The Influence of Layout on Energy Performance of University Building

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Abstract. This paper analyzes the impact of the layout of university building architectural design on the annual energy consumption of the south and north classroom in the severe cold regions of Xinjiang. The aim is to reduce the waste of energy in university buildings and promote sustainable energy and environmental development. Using the Shihezi meteorological data, the energy performance of the four university architectural design layouts proposed by the hypothesis was numerically simulated by Energy Plus, and the results obtained were compared and analyzed. Through research, the atrium has the greatest impact on the energy consumption of the classrooms inside the building. The most energy-efficient university building layout is designed with an Inside corridor. Energy-efficient and sustainable solutions are designed to meet the energy needs of the classroom through the layout of the building.

1. Introduction

In recent years, the use of building air conditioning systems has created a suitable building environment for human beings, but also caused energy waste, which affects the sustainable development of the environment [1]. In the case of more dense and closed public buildings, people have higher requirements for the indoor thermal environment of buildings [2]. The urgent need for environmental comfort in building interiors has led to a dramatic increase in building energy consumption, further exacerbating the urban heat island effect, which has caused all humanity to face the grim situation of global warming [3]. This way of relying on the consumption of large amounts of energy to maintain the indoor thermal environment of the building is undoubtedly a vicious cycle and unsustainable process [4]. Especially for university buildings, the building is large in size and has the character of big population density. It is also necessary to find a way to solve the problem of excessive energy consumption and uncomfortable building thermal environment [5]. This paper studies the layout design of the university building. The layout design is most suitable for university buildings, achieves the goal of energy conservation, and becomes the key to design sustainable buildings.

2. Methodology

2.1 Location and climate of the study area

The study area is Shihezi City, Xinjiang, located in the middle section of the northern foot of the Tianshan Mountains, on the southern margin of the Gurbantunggut Desert (eastern 84°58′~86°24′, north latitude 43°26′~45°20′), belonging to the typical temperate continent[6]. The winter is long and cold, the summer is short and hot, the annual precipitation is rare and the climate is dry[7]. The annual average temperature is between 6.5 and 7.2 °C, and the hottest month is July and August.
2.2 Creation a hypothetical model

The hypothetical university buildings are divided into four layouts, building with One-sided corridor, building with an Inside corridor, building with a courtyard and building with atrium. Among them, building with One-sided corridor is divided into two types: the south-facing classroom and the north-facing classroom. The university buildings all have five floors and the floor height is 4.2m. The buildings are north-south oriented, the function rooms are classrooms.

The Building envelope is designed as a three-layer structure consisting of an inner wall made of light concrete brick (300mm), Polyurethane thermal insulation (70mm) and cement mortar (20mm) on the substructure. The glazing is made of three-layered glass framed by aluminum plastic profiles with thermal brake. The roof consists of a Polyurethane roof insulation (150mm), All construction elements comply with the current local regulations in terms of thermal conductivity. The achieved thermal conductivity coefficient \( U \ [\text{W/(m}^2\text{K)}] \) is 0.34 for the outer wall, 1.74 for windows and glazing, 0.39 for the floor.

The layouts of five types of university building are carried out using Sketch Up. Type 1 is a building with One-sided corridor. This type is a model of the north classroom (Fig.1 a) and a model of the south classroom (Fig.1 b).

![Fig.1. Model of the university building with One-sided corridor (Type 1).](image)

Type 2 is a building with Inside corridor, which both has south and north classrooms (Fig.2).

![Fig.2. Model of the university building with Inside corridor (Type 2).](image)

Type 3 is a building with a courtyard. The courtyard, positioned in the central area of the building, is open to external factors. No glazing is applied on its top. The building has corridors facing the inner open space (Fig.3).

![Fig.3. Model of the university building with a courtyard.](image)
Fig. 3. Model of the university building with a courtyard (Type 3).

Type 4 is a building with a glazed atrium. The inner courtyard of the building is closed with the glazed skylight on the top (Fig 3). The corridors are facing the atrium space.

Fig. 4. Model of the university building with an atrium (Type 4).

2.3 Modeling and Simulations

The energy consumption simulation of the building uses Energy Plus. It can be used for comprehensive energy simulation analysis and economic analysis of building heating, cooling, lighting, ventilation and other energy consumption [8]. The Energy plus in this article is modeled based on the Open Studio interface.

These four types are characterized by different envelope surfaces depending on the availability of an atrium and its features. Table 1 show the envelope and space characteristics of the designed types. The south classroom area and north classroom area of the four types are the same. The Total conditioned building area of the four types are the same. The Total conditioned building area and the other spaces volume of type D are the largest in four types, are 12974m$^2$ and 58212m$^3$.

Table 1. Envelope and space characteristics of the designed types.

|                        | Type A | Type B | Type C | Type D |
|------------------------|--------|--------|--------|--------|
| South Classroom Area(m$^2$) | 4491   | 4491   | 4491   | 4491   |
| North Classroom Area(m$^2$) | 4491   | 4491   | 4491   | 4491   |
| Total conditioned building area(m$^2$) | 6487   | 10971.51 | 11162.8 | 12974 |
| Window-Wall Ratio(%)    | 35.92  | 32.38  | 37.7   | 24.31  |
| Classroom volume(m$^3$) | 18862.2| 37724.4| 21672  | 21672  |
| Other spaces volume(m$^3$) | 1996   | 1996   | 14330.4| 58212  |
3. Results
The simulations of energy performances of the university building types show the amount of energy demands for heating and cooling of the south and the north classroom throughout the year, as well as the total annual amount of final energy for the classroom heating and cooling.

3.1 Cooling of the south and north classroom
Fig. 5 shows the final energy demands for cooling on south and north classrooms monthly. In the cooling energy consumption diagram of the south classroom (Fig.5a), the cooling energy consumption of Type C last from March to October, while the other types last from March to November. In August, the cooling energy consumption was the largest, and the cooling energy consumption of type D was much larger than other types, reaching 51466.62 KWh. The cooling energy consumption of type D was higher than the other types every month.

In the north classroom (Fig.5b), the cooling energy consumption is significantly less than the south classroom, and the cooling energy consumption was the largest in July. The cooling energy consumption of Type D is still the highest compared to other types.

3.2 Heating of the south and north classroom
Fig.6 shows that period of heating demands coincide with district heating season in Shihezi, which lasts from November until March. In January, the heating energy consumption was the largest both in south and north classroom, is 24191.69KWh and 47105.99 KWh. In the south classroom (Fig.6a), the heating energy consumption of Type C is highest in each month of the heating cycle, while Type B has the lowest heating energy consumption.

The heating energy consumption of the north classroom is greater than the heating energy consumption of the south classroom. The heating energy consumption of Type A and Type B is almost the same.
3.3 Annual final energy of both the south and north classroom

The comparison of the annual cooling and heating energy consumption of the three types is shown in the figure 7. The summer cooling energy consumption of the north and south classrooms of the university building with an atrium are significantly higher than that of other types, which is 344193.6 KWh. And the heating energy consumption in winter is lower than that in the university building with a courtyard, which is 174551.35 KWh. The total energy consumption of the north and south classrooms of the university building with an atrium is also the highest among the three types, which is 518744.95 KWh. The total energy consumption and heating energy consumption of the university buildings with the inner corridor are the least among the three types, which are 156881.47 KWh and 431433.46 KWh. The total energy consumption of the three types in the north and south classrooms increases by about 11%.

4. Conclusions

This paper presents the impact of university building layout on energy consumption in the north and south classrooms of buildings under the severe cold weather conditions in Xinjiang. The study selected four different types of university buildings common layout, using Energy Plus software to simulate their annual building energy consumption, and conducted a comparative analysis to find the best university building layout design. The results show that the classroom energy consumption of university building with a courtyard and university building with an atrium is greater than that of university building with an inner corridor and university building with One-sided corridor. The
university building with atrium is only reduced heating in winter, compared with other types of buildings due to the chimney effect of the atrium. But the total energy consumption for the whole year is still the largest among these types of building layouts.

The research will help to design and optimize the layout of university buildings in the cold regions of Xinjiang. Considering the simultaneous use of functions and the same number of classrooms, we can first consider the university building with inner corridor, which is conducive to energy conservation and sustainability of the campus environment.

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