Special Engineering Techniques - Ecole Des Trèfles

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Abstract. This paper presents the challenges encountered in designing and planning an educational building complex in order to have a very low energy standard and thus reaching the exemplary building objectives. The case study building is part of the Exemplary Buildings program launched by the Brussels-Capital Region, through which the building sector is encouraged to produce sustainable buildings. This project addresses the sustainability topic in an important building category, as the educational environment is and always will be a central part of everyone's life. The paper aims at showing the technical solutions proposed by the architects and design engineers towards achieving high energy performance, sustainability, good water and waste management and offering at the same time high standard conditions to the building users, architectural quality and economic efficiency.

1 Introduction

Pollution and climate change combat are global priorities nowadays. The European Union has set objectives to gradually reduce the green house gas emissions so as to achieve a 80% to 95% reduction by 2050, compared to 1999 levels [1]. In this context, reducing the energy consumption in the building sector has become a central activity in the European Union environment as it is the sector responsible for approximately 40% of the total energy consumption. A positive example of the EU countries involvement in this direction is the Exemplary Buildings program launched by the Burssells-Capital Region with the purpose of building or refurbishing following passive or low energy standards [2]. This paper presents the case study of a highly energy efficient school building, which is a successfully implemented project part of the Exemplary Buildings programme. The study puts emphasis on the technical aspects of the design and planning of the building, for which all the requirements of the passive standard were used. The Department of Public Works of Anderlecht, Bruxelles had commissioned a new school and gym building complex for 750 students, having a surface of 9100 m^2. The present project won the BATEX 2012 competition and aims to be exemplary in terms of energy performance and sustainable development, but also incorporates the desire to involve children in energy management by teaching them the right reflexes in terms of energy efficiency.

2 Case study building description

2.1 Architectural concept

The case study building is located in Anderlechten, which is one of the 19 municipalities of the Brussels-Capital Region. The architecture of the building is quite innovative, as it can be seen in Figure 1, geometrically speaking, the building is composed of four circles and a rectangle. The circular form inspires and encourages the children to exercise more. The architecture, with the 4 circles, is inspired by a four-leaf clover (Figure 2). Each circle has its own age section and own playground. The circles are interconnected.

Fig. 1. Architectural model

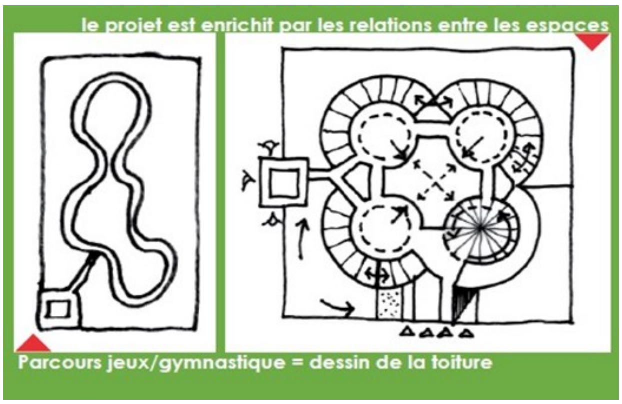

Fig. 2. "Clover Leaf" inspiration for design

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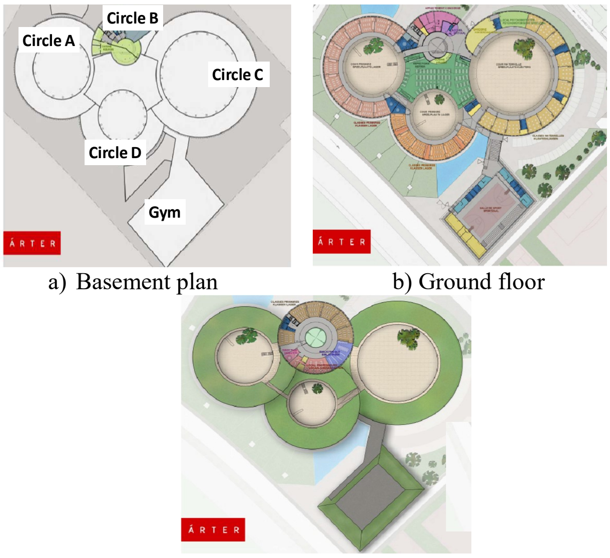
In Figure 4 are presented the horizontal plans of the case study building. The school includes: a basement where the kitchen is functioning, technical rooms, cloakrooms, toilets. The ground floor spaces are distributed in the 4 main circles - circle A includes primary classes; circle B is composed of the entrance hall, cafeteria, concierge; in circle C are the nursery classes and in circle D, the primary classes. The 1st floor is composed of the teacher rooms, the executive offices, the library, primary classes. The gym building includes: The gym, cloakrooms, toilets, storage, technical premises



a) Basement plan b) Ground floor

c) First floor plan

Fig. 3. Architectural horizontal plans

The *vegetation* is visually important in the project: the surroundings of the school are treated in a landscaped way by proposing a *succession of vegetable spaces, facades and green roofs*, ponds, all contributing to the development of the site's biodiversity, which was one of the exemplary building requirements. Sustainable water management incorporates *rainwater recovery* to avoid over consumption of drinking water.

2.2 Building design requirements

Each assignment was the subject of a specific study leading to appropriate technical choices in terms of energy needs, insulation, ventilation, solar gains, lighting, regulation etc. For each parameter having an influence on the energy performance, an optimisation of the solutions has been made in accordance with the Public Works' and architectural requirements. This optimisation has allowed us to achieve a high energy standard in order to meet the passive construction criteria. As we can see in the charts in Figure 4, the building energy demand is in compliance and well below the passive house standard criteria for primary energy and heating energy demand. The design phase of the building included a series of studies such as: energy feasibility study, the study of passive building certification, the dynamic simulation with TRNSYS software [3], lighting with the ECOTEC software study [4], study PEB, the study of special techniques, recovery and water management.

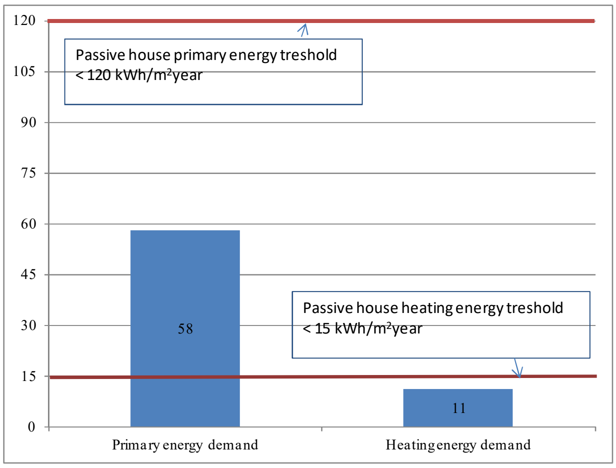


Fig. 4. Design phase energy demand

Features and special items studied are at the level of: ventilation, solar radiation, cooling load, lighting load, domestic hot water and BMS.

2.1.1 Ventilation

The ventilation and heating are independent ensuring adequate thermal comfort in every space regardless of the change of occupation and without interference between spaces.

2.1.2 Solar radiation

The building enclosure is made of precast concrete in order to achieve a high thermal inertia. The windows glass have a high solar factor and overflowing caps for shading during summer, but letting the lower rays of the winter sun heat the building.

2.1.3 Cooling load

The problem of overheating is controlled through passive strategies, so as to ensure indoor comfort during summer without the use of an active cooling system. These strategies are the green intensive roofs and a strategic and automated shielding of solar radiation.

2.1.4 Lighting load

An important goal of the design phase was the optimisation of natural light in order to achieve a factor of daylight in classes over 5% and daylight autonomy in the classes of 80%. Also, high performance lighting equipment was used and a management system of artificial lighting by probes of brightness depending on the natural lighting was implemented. Light output is less than 2 W/m²/100 lux for classes and cafeteria and for the gym is less than 1.5 W/m²/100 lux. The Hall is justified with natural light requiring very little artificial lighting.

2.1.5 Domestic hot water

The production of domestic hot water for the kitchen of the school is using a gas condensing boiler. The production of domestic hot water to the gym is via the boiler room and a cogeneration gas.

2.1.6 BMS

The use of an overall building automation/ management system can be an effective solution to increase comfort and energy efficiency in the operational building phase. Thus, a building management system was implemented: electronic control for all heating and ventilation installations. Cogeneration is also integrated into this regulation to operate primarily from the boilers.

3 Overall design concept

3.1 Building envelope

The quality and comfort of the indoor climate, both guaranteed within the buildings, are paramount to the health of students and teachers. In addition to significantly limiting primary energy requirements through efficient thermal insulation, the planned interventions also include the use of high-efficiency technical facilities and production systems. In the design of the building envelope, two major aspects were considered: daylight optimization and a high performance of thermal insulation. In Figure 5 we can see the design concept of a typical classroom.

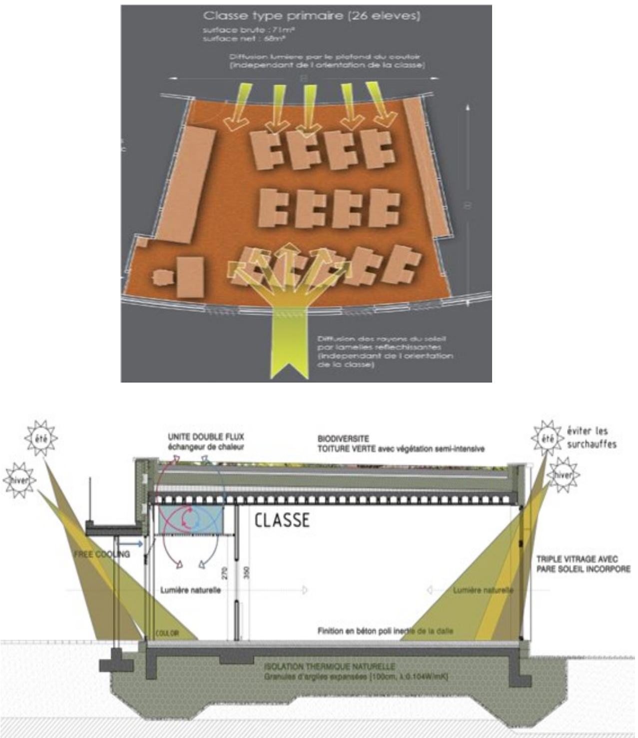


Fig. 5. Typical classroom model

The rooms design was conducted in such a way as to achieve an important contribution of daylight independent from the artificial lighting during the school hours. As mentioned earlier, the target daylight factor in the classrooms must be higher than 5% while the daylight autonomy higher than 80%.

The envelope elements are highly insulated as follows:

- Ground floor: 30 cm of expanded clay granules, achieving a U-value of 0.78 W/m²K;
- Exterior walls: 36 cm of glass wool and the U-value is 0.097 W/m^{2}K;
- Roof: 30 cm of rigid polyurethane, obtaining a U-value of 0.09 W/^{2}K

The exterior fenestration system is composed of highly energy efficient triple glazed window and insulated frames. The windows U-values are: frames U_f=0.8 W/m²K and glass U_g 0.6 W/m²K. The windows and doors were installed in the insulation layer, which is a common technique used in the passive house buildings design and construction, to minimize thermal bridges and improve building airtightness. Figure 6 shows a detail of an exterior wall insulation and window.

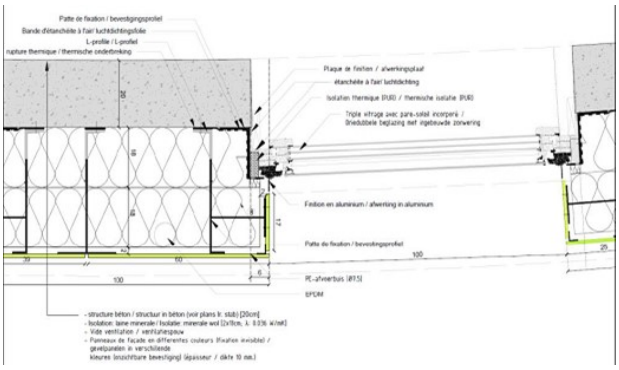


Fig. 6. Wall and window detail

All the constructive details have been detailed and simulated with the help of a program to ensure the perfect continuity of the insulation in order to achieve an airtight building envelope, in accordance with the passive house requirements (number of air changes measured at a 50 Pa pressure to be below 0.60 h^{-1}). The heating energy demand of the building is well below the maximum allowed for a passive building, therefore the building aims at achieving a zero-energy balance.

3.2 Heating system

The design of the heating system was made in accordance to the Belgian standards [4-9]. For the school the primary heat source is gas condensing boilers. Heating independent of ventilation ensures an optimal thermal comfort through the internal and external intake in the classrooms. The rooms heating is made with radiators put in classrooms and other rooms and floor heating in the hallways. The heating plant of the gym consist of a gas condensing boiler – cogeneration. The heating is achieved by means of ventilation system, radiant panels and radiators. At the sports hall level, ***domestic hot water*** is produced from ***cogeneration*** (simultaneous production of electricity and heat) and, in addition, by the heating system. Figure 7 to 9 shows the heating systems schemes of the school, while Figure 10 to 12 show the systems scheme of the gym building.

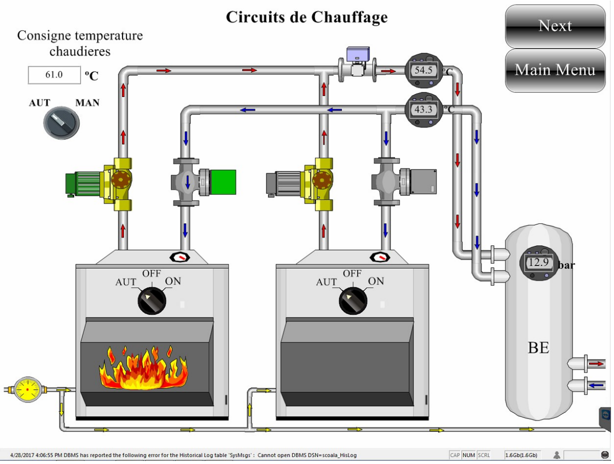


Fig. 7. School boiler plant – heat source

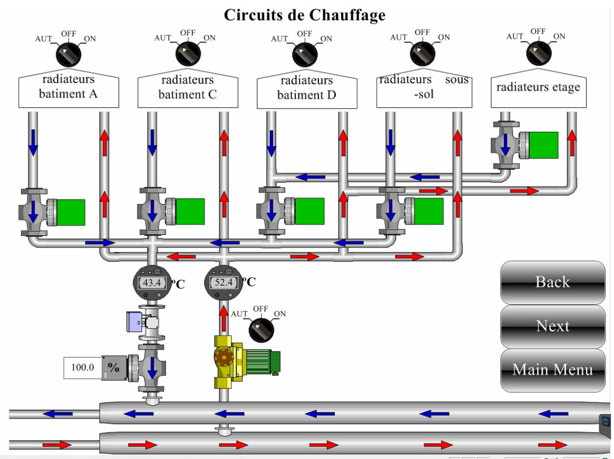


Fig. 8. School boiler plant – radiator manifolds

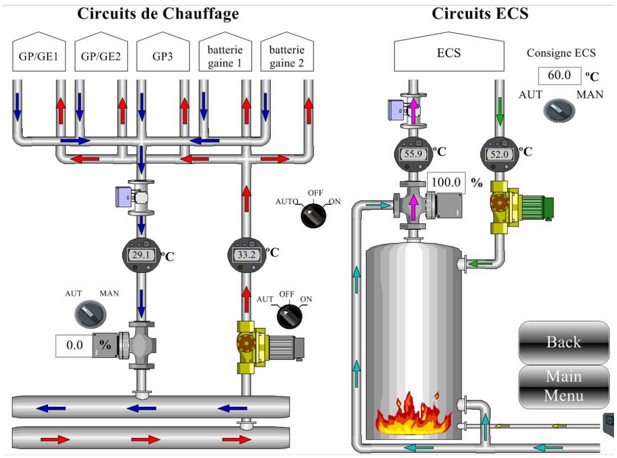


Fig. 9. School boiler plant – air handling unit batteries manifolds; production of domestic hot water

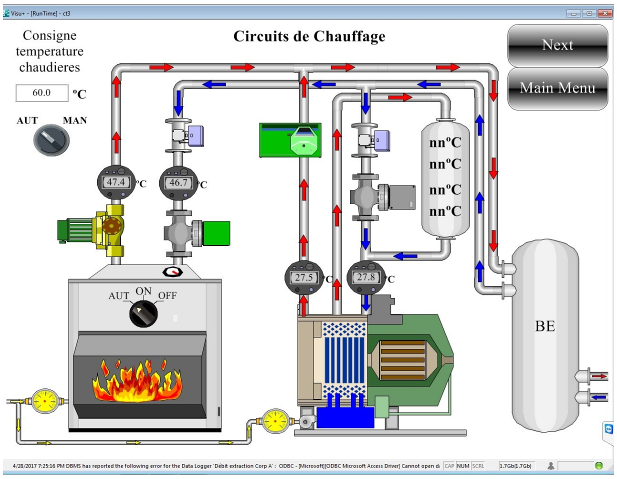


Fig. 10. GYM boiler plant – heat source and cogeneration

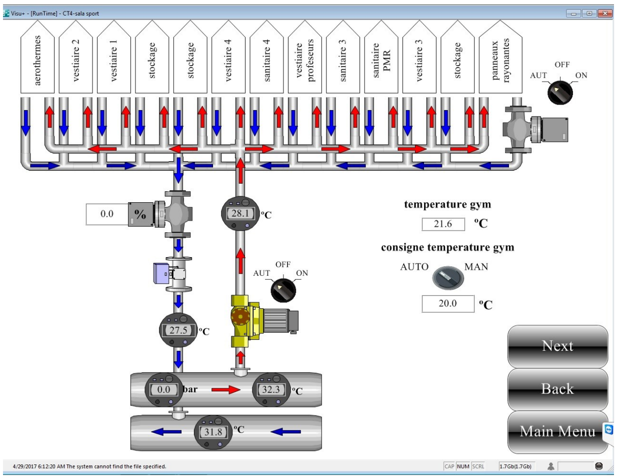


Fig. 11. GYM boiler plant – manifolds for radiators, heater batterie, radiant panels

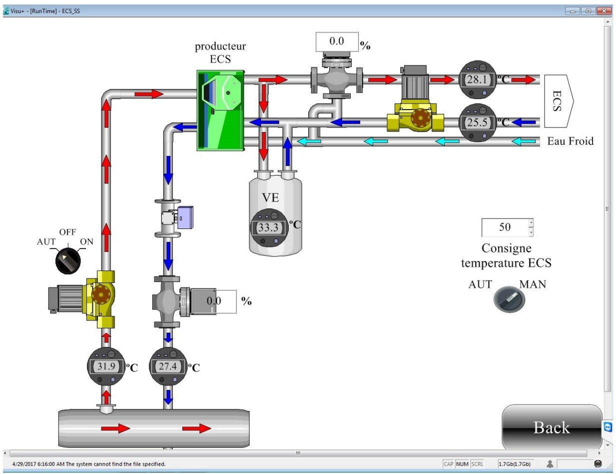


Fig. 12. GYM boiler plant – domestic hot water

3.3 Ventilation system

The ventilation of the school premises is ensured by a very high efficiency double flow unit installed in each class. Thanks to the air quality CO_2 sensors, the flow of the ventilation system is permanently controlled according to the occupancy. The design of the ventilation system was made in accordance to the

Belgian standards [4-9]. Figure 13 displays the building C circle ventilated rooms.

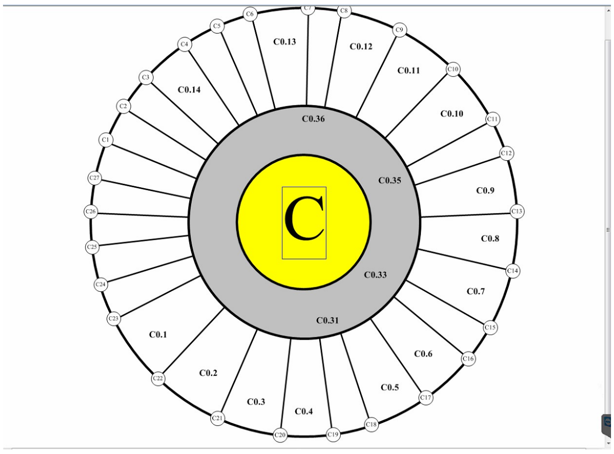


Fig. 13. Ventilation building C – display of rooms

3.3.1 Classroom model

Due to the large amount of natural lighting, the majority of classes will be able to do without artificial lighting during class hours. Triple glazing windows will be combined with a fourth integrated sunshade to prevent overheating in the summer. No active cooling system is needed to control overheating. Figure 14 shows an image from the construction phase of the building in the left, while on the right a classroom model is displayed with the air handling unit piping system. The building heating and ventilation systems parameters are monitored (Fig. 15 and Fig. 16).

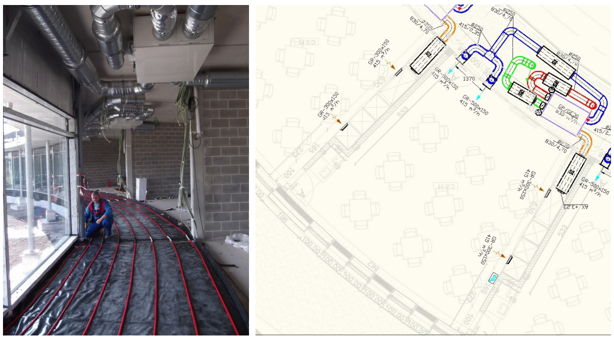


Fig. 14. Example of model classroom (C.0.11) AHU installed

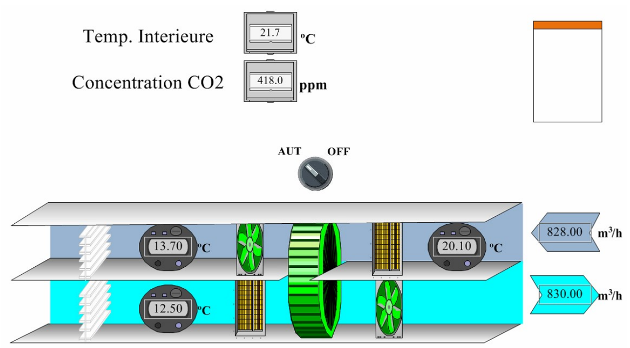


Fig. 15. Model classroom (C.0.11) AHU monitoring

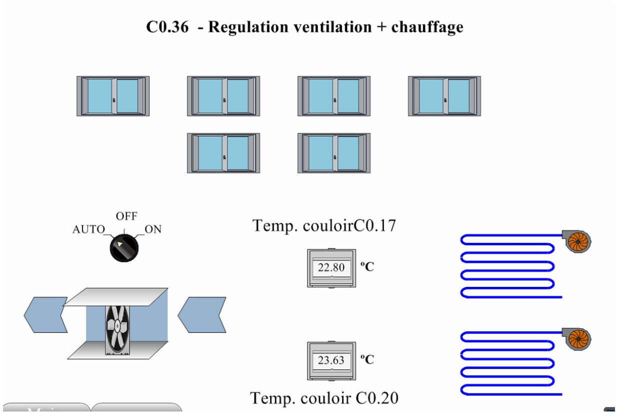


Fig. 16. Monitoring of heating and ventilation

Indeed, a system of free cooling and night cooling via double flow and natural ventilation is integrated into the buildings. In winter, however, solar gains reduce the heat load. Monitoring makes it possible to check and make sure that the building functions according to its original design. These measures make it possible, in addition to the GTC (centralized technical management), to monitor indicators of energy and water consumption, thus avoiding any drift.

4 Building monitoring and management system

The figure above sets the premises with all the consigned: corridor temperature (20 °C), 2 temperature values for corridor free cooling (26 °C and 30 °C), minumum vetilation flow 50% and maximum CO_2 sensor setting, in relation to the outside temperature (13.5 °C).

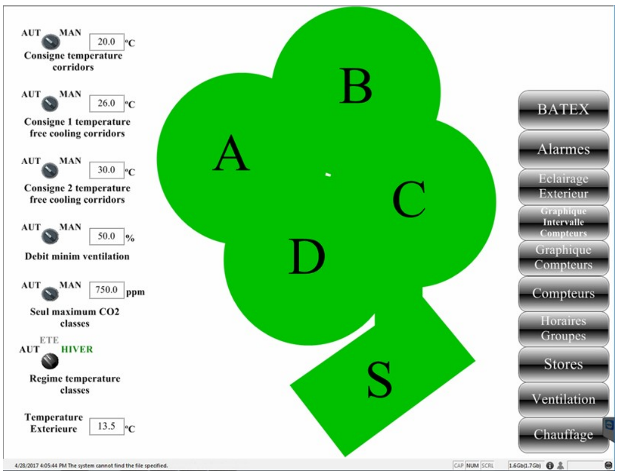


Fig. 17. Heating and ventilation control parameters

The BMS basement integrates via m-bus interface the following energy meters:

- ✓ gas (w01);
- ✓ hot water supplied by boilers (w12);
- ✓ thermal energy meter used by groups of ventilation (w04);

- ✓ meter for thermal energy of central heating radiators (w03);
- ✓ meter hot sanitary school (w05);
- ✓ counter of all switchboard;

4.1 Boiler integration

Every boiler is equipped with a managing controler:
- a control aquastat
- a security thermostat
- a pressure switch
- a flow switch
- the burner
- the temperature sensors
- the pump

The temperature of primary fluid varies between 30 °C - 60 °C influenced by the outside temperature. The automation panel DDC in the basement is responsible for service or boiler shut down. Before the burner starts operating, the gate on / off valve opens and the corresponding pump starts operating. Through lack of pressure in the installation, a pressure switch cuts the functioning of the burner, a red lamp signals this. The circulating pumps have an adaptable time delay via the local regulator.

4.2 Collector

The temperature from circuits is individually regulated by a 2 way gate valve, ordered via DDC basement panel, by an outside sensor (station weather forecast). Circuits can work, either in normal paces, or in decelerated paces, or in speeded up paces. The passage from one to the other is automatically done by a clock with daily and weekly cycle. The heating pumps stop when all conditions are satisfied, with a time delay from 5 to10 minutes.

4.3 Zoning valves

On/off valves are also used for every zone of the building to regulate the installation according to needs. Every valve can be more ordered by an independent hourly program to fit in with BMS and coupled with the optimiser.

4.4 Domestic hot water

The domestic hot water boiler functions autonomously. The basement DDC panel controls the circulator via MosBus and the 3 way regulating valve according to the temperature supply / return sensors.

4.5 Ventilation groups

Cafeteria: the operation of ventilation units is dependent on a schedule. The group works in full fresh air supply. The supply temperature of 20 ° C is kept constant by acting via the local controller on the heating valve and via the flow valve on the supply manifold. The fresh air intake register closes when the group stops. The unit is started by opening the damper. The recovery battery is by-passed if the free cooling conditions allow it. The condition of the air filters is controlled by measuring the pressure loss. The temperature of the supply air is read by both the local controller and the BMS. If the GP / GE-1's heating coil is not enough, 2 post-heater batteries are controlled by the DDC panel by acting on the 2-way valves.
Classrooms, offices, teachers' room: the operation of the ventilation units is dependent on a time program and an integrated control of ventilation groups with ModBus interface to the local building BMS. The group works in all fresh and variable air depending on an air quality sensor and temperature in the room. The local controller reads the temperature sensor and $CO2$ and controls the analog input of the ventilation unit accordingly. The fresh air intake register closes when the unit is shut down. The start of the group is done by opening the register. The recovery battery is by-passed if the conditions of free cooling or nightcooling allow. In this case, the fan unit operates at a nominal flow rate. The condition of the air filters is also monitored by measuring the pressure loss. The fouling threshold is indicated by a warning light and a report of the status to the BMS.
Terminal control cafeteria the cafeteria management includes for each zone:

· An atmosphere probe.
· A probe of air quality.
· Valve regulation VAV
· A transmitter of air
· A smoke detector

4.6. Regulation Free cooling - Night Cooling

During summer, by free cooling ventilation day and night cooling is done automatically: energy recovery battery is bypassed 100% and the windows of the corridors will open automatically by the SDC and the local controllers. During the night cooling, the point of air flow of ventilation groups, as well as extractors intended for this purpose, is brought to its maximum capacity. For corridors, the principle of free cooling and cooling night is this:
Step 1: If a first threshold temperature is reached, the opening of windows opening is controlled
Step 2: If a second temperature threshold is reached, the Group extraction at the level of the health are provisioned until where the descent below the temperature 1 temperature. Each Corridor has its independent regulation which includes: A temperature ambient. probe For each window opening control modules. In the case of free cooling, the planned extractors will be piloted by probes of temperatures throughout the corridors.

4.7. Store Regulation

Control functions are the following:
•local control by motor or several motors in the same room;
•each service of a floor;
•automatic control order by area depending on the conditions of luminosity (Sun) and wind for 8 or 16 climate zones.
•function 'wind protection' (value and delay) configurable per area. In case the wind exceeds a given value and after the delay of onset of wind, all the blinds in the building will be back in the position required by the light conditions. These blinds will remain blocked until the wind speed will remain above this value or the disappearance of the wind delay will not be completed (ex 12 or 15 min).
•the 'Sun control' function is customizable for each of the planned climate zones. The thresholds of appearance and disappearance as well as timers can be programmed for each of these areas. The Sun function ensures the descent of the blinds and the rise in intermediate positions, defined by a % of descent (e.g. 80% or 100%) and an inclination of the store.
•central control priority to rise based on alarm 'fire' and a lock for 'window cleaner'
•'Weather station': the weather station consists of 4 solar cells, an anemometer and a temperature sensor. The interface allows the management of 8 solar cells, 2 anemometers, to a direction indicator of wind, rain and a temperature probe detector.

References

1. European Comission, COM (2011) 112 final, (2004)
2. Exemplary buildings
3. http://www.trnsys.com/
4. Chaier de charges type 105/1990 – Chauffage central, ventilation et conditionnement d’air (‘Central heating, ventilation and air conditioning’).
5. NBN B61-001/1986 – Chaufferies et cheminees (‘Boiler rooms and chimneys’)
6. CSTC rapport no.14/2013 - Conception et dimensionnement des installations de chauffage central à eau chaude (‘Design and sizing of hot water central heating installations’)
7. CSTC rapport no.15/2013 - Calcul des pertes de pression et dimensionnement des réseaux aérauliques
8. NBN D 51-003/2010 - Installations intérieures alimentées en gaz naturel et placement des appareils d'utilisation - Dispositions générales (‘Indoor instal lations fueled by natural gas and placement of appliances for use - General provisions’)
9. NBN S01-401/1987 – Valeurs limites des niveaux de bruit en vue d’eviter l’inconfort dans batiments (‘Limit values of noise levels to avoid discomfort in buildings’)
10.