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Energy Consumption Simulation Analysis of Zhuyuan Dormitory Building in Zhengzhou

Bingqi Li*

School of Civil Engineering, Henan Polytechnic University, Jiaozuo 454003, China

*Correspondence Author: 18272697752@163.com

Abstract

As the Chinese economy rapidly transitions from high-speed to high-quality development, shocks to the energy industry structure drive the push for green transformation. Building energy efficiency emerges as the most effective solution to alleviate the economic and energy shortage contradictions, playing a crucial role in the strategy for sustainable development. The thorough consideration of energy efficiency in architectural design becomes paramount, highlighting the increasingly prominent role of building energy consumption simulation technology in this context. Therefore, energy-saving retrofitting is proposed for this building. Due to the excessively high heat transfer coefficients of the exterior walls and windows, there is significant potential for improvement. Consequently, this paper primarily focuses on the retrofitting of the building's exterior walls and windows to achieve energy efficiency. The retrofitting plan for the exterior wall involves transforming the existing 24-brick wall with polystyrene board insulation into a 24-brick wall with porous concrete and cement fiber board insulation. The retrofitting plan for doors and windows involves upgrading the single-layer 3mm ordinary glass to ordinary double-glazed glass with a 6+9+6 configuration (9mm space in between). After energy-saving retrofitting, the building's annual cumulative heating load is 38,426.15 KW·h, and the cooling load is 9,656.5 KW·h. The energy-saving rate reaches 11%, indicating a significant improvement in energy efficiency.

Keywords

Energy Consumption Simulation; Thermal Load; Building Energy Conservation; Energy-Saving Retrofit.

1. Introduction

With China's economy transitioning from high-speed development to high-quality development, the existing energy industry structure is facing impacts, prompting the shift of energy towards high-quality development. Therefore, the task of green transformation has also become a significant challenge currently faced. At present, among various approaches to alleviate the contradiction between economic development and energy shortages, building energy conservation is considered the most direct and effective method. Building energy conservation is a crucial component of China's sustainable development strategy, with energy-saving considerations playing a significant role in the building design process. Building energy consumption simulation is increasingly playing a crucial role in energy-saving decisions during the architectural design process. In this context, building energy consumption simulation technology, as a powerful tool in energy-efficient design, has received unprecedented attention.

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2. Building Overview

This project involves the energy consumption simulation analysis of Zhuyuan Dormitory Building in Zhengzhou City. The building has a total of 6 floors, with each floor having a height of 3.6 meters. The total height of the building is approximately 22 meters, and the total floor area is around 1800 square meters. The south-facing window-to-wall ratio is 0.37, and the north-facing window-to-wall ratio is also 0.37. The floor plan of the first floor is shown in Figure 1, and the isometric view of the dormitory building facing southwest is depicted in Figure 2.

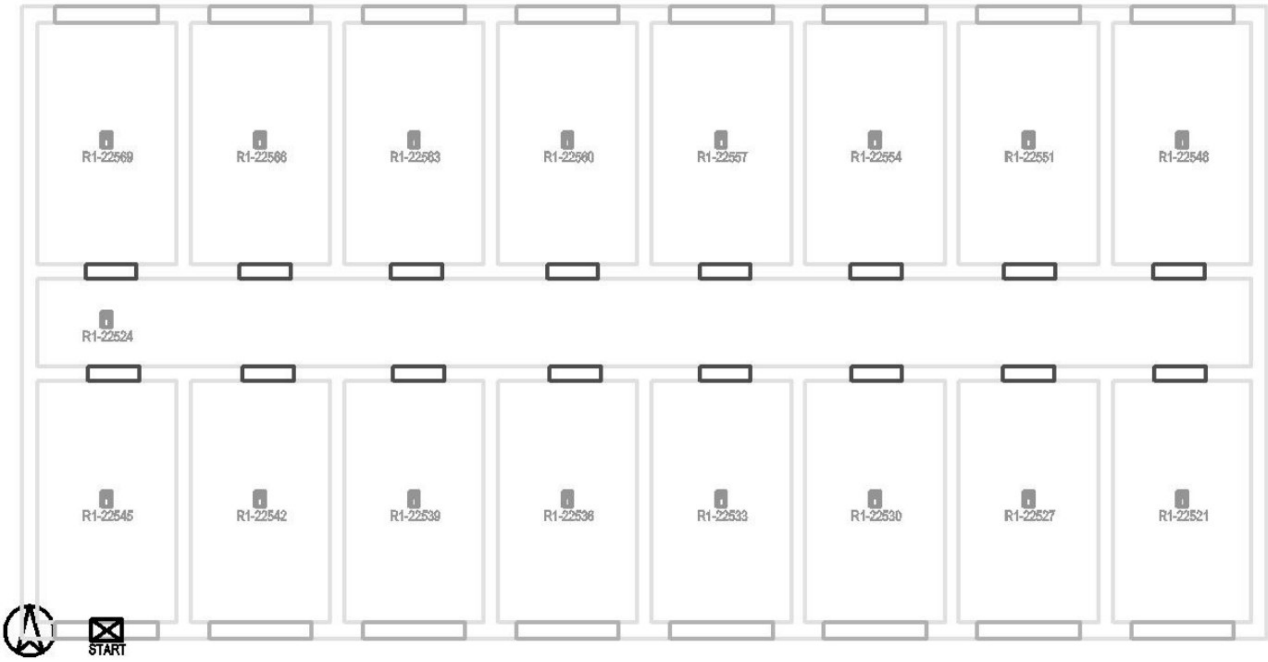

Figure 1. First Floor Plan

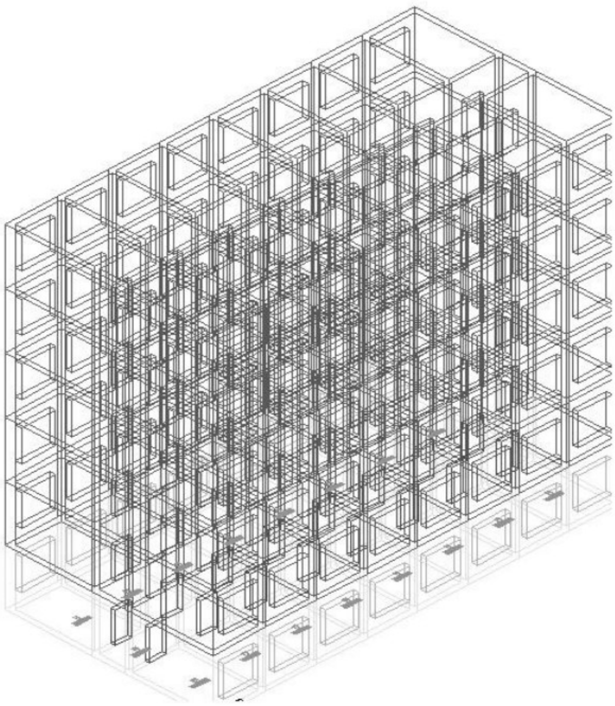

Figure 2. Isometric View of the Dormitory Building Facing Southwest

2.1 Enclosure Structure Parameters

Setting the model's building enclosure structure according to the actual construction enclosure structure materials, the input parameters for the building enclosure structure are as follows in Table 1.

Table 1. Enclosure Structure Parameter Table

Enclosure structure	Material composition	Thermal conductivity W/(m^2·K)	Thermal resistance (m^2·K/W)
Exterior wall	Heavy mortar clay 240mm	0.564	1.6
	Pure drywall 10mm		
	Polystyrene foam 60mm		
	Pure drywall 8mm		
Interior wall	Cement mortar 20mm	1.515	0.43
	Ceramic concrete 180mm		
	Cement mortar 20mm		
Roof	Cement mortar 20mm	0.812	1.074
	Porous concrete 200mm		
	Reinforced concrete 130mm		
Exterior window	Ordinary 3mm flat glass Height 2000mm, width 2000mm	6.4	/
Door	The wooden exterior door is made of pine and cloud Fir, thickness 25.3mm	/	/

2.2 Weather Parameters

Zhengzhou, the capital of Henan province, is located in the central part of China and experiences a temperate continental monsoon climate. The temperature is relatively moderate, making it suitable for habitation. After conducting DeST meteorological simulation, the hourly meteorological data and statistical values of various meteorological elements in Zhengzhou are as follows: the annual hourly dry-bulb temperature , hourly specific humidity throughout the year , and annual solar radiation statistics (see Figure 3).

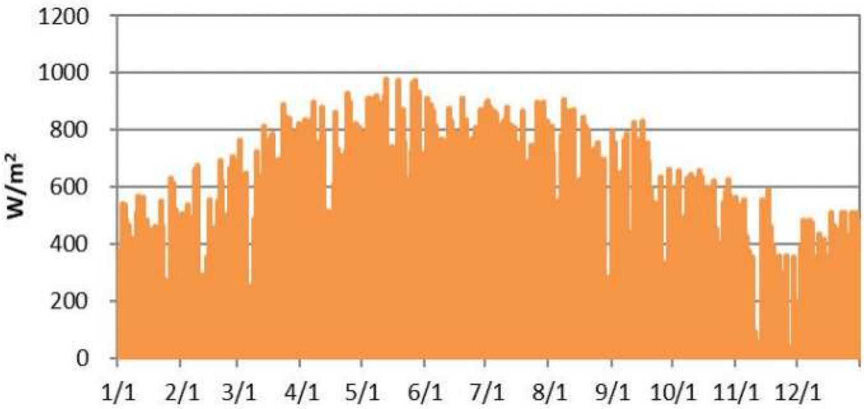

Figure 3. Hourly Solar Radiation in Zhengzhou

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3. Load Calculation and Analysis

The magnitude of the building's load determines the size of the heat source selection, and the characteristics of the building's load determine the energy consumption characteristics of the building. To achieve energy efficiency in buildings, it is essential to understand the characteristics of building energy consumption, and this necessitates a prior understanding of the load characteristics of the building.

3.1 Air Conditioning, Heating, and Classification of Transitional Seasons

The terms 'air conditioning season' and 'heating season' primarily refer to the periods when the air conditioning and heating systems are in continuous operation. Except for the air conditioning season and heating season, the remaining periods throughout the year are considered transitional seasons. During these transitional seasons, natural ventilation or solar energy can be fully utilized as natural cooling or heating sources to maintain indoor environments within the comfortable range for occupants, achieving maximum energy efficiency in building operation. The schedule for the heating and air conditioning seasons is provided in Table 2 below.

Table 2. Schedule for Heating and Air Conditioning Seasons

Seasonal Setting	Months	Date
Heating season start date	11	15
Heating season end date	3	15
Air conditioning season start date	6	1
Air conditioning season end date	8	30

3.2 Load Calculation

Based on the principles of dynamic energy consumption analysis, simulated results through DeST analysis are presented in Table 3.

Table 3. DeST Simulation Analysis Calculation Table

Statistical Items	Unit	Statistical Value
Building air-conditioned area	m^2	1728.00
Annual maximum heat load	kW	127.47
Annual maximum cooling load	kW	169.11
Annual cumulative heat load	kW·h	46781.97
Annual cumulative cooling load	kW·h	128031.98

Through the simulation calculation using DeST, it is determined that the annual cumulative heat load of the dormitory building is 46,781.97 kW·h, and the cooling load is 12,831.98 kW·h.

4. Building Energy Efficiency Retrofit

Due to the high thermal transfer coefficients of the external walls and windows of this building, there is significant room for improvement. Therefore, this study primarily focuses on energy-efficient retrofitting by modifying the external walls and windows of the building.

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4.1 Exterior Wall Retrofit

The retrofit plan for the exterior wall involves transforming the existing 240mm brick wall with expanded polystyrene (EPS) insulation to a 240mm brick wall with porous concrete and cement fiberboard insulation. The thermal resistance has been improved from 1.616m²·K/W to 0.951m²·K/W, enhancing the insulation performance of the wall and reducing overall building energy consumption.

4.2 Window Retrofit

The retrofit plan for doors and windows involves transforming the existing single-layer 3mm regular glass to ordinary insulated glass 6+9+6 (9mm gap). The window's thermal transfer coefficient has been reduced from 5.7 W/(m²·K) to 3.1 W/(m²·K), significantly improving the insulation performance of the windows and achieving energy-efficient retrofitting.

4.3 After the Energy-efficient Retrofit, Building Energy Consumption Simulation Analysis

After the energy-efficient retrofit, the building's annual cumulative heat load is 38,426.15 kW·h, and the cooling load is 9,656.5 kW·h. The energy-saving rate reaches 11%, indicating a significant improvement in energy efficiency.

5. Conclusion

This study, based on the principles of dynamic energy consumption analysis, utilized the DeST simulation software to conduct building energy consumption simulation analysis on a dormitory building in Zhengzhou. A comprehensive analysis of the load characteristics of the building, factors affecting the load of typical rooms, and the annual heat and cooling loads, as well as seasonal load indicators for the building, was performed. Following energy-efficient retrofit analysis, the exterior windows and walls of the building were subjected to energy-efficient retrofitting. The 240mm brick wall with expanded polystyrene (EPS) insulation was transformed into a 240mm brick wall with porous concrete and cement fiberboard insulation, resulting in a reduction of thermal resistance from 1.616m²·K/W to 0.951m²·K/W and an improvement in the insulation performance of the wall. The retrofit involved transforming the existing single-layer 3mm regular glass to ordinary insulated glass 6+9+6 (9mm gap). The window's thermal transfer coefficient was reduced from 5.7 W/(m²·K) to 3.1 W/(m²·K), enhancing the insulation performance of the windows. In the end, the energy-saving rate reached 11%, indicating a significant improvement in energy efficiency.

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