indoor Air Quality, Refurbishing, Mechanical Ventilation, Energy Savings, Demand Control Systems.

INTRODUCTION

Currently in France most of the schools are naturally ventilated by opening windows. Depending on the external conditions, in case of noisy surrounding or during winter time, people might be reluctant to the aperture of the windows. In these conditions the indoor air quality in classrooms can reach rather poor levels, with high CO_2 concentration and humidity levels. This indoor environment is of course not favourable for sensitive people like young children, and has negative effect on their capacities to be concentrated.

The purpose of this project was to analyse how an adequate mechanical ventilation system can provide a good indoor air quality in classrooms, and in parallel allow substantial energy savings, comparing with airing by opening windows. This study has been supported by the regional branch in Rhône-Alpes of Ademe (french Agency for Environment's Defence and Energy Savings) in the frame of its experiments and demonstration program. The project team including the building owner Ville de Lyon, the consultant Tellitech, and two laboratories CETIAT and CETE de Lyon has been built since the beginning of the project and maintained till the reception of the new installations and validation of their performances.

This paper describes first the objectives of the project, and the approach retained. Then a row description of the building and of the new ventilation systems is given. After, the main results of the different measurements performed before and after refurbishing are presented. Finally, analysing the data collected an estimation, of the energy savings is given by referring to the previous situation and to a mechanical exhaust ventilation system.

OBJECTIVE AND APPROACH

The objective of this project was to demonstrate how a mechanical ventilation system can both optimise the indoor air quality in the school, and limit the energy consumption due to air renewal.
To achieve this objective different choices have been made :
- assess the needs of the occupants;
- adapt air flow rate to the occupation rate of the rooms as far as possible;
- pay attention to the air tightness of the ductworks (class B);
- install a performing balanced ventilation system with heat recovery.

The collaboration established between the different partners all along the project has allowed a sharing of competencies and knowledge favourable to the optimisation of the definition of the systems and to the controls and validations during and after refurbishing. Inspections have been performed by CETE de Lyon and CETIAT.

DESCRIPTION OF THE SCHOOL

The school complex consists of five buildings. Two buildings are from the year 1960, the others have been added in 1982. In these buildings there are mainly a primary school, a nursery school, a general purpose room and a canteen. In total 25 classrooms are present.
Since the beginning in 1982, new buildings have been equipped with a mechanical balanced ventilation system. But due to several lacks in the installation and maintenance, these systems have not worked properly on a long period, and have rapidly been shut off. So in fact, even if a mechanical system was present, the school was naturally ventilated by opening the windows for already many years.
Most of the ducts were flexible ducts ruined by outdoor conditions. The air handling units could run but they were old patterns without insulation adapted to outdoor conditions. These elements have led to the decision to remove completely the old systems and install new ones.

The refurbishing operation exposed here has only concerned rooms located in the buildings built in 1982.

DESCRIPTION OF THE NEW SYSTEMS INSTALLED

As it was a first step, the refurbishing of the ventilation systems has concerned only 6 classrooms of the nursery school, 2 classrooms of the primary school and the general purpose room. In this paper we only consider the operation concerning the classrooms.
The systems installed in the classrooms are mechanical balanced systems (see figures 1 and 2). One unit supplies the air in two rooms. According to the French regulation for hygiene (15 m3/h for pupil and 25 m3/h for adults) and to the maximum number of people expected in each room (30 children, 2 adults) one system has an air flow rate capacity of 1100 m3/h. An heat recovery unit with an efficiency of 65%, an F7 type filtration unit and an electrical heater are also included. The ventilation unit is installed outdoor on the terrace-roof of the

classrooms. The ductworks are made with double skin rigid ducts, including a 50 mm thick layer of mineral wool for thermal insulation and acoustical absorption. Junctions are sealed with mastic and adhesive tape. Three air diffusers supply the fresh air in each room. The exhaust is located in the corridors. Acoustic grilles are installed in doors bottom for air transfer.
For all these systems, the air flow rate is regulated according to the $C0_2$ level detected in the classroom. A damper is present in each branch supplying the air in the rooms. The aperture of the damper is function of the CO_2 level detected.

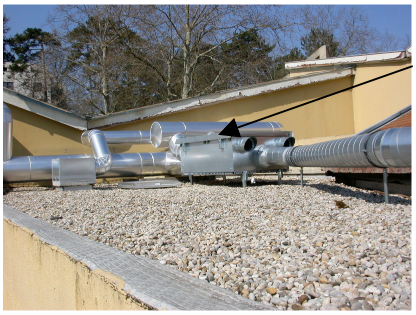

Figure 1 : Air handling unit on terrace roof

Figure 2 : Air diffusers in classrooms

INSPECTIONS PERFORMED

Preliminary inspections

In order to help for the design of the future ventilation systems, a first inspection has been made at the very beginning of the project, in order to :
- get useful information about the activities and occupation rate in the different rooms of the school supposed to be refurbished;
- estimate the quality of the building, regarding especially the air tightness of the walls.

Questionnaire

To get information about the use of the classrooms several interviews have occurred between the teachers of the primary and nursery schools and the members of the project team. A questionnaire has also been circulated. Main points addressed by the questionnaire were concerning the activity and the occupation rate in the classrooms and also the way people perceived the indoor air quality.
The results of this survey have shown that from 8h30 to 11h30 and from 13h30 to 16h30 the number of people present in classrooms varies. Due to the fact that all the rooms are not occupied, the teachers are used to separate the pupils in several groups for different indoor activities. Activities outside the school also happen during the week.

Airtightness of the building

Using a specific fan connected to a false door in the entry of the classroom, it is possible to create a depression in the room. An airflow-meter measures the air flow rate leakage. Tests performed have shown that the building was rather leaky, with 2.6 to 3.8 Vol/h under 4 Pa. These values are very high compared to the reference value of 0.9 Vol/h recommended in guidelines for this kind of buildings. Highest value 3.8 Vol/h was due to the casing of the shutters that was almost not fixed. The other leaks were mainly located around the frame of the windows and to the junction between walls and ceiling.

Inspections after refurbishing of ventilation systems

Once the new ventilation systems have been installed, different inspections have been performed. Tests to assess the air tightness of the new ductworks have been carried out first. Then a measurement campaign during the heating period in the classrooms has been organised to evaluate the indoor air quality level and the capability of the systems to adapt the air flow rate to the occupation rate. These last measurements have been performed with and without the new mechanical ventilation system running in order to compare the new situation with the previous one.

Airtightness tests

The tests have been performed two times on the first ductworks installed, according to the standard EN 12237. Results obtained the first time were rather poor. The leakage was more than ten times superior to the limits of the air tightness class B required. The reasons identified were mainly leaky junctions between the ducts and the inlet of the air diffusers. A second test has been performed once the defaults have been eliminated. The results obtained satisfied the air tightness class C. The requirements were so quite respected.

Measurements of indoor air quality in classrooms

The parameters controlled during this campaign were temperature, relative humidity, CO_2 concentration (indoor and outdoor), ventilation air flow rates and occupation rate. Air flow rates were not directly measured but deduced from the damper position. Preliminary measurements had actually allowed to determine the relationship between these two parameters. Tests have been performed over two weeks in two primary classrooms and two nursery classrooms.

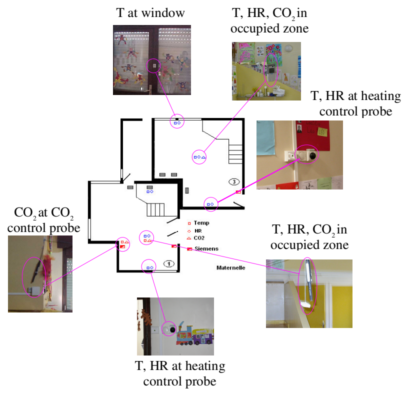

Figure 3 : Map of the nursery classrooms and sensors positioning

The sensors have been installed in the rooms in order to get CO_2 level, temperature and HR in the middle of the occupied zone, and also in the proximity of the CO_2 and temperature sensors used to drive respectively the ventilation system and the heating system. Temperature sensors have also been put near the windows or doors used to naturally ventilate the rooms in winter when mechanical ventilation was not running. The figure 3 gives an illustration of the sensors positioning in the nursery classrooms.

The results obtained during this campaign show that the CO_2 level is generally higher during periods where the ventilation mechanical is not running. The maximum concentration are 1400 ppm in nursery classrooms without mechanical ventilation and 1000 ppm with mechanical ventilation. In primary classrooms the values are similar. Figure 2 show the variation of the temperature, $C0_2$ concentration and relative humidity for a nursery school classroom and figure 3 for a primary school classroom. The blue underlined periods in the graphs correspond to the periods where mechanical ventilation is running.

Concerning the ability of the system to adapt the air flow rate to the occupation rate, the results are rather good. As it is shown in figure 4, since the people enter the classrooms the CO_2 level is increasing and the air flow rate follows within a certain delay but without ever that the CO_2 level overtakes a threshold value of 1000-1100 ppm. We can notice that during unoccupied periods the air flow rate is maintained at a rather high level, from 170 to 390 m^3/h depending on the classrooms. This is in fact because of the safety of the preheating system of fresh air that is shut off if pressure in the casing of air handling unit is too high. So it prevents from closing the damper more than a certain point and maintains rather high the air flow rate level.

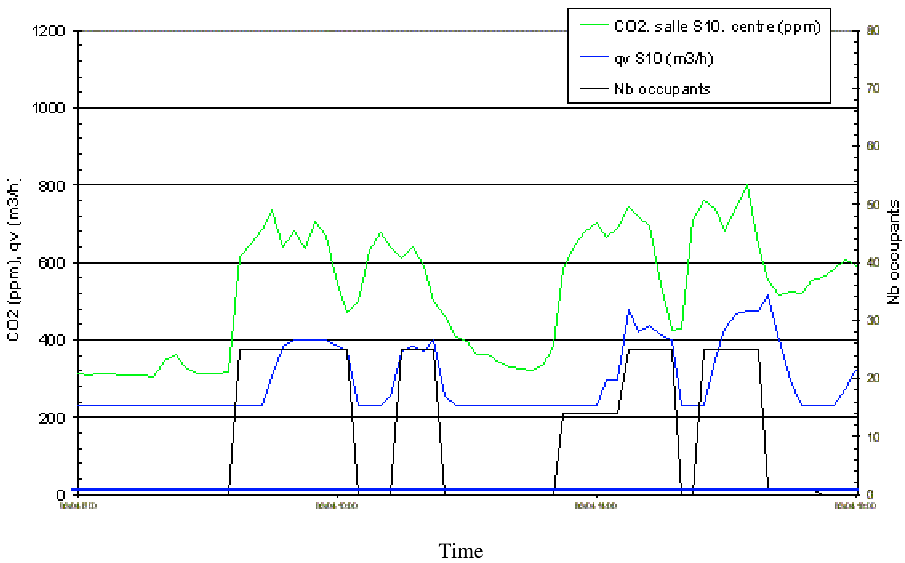

Figure 4 : CO_2, occupancy and ventilation air flow rate in a primary school classroom

PREDICTION OF ENERGY SAVINGS

Analysing the air flow rate measurements it appears that the average air flow rate in the different classrooms compared with a constant air flow rate system is reduced by 17 to 60 %. Adapting the minimum air flow rate during unoccupied periods (fixing at 50 m^3/h only) the reduction could reach 53 % to 77 %.
Calculation of the global energy consumption can be made considering the electrical consumption of the fans and energy necessary to heat the fresh air. The average outdoor conditions retained correspond to the French climatic zone H1 (3174 degree.day heating for indoor temperature 21°C).
Estimation of the energy savings have been made comparing with constant air flow exhaust system (respecting regulation level) and with a natural ventilation system by opening windows. For this last one the reference air flow rate, defined in French thermal regulation, is 1,8 times the regulation level. The average heat recovery efficiency retained is 60%. Results are given in table 1.

TABLE 1

Level of energy savings

Cases	Part of gains due to demand control	Part of gains due to heat recovery	Global gain
Comparing with constant air flow rate mechanical exhaust system	39 % (70 %)*	61 % (30 %)*	14 289 kWh/an (16 792 kWh/an)* 62 % (73 %)*
Comparing with ventilation by opening windows	72 % (85 %)*	28 % (15 %)*	30 962 kWh/an (33 465 kWh/an)* 78 % (85 %)*

*: Values in brackets are corresponding to the gains calculated with an optimised air flow rate of 50 m3/h when rooms are unoccupied.

The potential of energy savings is important. The main gains are due to the modulation of the air flow rate more than to the heat recovery to the condition to have a real reduced ventilation air flow rate during periods where classrooms are unoccupied.

CONCLUSION

Considering the objectives of this study, demonstration has been achieved that the mechanical ventilation can provide a good indoor air quality, with limiting energy consumption comparing to airing by opening windows. The use of demand control systems to adapt the air flow rate to the occupation rate seems quite adapted for schools. The reduction of the airflow rate can reach at least 50% compared to a constant air flow system. Corresponding energy savings are also important from 40 % to 70%, and more again if the comparison is made with ventilation by opening windows.