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RESEARCH ON MULTI-CRITERION DESIGN FOR ENHANCING THE SUSTAINABILITY OF MODERN ARCHITECTURE

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Abstract

This paper focuses on high-rise residential buildings in Hainan as the research subject. By considering multiple dimensions, including energy efficiency, material recycling and utilisation, and spatial layout optimisation, this study integrates the climatic and regional characteristics of Hainan with sustainable design theory, passive low-energy consumption technology, PKPM tools, and the application of Tsinghua Swel software to construct a multi-standard collaborative design framework. The effectiveness of the proposed design strategy was validated through case analysis, resulting in a significant reduction in energy consumption while ensuring indoor comfort within the building.
Keywords: Multi-standard combination, photovoltaic, thermal comfort, sustainability

Introduction

The principle of achieving building sustainability through the design of multi-standard combinations involves several key strategies: First, exterior structures are constructed using prefabricated methods, while interior walls incorporate prefabricated wall systems, thereby reducing carbon emissions. Second, by optimising the internal layout, natural ventilation is achieved, which not only reduces energy consumption but also enhances indoor comfort. Third, in respect for local culture, an elevated design is adopted for the first floor to enhance the microclimate. Fourth, photovoltaic power generation systems are installed on roofs to utilise renewable energy and reduce energy consumption. Finally, a green roof system is implemented, and external shading devices are applied to the facade to mitigate heat gain from auxiliary building heat sources. The following key data types are instrumental in reflecting the principles of sustainable design and their applications: First, optimise Energy Design: Based on energy consumption data and climate data, develop efficient HVAC systems and natural ventilation strategies. After calculating the building's heating and air conditioning loads along with its energy consumption, it was determined that the energy-saving rate of the envelope structure θ_{ENV} reached

$$\theta_{ENV} = \left(1 - \frac{E_{bld,des}}{E_{bld,ref}}\right) \times 100\% = 10.79\%,$$

Where $E_{bld,des}$ – total annual energy consumption of the designed building per square meter of the floor area, kWh/m^2×a;

$E_{bld,ref}$ – total annual energy consumption of the reference building per square meter of the floor area, kWh/m^2×a;

Second, Research on Multi-Criteria Design for Enhancing the Sustainability of Modern Architecture: An Integrated Optimisation Approach Focusing on Energy, Material, and Spatial Efficiency. Third, Enhanced user comfort: By leveraging user satisfaction and health data, the indoor environment design has been optimised. Table 1-3 represents the obtained results regarding the above-mentioned influence criteria before and after the optimisation.

Table 1. Carbon emission statistics table

Category	Annual operating carbon emissions per unit area of designed building ($kgCO_2/(m^2.a)$)	Annual operating carbon emissions per unit area of the reference building ($kgCO_2/(m^2.a)$)	Optimisation ratio %	Annual carbon emission reduction per unit area ($kgCO_2/(m^2.a)$)	Judgment
Heating	0.91	1.85	50.5	0.93	--
Air conditioner	3.56	9.21	61.37	5.65	--
Fan	0	0	--	0	--
Lighting	3.03	3.88	21.94	0.85	--
Elevator	1.13	1.13	0	0	--
Solar energy	-2.56	0	--	2.56	--
Greening the carbon sink	-0.58	0	--	0.58	--
The total	5.49	16.07	65.82	10.58	Meet the standard

Table 2. A list of calculated values for PPD and PVC

Room type	Room area (m^2)	Summer working conditions		Winter working conditions		Overall evaluation index	Whether it meets the standard
		PPD calculated value (%)	PMV calculation value	PPD calculated value (%)	PMV calculation value		
Living room	5251.5	5.03	0.04	12.28	-0.59	II	Yes
Bedroom	5853	5.03	0.04	12.28	-0.59	II	Yes
Kitchen	714.5	5.03	0.04	12.28	-0.59	II	Yes

Finally, achieve resource recycling: Based on water resource data and material recovery rate data, design rainwater collection and reuse systems for reclaimed water.

Table 3. Renewable Energy Utilisation Rate Calculation Table

Region		Residential building
Renewable energy	Photovoltaic power generation	39240
	Solar hot water	0
	Total	39240
Energy consumption volume	Annual heating consumption	0
	Annual cooling supply and consumption capacity	56169.64
	Annual heat consumption of domestic hot water	87600
	Annual energy consumption of the lighting system	46311.73
	Annual energy consumption of the elevator system	36891.24
	Total	226972.61
Utilisation rate of renewable energy		17.29%

Conclusions

Sustainable design guidelines must be quantified and rigorously evaluated using multi-dimensional data to ensure the environmental, economic, and social sustainability of the design. This article uses high-rise buildings in Hainan Province as a case study, translating sustainable design principles into a practical model applicable to tropical islands. The implementation has substantially reduced energy consumption while enhancing indoor comfort, achieving the one-star green building standard and offering a valuable reference for similar climate regions worldwide. Consequently, the design demonstrates successful integration of environmental, economic, and social sustainability.

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