BUILDING ENERGY MODELING OF A STUDENTS’ RESIDENCE IN TIMIȘOARA

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Abstract. It is well known by know that buildings have a key role towards the reduction of energy consumption from fossil fuels and decarbonization of EU. However, currently there is little knowledge about energy demand from the higher education sector. Addressing energy efficiency in buildings of higher education institutions emissions is particularly important. This paper presents the case study of a student residence, which is currently under construction in Timisoara, Romania. The building has highly energy efficient envelope and ventilation with heat recovery. The study is focused on assessing the energy consumption and indoor environmental conditions of the building by means of energy modelling and hourly simulation. The building consumes in total 132.55 kWh/m²year, which is below the maximum limit for class A of energy efficiency in Romania.

Keywords: energy efficiency, building energy modelling, hourly simulation, interior comfort.

1. Introduction

It is well known already that buildings account for approximately 36% of the greenhouse gas emissions in the European Union. Therefore, the concern related to the energy consumption of buildings has become widespread and resulted in all kind of measures to reduce building’s impact on the environment. Various studies show that the highest potential for reducing energy consumption from fossil fuels and the related greenhouse gas emission (GHG) lies in the building sector [1]. Therefore, improving buildings from the energy performance perspective is crucial towards achieving the European Union long term goal of reducing greenhouse gas emissions with 80-95% by 2050 compared the levels in 1990 [2]. New buildings designed and constructed in the present have a great energy efficiency and optimisation potential. Addressing energy efficiency in buildings of higher education institutions emissions is particularly important. In a study made by Petidis et al [3], several scenarios for reducing the energy consumption of a students’ residence were investigated and led to energy savings of about 36%. The study concluded that energy saving measures should be focused on the thermal insulation of the building envelope, use of efficient lighting and appliances and...
reduce energy waste [3]. The use of simulation models for building energy is suitable for both the design of energy-efficient buildings and the design of renovation solutions for existing building stocks and allows a precise and detailed calculation of the building energy requirements for providing a comfortable and healthy indoor environment under the influence of external factors. This paper presents the energy modeling and simulation results for a students’ residence. The main goal of this study is to assess the energy use of the students’ residence and validate the energy performance of the building envelope in combination with the designed HVAC system.

2. Case study building

2.1. Architectural and functional characteristics

The building subjected to analysis is a new student residence, currently under construction, located in the city of Timisoara, south-west Romania. From architectural perspective, we can see the building has quite an interesting layout, with the horizontal plan presented in the situation plan in Fig.1.

![Fig. 1 – Site location and orientation of the building](image1)

![Fig. 2 – Architectural renderings](image2)
In Fig. 2 are presented the architectural renderings of the building. The building has a total of 9 levels, including the basement and top withdrawn floor. From a functional point of view, in the basement there are technical spaces and parking lots. The ground floor contains administrative offices, technical spaces and spaces for commercial activities. On floors from 1 to 6, there are 222 student accommodation rooms, each equipped with 3 beds, except one room per each floor, which is equipped with only 2 beds and arranged for students with disabilities. The top floor is composed of a study room and a gym, which provide optimum conditions to the students for individual learning and recreation. Also, on the top floor there are technical spaces where the building equipment are placed. The building facades are composed of two main types of exterior walls, presented in Fig. 3. The walls of the top floor consist in masonry walls with 10 cm layer of insulation. The floors that are in contact with the outdoor environment (terraces, floor above ground level) are also insulated with at least 20 cm thickness of thermal insulation. Table 1 presents the thermal transfer resistance of the envelope elements, as they were used in the simulation.

![Wall type 1](image1)
![Wall type 2 (curtain façade)](image2)

**Fig. 3 – Main types of exterior walls**

**Table 1**

| Envelope element                              | Thermal transfer resistance [m²K/W] |
|-----------------------------------------------|------------------------------------|
| Exterior walls type 1                         | 5.94                               |
| Exterior walls type 2                         | 6.16                               |
| Exterior walls top floor                     | 4.63                               |
| 6th Floor Terrace                             | 5.23                               |
| Top floor terrace                             | 5.65                               |
| Floor above ground level                     | 5.77                               |
| Windows (triple glazed and aluminium frame)   | 1.25                               |

### 2.2. HVAC system

The building is equipped with a complex system for heating, cooling and ventilation. The heating plant consists in a 1440 kW boiler, while the cooling plant is a chiller that has a thermal power of 1200 kW. The building is heated/cooled by using 4 pipe fan coil
units installed in the ceiling. Fresh air is provided by means of mechanical ventilation with the help of an air handling unit, equipped with heating and cooling coils and heat recovery with a minimum efficiency of 50%. The air handling unit only serves the spaces from 1st Floor to the top floor. The distribution of fresh air is developed horizontally for each level. The connection between the air handling unit and the horizontal distribution on each floor is made by means of two air columns. Each room is connected independently to the main distribution channels. The fresh air is supplied in rooms and the exhaust air is extracted from bathrooms. The air transfer between bedrooms and bathrooms will be made through transfer grids preferably placed in doors. The mechanical ventilation system assures a slight pressurization of the entire buildings. Domestic hot water is provided with the help of the heating boiler and solar collectors placed on the roof terrace. The solar collectors are with vacuum tubes, mounted with an angle of inclination of minimum 25° between horizontal and panel.

3. Building energy modelling using VABI Elements

Building energy modelling is the computational simulation, performed to estimate and evaluate the energy consumption of a building. A building energy model is created in a simulation tool and represents the most effective way of predicting consumption of energy of a building in the design phase [4]. The energy performance of a building can be analyzed by means of steady-state or dynamic simulation. Depending on the type of simulation and used software, the volume of input data and complexity and accuracy of the results might vary significantly. The process of whole building energy modelling (BEM) for dynamic energy simulations is a complex activity that requires detailed information related to the building envelope, systems and operation. The study presented in this paper is based on a complex energy modelling of the students’ residence by using Vabi Elements tool. The building simulation module in Vabi Elements simulates hourly energy flows and temperatures for a whole year, presenting results and visualizations of the building’s performance. The calculation is based on the selected building characteristics such as climate, HVAC systems, internal heat gains and the properties of the building materials. The software calculates hourly temperatures and the heating and cooling energy use of the building.

3.1. Modelling building envelope and thermal zones

This study aims at determining the energy use associated to student accommodation and facilities, therefore the basement and the ground floors were not considered in the calculation. However, the ground floor was introduced in the building energy model in order to properly assess the heat transfer between the first floor and ground floor. To create the building energy model, division of the building into thermal zones was the first step. Not to confuse a thermal zone with a geometrical zone. A thermal zone is the space inside the building that is characterized by the same set-point temperature and ventilation requirements and has negligible temperature variation between rooms.
A thermal zone can be composed from multiple rooms of the building. The studied building was divided into several types of thermal zones on each floor as follows: bedrooms, bathrooms, kitchen, laundry room, and corridors. In Figure 4 is presented the thermal zoning pattern of floors from 1 to 6. Each zone is coloured differently, depending on the type of thermal zones. For rooms, there are thermal zones that include 14 rooms, 4 rooms, 6 rooms, and 3 rooms. Similarly for bathrooms. The whole corridor area was considered as a single thermal zone, as well as the kitchen and dressing room. The top floor is divided into four thermal zones: study room, gym, corridors, and technical spaces. Figure 5 presents a perspective of the building energy model geometry.

### 3.2. Occupancy and lighting schedules

Internal heat gain is divided into gains associated to the building occupants and heat gains coming from the lighting system. Schedules of use are linked to the internal heat production of people and lighting. The building has a total of 222 rooms, out of which 216 rooms have 3 beds and 6 rooms have 2 beds, accommodating a total number of 658
students. Thus, for each thermal zone, depending on the number of rooms included, the corresponding number of people was defined. The rooms’ occupancy schedules were defined hourly, as fraction of the total number of inhabitants and is presented in Fig. 6. Similarly, the schedules were defined for the other thermal zones: kitchen, corridors, study room and gym.

![Fig. 6 – Rooms occupancy schedules](image)

A major part of the energy consumed by the interior lighting in the building becomes a heat gain and influences the building energy balance. In order to define as accurate as possible the internal loads associated to interior lighting, hourly use schedules were defined for each thermal zone, as fraction of the maximum lighting power. The data for lighting was defined separately for each thermal zone, depending on the lighting requirement established based on the room activity [5]. The rooms lighting schedules used in the building energy simulation are presented in Figure 7.

![Fig. 7 – Rooms lighting schedules](image)

In the occupancy and lighting schedules, we distinguish the days of the week, and the holidays. Being a students’ residence, the holidays include the summer vacation and the...
winter holiday. Thus, the simulation does not include the period from July until the end of September and the last two weeks of December.

3.3. Heating, cooling and ventilation

In order to assess the energy consumption of the building, interior air temperature was defined as control parameter for each thermal zone. The design temperature differs depending on the room destination and were defined in accordance with the Romanian standards [6]. Table 2 presents the heating and cooling temperature set-points for each type of thermal zone and the ventilation flow rate, extracted from the design project. The simulation was performed considering continuous operation of the HVAC system.

| Room type    | Heating temperature [°C] | Cooling temperature [°C] | Ventilation flow rate [m³/h] |
|--------------|--------------------------|--------------------------|----------------------------|
| Bedroom      | 22                       | 25                       | 90                         |
| Bathroom     | 24                       | 25                       | 90                         |
| Laundry      | 20                       | 25                       | 160                        |
| Study room   | 22                       | 25                       | 1800                       |
| Gym          | 18                       | 25                       | 560                        |
| Corridors    | 20                       | 25                       | 1000                       |

The building energy model accounts for air infiltration of exterior building enclosure area. The number of air changes due to infiltration rate was set to 0.20 h⁻¹ for thermal zones in contact with outdoor air. The air handling unit, boiler and chiller characteristics were defined using the parameters from the technical documents of each equipment.

3.4. Weather data

In addition to data relating to the building operating state, accurate weather data is required to suit the response of the building to external simulation conditions. The building is located in Timișoara and corresponds to climate zone II in accordance with Romanian regulations [7]. The weather data used in this study was provided by ASHRAE IWEC2 (International Weather for Energy Calculations). The IWEC2 weather files contain 'typical' year hourly weather data for Timișoara which can be used in building energy simulation programs [8]. Figure Fig. 8 show the graphs for air temperature hourly variation, with a maximum of 34°C and a minimum of -12°C.
4. Results and discussion

4.1. Energy consumption

Table 3 shows the simulation results related to annual energy consumption on categories of consumption. The highest energy consumption is related to domestic hot water preparation, representing approximately 35% of the total annual energy consumption of the building, followed by heating with a percentage of 33% (Fig. 9). The building consumes in total 132.55 kWh/m²/year, which is below the maximum limit for class A of energy efficiency in Romania. The solar contribution is not so high because the building is not in use during summer, when the solar hot water production is maximum.

| Consumption category               | Simulation results [kWh/m²/year] |
|-----------------------------------|----------------------------------|
| Heating                           | 43.3                             |
| Domestic hot water                |                                  |
| (natural gas)                     | 43.2                             |
| Domestic hot water                |                                  |
| (solar)                           | 3.67                             |
| Cooling                           | 3.00                             |
| Ventilation and pumps             | 26.02                            |
| Lighting                          | 14.07                            |

Fig. 8 – Hourly exterior air temperature in Timișoara – typical year
As we can see in Fig. 10, the consumption for ventilation and pumps has similar values for all the months of the calculation period. The highest consumption for heating energy is reported in January and a very low heating energy consumption can be observed in May. It is noticeable the energy consumption for cooling, which has a very small value due to the fact that the building is not in use for most of the summer, when buildings require cooling.
4.2. Indoor air quality and thermal comfort

Besides energy consumption calculation, the software also calculates hourly temperatures in the thermal zones of the building, as well as comfort temperature. Comfort temperature is the average comfort temperature in the room, calculated as the average of air temperature and radiant temperature. Fig. 11 and Fig. 12 show temperature analysis for a randomly chosen room, for a day in February (with the lowest outside temperature) and a day in June (with the highest outside temperature during the calculation period). It is noticeable that the air temperature closely follows the comfort temperature, independently of the outside temperature variation.

![Fig. 11 – Daily temperature variation during heating season in a thermal zone which includes bedrooms – day with the lowest outside temperature (JUNE)](image1)

![Fig. 12 – Daily temperature variation during cooling season in a thermal zone which includes bedrooms – day with the highest outside temperature](image2)
5. Conclusions

This paper presents the process of energy modeling and simulation results of a student’s residence currently under construction, located in Timișoara, Romania. In terms of energy efficiency, the case study buildings combine highly insulated envelope with efficient HVAC, ventilation with heat recovery and also integrates renewable energy as a secondary source for domestic hot water. The energy evaluation results show that the highest energy consumption is related to domestic hot water and for space heating, followed by ventilation, lighting and cooling. The building can be classified in class A of energy consumption, having a total energy consumption below 150 kWh/m²/year (maximum for class A buildings in Romania). The HVAC systems manages to maintain proper indoor conditions, providing comfortable air temperature. The student residence in Timișoara is one of the few documented new buildings for student accommodation in the higher education system. The results of this study aim at providing some indicators in terms of energy efficiency for new buildings in this category.

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