ISSN: 2710-0588

Energy Consumption Simulation of Winter Heating for a Building Based on DEST

Chen Wang

Henan Polytechnic University, Jiaozuo, China

Abstract

To address the issue of heating energy consumption in winter, this paper takes a public building in Zhengzhou City as an example and utilizes DEST simulation to analyze its energy consumption during winter heating. The simulated building energy consumption results indicate that compared to the baseline building, the designed building achieves a comprehensive energy saving rate of 38.53% and a heating energy saving rate of 37.35%.

Keywords

Winter Heating; DEST Simulation; Energy Saving; Heat Load.

1. Introduction

With vigorous economic development and sudden changes in the world situation, energy demand is steadily increasing, but energy reserves are running low. Alleviating the global energy crisis has become paramount, and finding new energy sources and technologies is crucial for the future development and progress of nations. In 2022, the total national electricity generation was 8848.71 billion kWh, and building energy consumption rose by 5% compared to the previous year, reaching 45.5% [1]. Public buildings account for 40% of this energy consumption. Given the current situation, the main energy consumption in public buildings is divided into: various office equipment energy consumption, lighting energy consumption, and air conditioning system energy consumption. As systems that regulate the environmental temperature to adapt to various working environments, air conditioning systems account for a high proportion of energy consumption in public buildings [2]. Therefore, the amount of indoor cooling and heating load determines the design focus of air conditioning systems. An important direction for achieving energy savings in public buildings is the precise calculation of the cooling and heating loads, especially the heating load.

Currently, various domestic scholars have conducted different studies on the energy consumption analysis of public buildings. This paper takes the winter heating of a public building in Zhengzhou City as an example and uses DEST for simulation analysis of winter heating energy consumption.

2. DEST Model Establishment

2.1. Building Overview

The building is located in Zhengzhou City, Henan Province, in a cold winter and hot summer climate zone, and functions as a dormitory building. The building has 4 floors, a total height of 15.5m, and a heated floor area of 3360m^2.

ISSN: 2710-0588

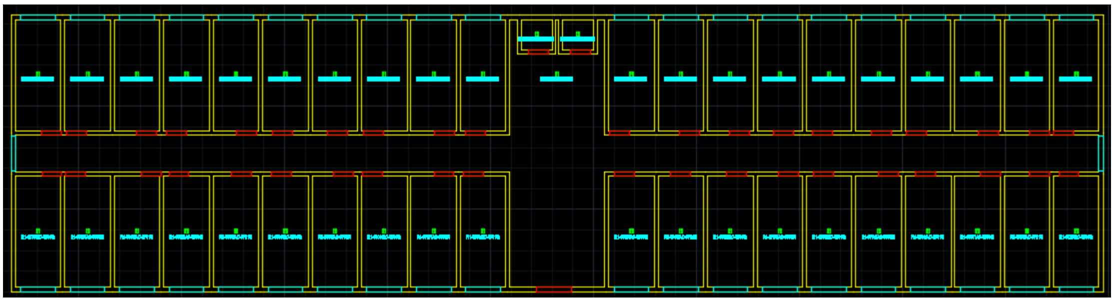

Figure 1. Building Floor Plan

2.2. Basic Modeling

First, CAD was used to draw the partition lines of each room based on the drawings, establishing each floor separately. As it is a dormitory building with consistent usage functions, the rooms are represented by a common color. After drawing all rooms, they were integrated and exported. The file was imported into DEST-H, a new building was created, followed by new floors, where only the room partition lines for that layer are displayed [3]. The building model is shown in Figure 2.

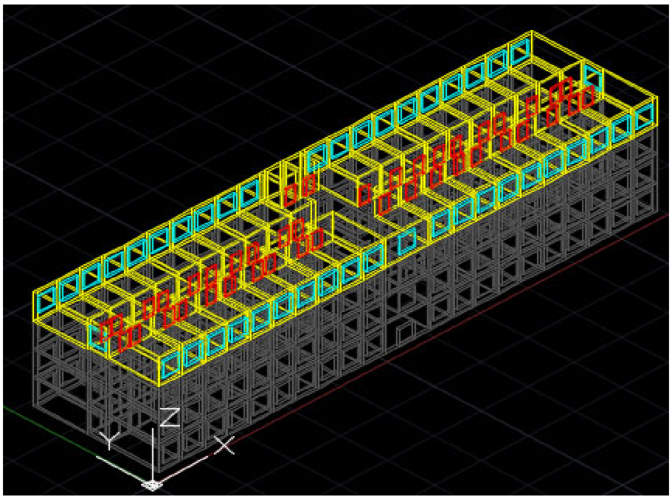

Figure 2. Dormitory Building DEST Model

3. Parameter Setting

3.1. Meteorological Parameters

The building uses the system's built-in settings. The city's meteorological reference obtained from the DEST software is shown in Table 1.

Table 1. Partial Meteorological Parameters for Zhengzhou City

City	South Orientation Angle	Longitude	Latitude	Ground Reflectivity
Zhengzhou	270	113.65	34.71	0.3000

3.2. Thermal Insulation Material Parameters

The thermal conductivity of insulation materials directly affects the heat transfer within building rooms. Different materials have different thermal conductivity coefficients; selecting

ISSN: 2710-0588

appropriate materials can reduce heat loss [4]. Based on the Design Code for Thermal Engineering of Civil Buildings, this paper uses different materials, as listed in Table 2.

Table 2. Thermal Parameters of Insulation Materials

Material	Thermal Conductivity (W/m·K)	Density kg/m³	Specific Heat Capacity kJ/(kg·K)	Correction Factor	Corrected Thermal Conductivity (W/ m·K)
Cement mortar	0.93	2500	1.05	1	0.93
Graphite EPS board	0.032	20	1.38	1.05	0.0336
XPS board	0.03	35	1.38	1.1	0.033
Fine aggregate concrete	1.28	2100	0.92	1	1.28
Aerated concrete block	0.14	500	1.05	1.25	0.175
FTC insulation mortar	0.07	300	1.05	1.25	0.0875

3.3. Building Envelope Parameters

Table 3. Building Envelope Parameters

Component	Composition / Window-to-Wall Ratio	Heat Transfer Coefficient (W/ m²·K)
External Wall	200mm reinforced concrete + 10mm adhesive mortar + 70mm graphite EPS board + 10mm mortar	0.403
Internal Wall	20mm FTC insulation mortar + 200mm aerated concrete + 20mm FTC insulation mortar	0.463
Roof	120mm reinforced concrete + 80mm XPS board + 40mm fine aggregate concrete + 30mm dry hard cement mortar	0.338
Floor Slab	100mm reinforced concrete + 40mm XPS board + 50mm fine aggregate concrete	0.602
East Window	0.35	1.8
South Window	0.30	1.8
West Window	0.35	1.8
North Window	0.30	1.8

In accordance with the "Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ134-2010)" (hereinafter referred to as the "Standard"), for residential buildings in Zhengzhou's hot summer and cold winter zone, energy saving measures

ISSN: 2710-0588

such as enhancing the thermal insulation performance of the building envelope and improving the energy efficiency ratio of heating and air conditioning equipment should be adopted. Under the premise of guaranteeing the same indoor thermal environment indicators, compared to before taking energy-saving measures, heating and air conditioning energy consumption should be reduced by 50% [5]. Since the standard has different requirements for the heat transfer coefficient of different window-to-wall ratios, and the shading coefficient (SC) for east and west external windows needs to be ≤ 0.45, appropriate building envelope components were selected. The parameters of the building envelope are detailed in Table 3.

3.4. Other Parameters

Internal heat gains are important parameters affecting the heat load. As the model in this paper is a student dormitory, the heat gains are related to the students' activities in the dormitory and are relatively fixed in time. See Table 4.

Table 4. Indoor Heat Gain Parameters

	Lighting (W/m^2)	Occupancy (W/m^2)	Equipment (W/m^2)
Time	6:00 -23:00	6:00 -24:00	6:00 -23:00
thermal disturbance	1.5	2.1	1.5

3.4.1. Ventilation Parameters

Occupants typically open and close windows to improve indoor air quality, which can lead to changes in indoor temperature. Therefore, indoor ventilation conditions also have a certain impact on the final simulation results. Generally, in northern regions, windows are opened for ventilation in summer to lower indoor temperature. When the outdoor temperature is very high, users employ air conditioning to reduce the indoor temperature and improve comfort. In winter, windows are also occasionally opened to refresh the indoor air.

4. Simulation Results and Analysis

As an indispensable building on campus, dormitories should consider energy saving and emission reduction. Dormitories occupy a large area, so based on the simulation results, their operational characteristics are analyzed to pave the way for energy-efficient buildings.

4.1. Analysis of Building Heat Loss

Before the standard simulation analysis, the internal heat gains were set to zero. Under these conditions, the heat consumption per unit area of the building calculated by DEST was 12.8 W/m^2. The average daily heating temperature output by DEST was 5.36°C, resulting in a temperature difference from the indoor temperature of 12.64°C, which differs significantly from the standard. The reason is: the standard assumes a heating period of 92 days, while the actual heating period in Zhengzhou is 120 days. Therefore, the temperature difference obtained by DEST is 89.7% of the standard value. Using 89.7% as a correction factor, the heat consumption per unit area is calculated, resulting in a winter heating load index of 14.27 W/m^2, which meets the standard requirements.

ISSN: 2710-0588

4.2. Heat Load Simulation Results

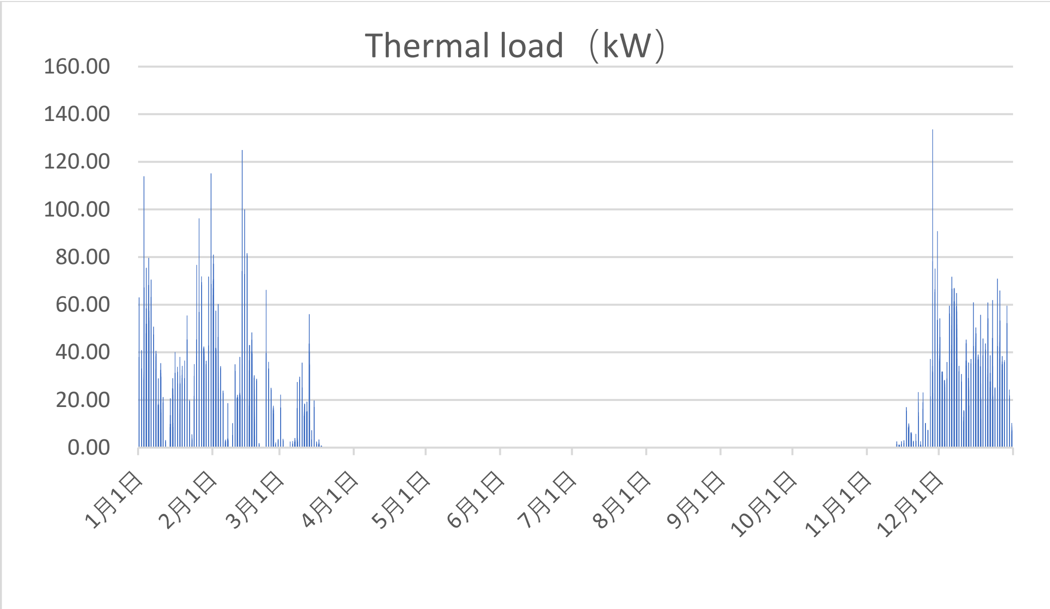

Figure 3. Building Hourly Load Throughout the Year

Loads are divided into cooling load, heating load, and moisture load. These three loads are the main parameters for selecting heating equipment and calculating system energy consumption. They vary depending on the room, occupant distribution, equipment operation time, and lighting usage. To provide students with a good living environment, a certain amount of heat (heating load) is required in winter.

Based on the model parameters, the annual cooling and heating loads can be simulated using DEST software, as shown in Figure 3. The total area requiring heating in the entire dormitory building is 4200m^2. The figure shows that the cumulative heating load during the heating season is 33723.07 kWh. The building's heating load is mainly concentrated from November to March because the average temperature from November to March is below 6°C, and most of the heat is used for heating. This aligns with Zhengzhou's heating season from November 15th to March 15th of the following year.

4.3. Typical Day Heat Load Analysis

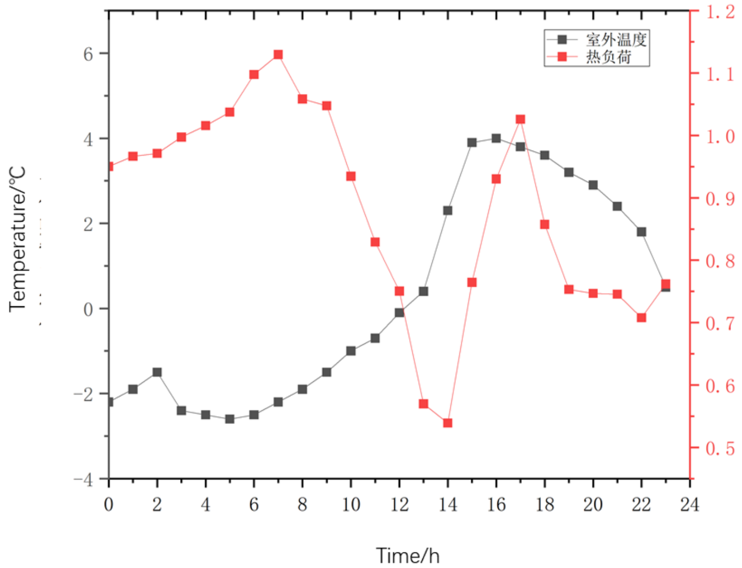

Figure 4. Variation Curves of Typical Day Heat Load and Outdoor Dry-Bulb Temperature

ISSN: 2710-0588

During heat transfer, the building envelope prevents direct heat transfer, causing the heat gain to exhibit attenuation and delay. For the heat load, its variation is mainly related to the temperature difference. Therefore, theoretically, the indoor temperature should change simultaneously with the outdoor temperature, but in reality, the indoor and outdoor temperature changes follow the same trend. The variations in outdoor dry-bulb temperature and indoor heat load for a typical day are shown in Figure 4.

From Figure 4, it can be observed:

① During 0:00-2:00, the outdoor temperature rises, and although the heat load has a downward trend, the slope is very gentle, almost imperceptible.

② During 7:00-8:00, the outdoor temperature rises slightly, while the indoor heat load shows a downward trend.

③ From 8:00-9:00, the temperature gradually rises, and the heat load changes slightly. From 9:00-10:00, the heat load drops sharply.

④ At 15:00, the outdoor temperature rises slightly and then begins to fall, but the peak heat load occurred at 14:00. After 14:00, the heat load gradually increases.

⑤ After 15:00, the outdoor temperature gradually decreases, but between 15:00 and 19:00, due to the thermal mass (heat storage capacity) of the building envelope, the building heat load even decreases within a certain range.

4.4. Building Energy Saving Analysis

The "Standard" stipulates: Building Energy Saving = (Baseline Building Energy Consumption - Designed Building Energy Consumption) / Baseline Building Energy Consumption. The building energy consumption defined in this paper excludes renewable energy and is considered as the building's own energy consumption. The baseline and designed values for building energy consumption are shown in Table 5.

Table 5. Energy Consumption Values for Various Building Components

Building Mode	Heating Season Heating /kWh	Heating Season Lighting /kWh	Heating Season Elevator /kWh
Baseline Model	90284.30	39940.95	1809.43
Designed Model	33723.07	21609.10	1809.43

The baseline building's own energy consumption value is 116.920 kWh/(m^2·a), and the designed building's own energy consumption value is 71.874 kWh/(m^2·a). According to the "Standard", the energy saving rate of this building is 38.53%.

Analyzing the individual energy consumption values, the relative energy saving rate for heating energy consumption is the largest at 37.35%. The energy saving in heating is the result of the combined effects of reduced cumulative heat load, exhaust air heat recovery, and optimization of the air conditioning system in the designed building. Calculations of the building load show that due to good airtightness and the external envelope, the cumulative heat load is reduced by 37.35%. Due to natural lighting design and the use of energy-saving lamps, the annual lighting energy consumption of the designed building is saved by 45.9%, verifying the role of natural lighting and energy-saving lamps in building energy efficiency. Because the optimized external envelope practice is not conducive to dissipating accumulated indoor heat when the outdoor temperature is suitable, the cumulative cooling load of the designed building in summer increased to some extent.

ISSN: 2710-0588

5. Conclusion

The building in this paper is located in Zhengzhou City, where the heating period is long, making energy saving of the heating system particularly important. Using the energy consumption simulation software DEST as a calculation tool, and based on the requirements of the "Standard", the building energy consumption was analyzed by establishing baseline and designed building models. The building's energy saving effect was evaluated based on the component energy consumption and the building's own energy saving rate. The energy saving effect of the designed building model was evaluated. The baseline building's own energy consumption value is 116.920 kWh/(m^2·a), and the designed building's own energy consumption value is 71.874 kWh/(m^2·a). According to the "Standard", the energy saving rate of this building is 38.53%. Among the individual energy consumption items, the relative energy saving rate for heating energy consumption is the largest, at 37.35%, indicating significant potential for energy savings. Good airtightness and the external envelope can reduce the cumulative heat load during the building's heating season.

References

[1] Wen Lei. Research on the Development Strategy of H Coal Enterprise [D]. Inner Mongolia University of Finance and Economics, 2024.

[2] Wang Zhonghua, Shi Xiugang, Yue Zengang, et al. Three-dimensional numerical study on anti-freezing characteristics of natural ventilation wet cooling towers based on constant heat load [J]. Thermal Power Generation, 2024, 53(06): 132-141.

[3] Wu Ruhong, Jiang Yi. Building Environment Design Simulation Software DeST Lecture 12: Software Architecture [J]. Heating Ventilating & Air Conditioning, 2005, (07): 54-67+121.

[4] Shen Heqing, Ye Wuping, Cao Liqiang, et al. Exploration of the evaluation index system for the technical performance of external wall external insulation [J]. Northern Architecture, 2024, 9(03): 109-114.

[5] Liu Qian. Application Analysis of Energy-Saving Technology in HVAC in Construction Engineering [J]. Intelligent Building & Smart City, 2024, (03): 119-122.