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ENERGY EFFICIENT SCHOOL BUILDING HVAC SYSTEMS MONITORING PLAN

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ABSTRACT:

The paper presents aspects regarding the component of the HVAC system and their monitoring system of a school building, which use both energy efficient concepts and renewable energy solutions.

1. INTRODUCTION

It is well known that the maintenance and the operation costs of a school are very important, thus it can be serious financial burden (Stoian 2013). In 2014, when it was decided that an energy efficient school is to be built in Salonta (Romania, Bihor county) a team was gathered to design a solution which is better than a traditional one by using both the Passive House Planning Package (Feist, 2007) and the national methodology (MRDT, 2005). The global number of energy efficient school buildings is low and the most are located in Western Europe (Passive House Database, 2016). The preliminary costs turned out to be greater than the initial investment (10%), but with a return period of 6 years, due to the significantly reduced maintenance cost (Boros, 2015a). This was a significant factor in selecting the adopted solutions. The construction of the 4000 m^2 multi-purpose building (Figure 1) began in October 2014. The ground floor contains the main entrance, a library, a garage, storage rooms and a 500 meals / day capacity canteen. The first and second floors are dedicated for classrooms, laboratories and administration offices, while the third floor represents the housing area, which can accommodate 60 students. The school total capacity is 450 students, 65 teachers, plus staff (Boros, 2015b).

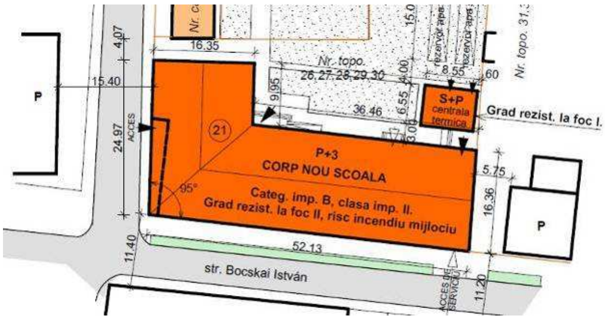

Figure 1. Site plan

The energy efficient version of the proposed building design, resulted in 565 EUR + VAT/m^2 expended costs. The entire structure was completed in September 2015, with approximately 10% additional costs as the framework and the masonry had a higher cost than foreseen. The building is expected to be finished in March 2017. The building has a reinforced concrete frame structure, a pitched roof and two perimeter firewalls. The exterior walls are made of autoclaved aerated concrete (AAC) masonry and mineral wool insulation. The floors are made of concrete slabs and extruded polystyrene towards the ground, and concrete slabs with mineral wool towards the roof. The design of the structural elements was realised with a great emphasis to reduce and eliminate all possible thermal bridges. The windows have PVC frames and three-layer glazing. An important measure for obtaining energy efficiency is obtaining a

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good air tightness of the building (Rolfsmeier), thus installing the windows had to be carefully done using special tape on both sides (Relander, 2008).

2. CASE STUDY

To provide comfort and utilities necessary for the designed function (table 1), heating and cooling equipment, cold and hot water supply, ventilation and equipment required by the kitchen were installed.

Name	Q heating [W]	Q cooling [W]	Tmax
Ground floor	44201	47381	12
First floor	36527	37483	10
Second floor	35046	40476	16
Third floor	31051	18837	19
Total	146825	137916	

Table 1. Heating and cooling demand

The heating (Figure 2) is provided by 1.2 / 1.4 kW and 2.5 / 3.5 kW ceiling and floor fan coils, with thermostatic valves, except the bathrooms from the students housing area, where steel radiators are installed. The equipment activation for rooms with more than one unit is executed by the wall fixed thermostats, respectively individual command points installed on the fan coils in the rooms with only one unit. The agent temperature is 45 / 35°C for heating and 10 / 15°C for cooling.

Heat recovery ventilation units (Figure 3) were provided for reducing the energy use and assuring the fresh air demand. The building is divided, in distinctive areas based on building functions: a unit for each of the 3 superior floors with 4000 m^3/h debit, a unit for the ground floor canteen with a 4000 m^3/h debit, a unit for the ground floor library area with a 1000 m^3/h debit and a professional hood with energy recovery for the kitchen on the ground floor with a 10000 m^3/h. The ventilation units are provided with heating batteries of 21 kW and 7 kW, as the indoor environment can be adjusted, for the winter season, from 15 °C to 22 °C, respectively cooling batteries of 8 kW and 5 kW, as the indoor environment can be adjusted, for the summer season, from 32 °C to 26 °C. Heat recovery systems with 75 % efficiency are used and the ventilation equipment automation is handled by placing CO_2 monitoring sensors on the suction tubing, thus providing a proper indoor environment.

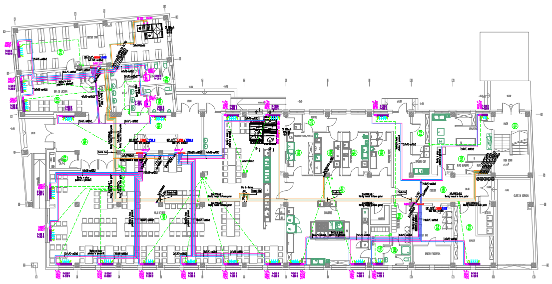

Figure 2. Ground floor heating / cooling system

The heating / cooling thermal agent and hot water are prepared in an individual building trough the water / water and soil / water heat pumps with an approximate power of 75 kW for each system. As a backup, for the situation when the pumps cannot reach the energy demand, there is a 100 kW gas based system provided. Hot water is prepared with a 3000 l boiler.

The soil / water heat pump is powered by 10 wells with 120 m depth placed with a 6 m distance apart, and the thermal agent used is realized with a distilled water mixture with 25% monoethylene glycol. The water / water heat pump is powered with water from 2 extraction boreholes and is provided with a heat exchanger, the rest of the circuit closes in 2 injection boreholes.

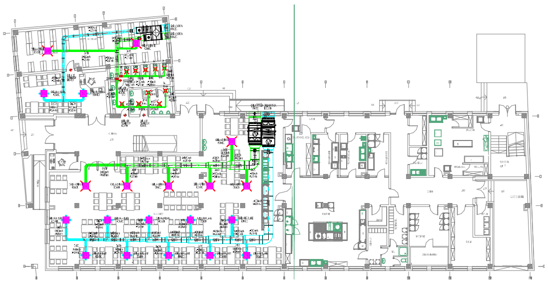

Figure 3. Ground floor ventilation system

3. MONITORING SYSTEM PLAN

To determine the real-time behaviour of the equipment installed in the building and also to calibrate de designed model, a monitoring system was provided (Boros, 2015c), with over 200 sensors the measure the temperature of all parameters that define their functioning. Taking into account that the thermal systems represent complex equipment networks and system distribution from the source to the consumers (Sarbu, 2014), several temperature sensors were placed in various relevant points of the circuits.

To determine the detailed behaviour of the vertical boreholes that correspond to the soil / water pumps, temperature sensors (Figure 6) were placed each 20 m, in 2 drills from opposite sides of the network (Nyers, 2009). In the distributor – collector of the network, sensors are placed on the tour and retour pipes of each borehole, thus offering an overview of the whole systems functioning.

The monitoring of the heating / cooling system in the equipment room is made by placing temperature sensors (Figure 7, 8 and 9) in each case, on tour and retour in places like: between borehole and pumps, between heat exchanger and pump, between pump and buffer tank, between buffer tank and distributor, gas station and distributor, on each distributor circuit and on the height of the buffer tank, etc. This part of the monitoring system offers important data regarding the contribution of each subassembly of the heating / cooling system, respectively the energy use in different areas of the building. In the interior of the building there are sensors placed on each fan coil and radiator distributors (Figure 10 and 11), both on tour and on retour tubing. The same placement strategy is used also on the ventilation equipment supply (Figure 14). By reading the supplied data from these subassemblies of the monitoring system, energy use values for heating and cooling

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can be estimated on different areas and functions of the building. Their fitting is done on the exterior of the tubing, under the insulation.

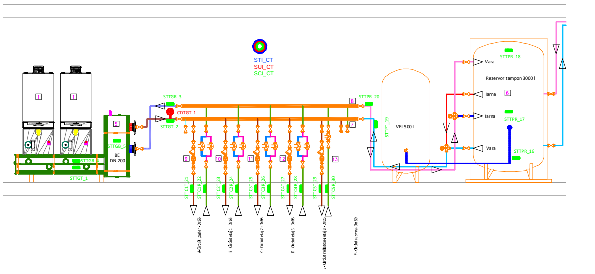

Figure 4. Equipment room monitoring plan (part 1)

Regarding the hot water, sensors were provided in the following positions: tour – retour between the pumps and the boiler, on each recirculation circuit and on the cold water tour distributors, hot water retour and boiler height. The information provided by the subassemblies refers to usage of hot water preparation and losses on the distributor circuit.

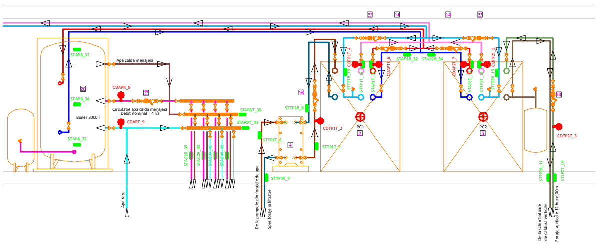

Figure 5. Equipment room monitoring plan (part 2)

Figure 6. Borehole sensors

Figure 7. Equipment sensors

Figure 8. Equipment sensors

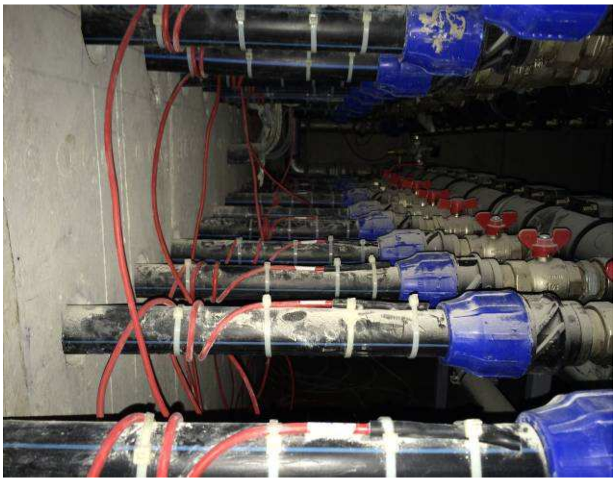

Figure 9. Equipment sensors

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Figure 10. Distributors sensors

Figure 11. Distributors sensors

Figure 12. Ventilation unit sensors

Figure 13. Ventilation unit sensors

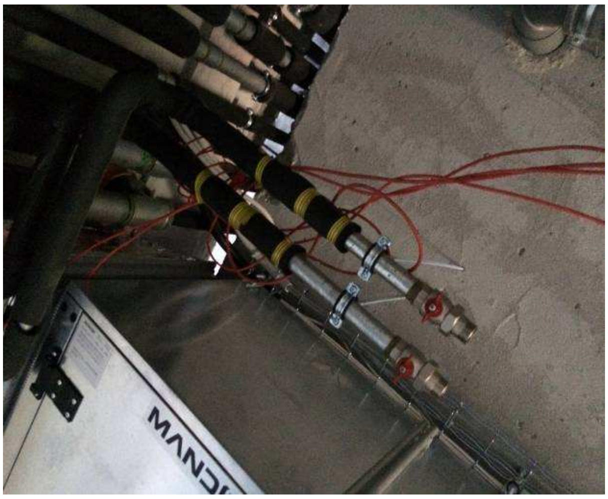

Figure 14. Ventilation supply sensors

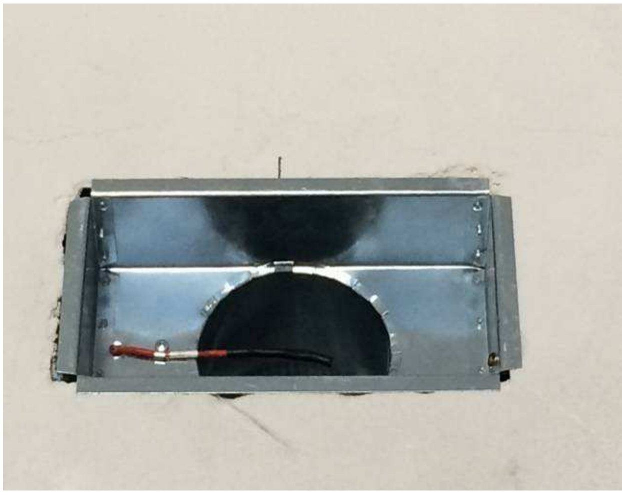

Figure 15. Discharge port sensors

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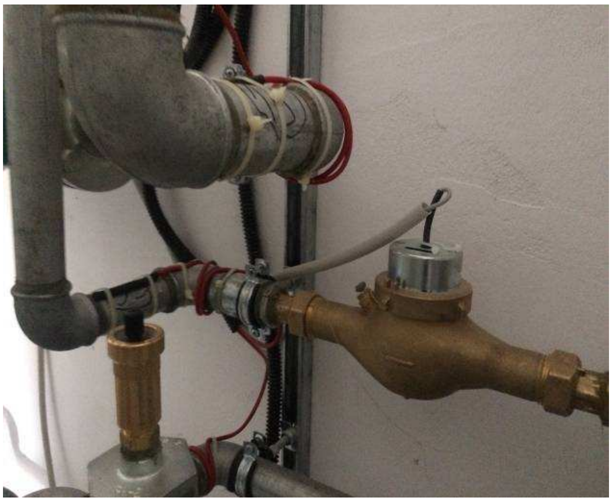

Figure 16. Equipment room flow meters

Figure 17. Equipment room flow meters

The ventilation system is fitted with 5 temperature sensors on each unit. Sensors (Figure 12 and 13) are placed before and after the heat exchanger, both on the discharge circuit as on the suction circuit, respectively a sensor after the heating and cooling battery. This measuring system indicates the suction and discharge temperature to exterior and interior, recovered energy by the exchanger and the contribution of the batteries. Also to determine the losses on the ventilation circuit, sensors are placed on the farthest discharge ports of each system (Figure 15). The installation of the sensors in the air treatment systems is done the perforating the equipment metal sheet and their further sealing but using airtight closing.

A number of 7 flow meters (Figure 16 and 17) were installed on the tour circuits of the heat and hot water sources: between drill holes and pumps, between pumps and buffer tank, between pumps and boiler, respectively gas station and distributor. Also, another 2 flow meters were placed on the tour circuit of the cold water supply and on the retour circuit of the hot water. The flow meters provide relevant information (Sarbu, 2016) about the contribution and the energy produced by the boreholes, heat pumps and gas stations for assuring the heat, cooling and hot water demand.

Temperature, humidity and CO_2 level measuring systems (Figure 18) of the exterior and indoor climate are also provided (Földváry, 2015), in every room type: library, hallways, dining area, laundry, and garage, offices, classrooms, bathrooms, rooms, attic and equipment room.

Figure 18. Indoor climate sensors

The electric energy use is also monitored separately (Sabău, 2013) on each ventilation unit and each heat pump, respectively the gas use separately for ensuring the heat demand and kitchen equipment supply.

Centralizing all the sensors and measuring systems is done with a number of data-loggers (Figure 19.) placed in the high-school building and technical room. By assuring internet supply for the data collector devices, also the use of personalized automatic data processor software will provide relevant information regarding energy efficiency. Specialists, together with the administrator, will be able to adapt the utilization patterns of the building so that the energy use is reduced to a minimum (Boros 2015d).

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Figure 19. Data loggers

4. CONCLUSIONS

Energy-efficient buildings have gaining more attention due to internal comfort benefits and financial reasons. The presented building is unique in Romania, with a significant research potential, because of renewable energy use, a non-continuous occupancy factor, energy efficient design and construction. The monitoring system helps to find the right set of parameters for a better use of the building, including energy, heath and comfort for the users. The measured parameters obtain important information, which can be used in the design and construction of new buildings and thermal rehabilitation of existing ones, thus promoting a sustainable future and raising environmental awareness.

5. ACKNOWLEDGEMENTS

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