Preliminary exploration of energy-saving residential design in hot summer and cold winter area taking Wuhan as an example

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Abstract. In today’s architectural design industry, building energy-saving design has become a hot topic, and it is a necessary link for the construction industry to implement sustainable development. However, most areas in China are in hot summer and cold winter. It is very meaningful to design energy-saving residential buildings in combination with the climate to make the buildings more livable and environmentally friendly. This paper demonstrates the design process of a small house in the suburbs of Wuhan, comprehensively considers the building shape, building natural lighting and ventilation, building maintenance structure, the actual application of new materials and new technologies for green house design. At the same time, it combines Ecotect and other computer technology to design the green house. The applied building energy saving technology is analyzed and optimized to provide new ideas for other related designs.

1. Introduction
With the growing of technology and economy, environmental problems are becoming more and more serious, and energy is ultimately limited. In addition to opening up and using new energy sources, energy-saving measures are also essential. Combining energy-saving measures with housing to create a living space that reduces energy consumption while improving the quality of life is bound to be loved by people.[1]

This article mainly describes the progress of the design of small houses in areas with hot summers and cold winters (take Wuhan as an example). The design combines the geographical conditions and climatic environment of Wuhan to create green and livable houses using energy-saving building technology. At the same time, computer software is used to simulate the situation of the building and to research the building energy efficiency data to optimize the building.

2. Preliminary investigation of architectural design
Wuhan has a typical climate with cold winter and hot summer, with obvious changes in wind direction in winter and summer. The dominant wind directions in winter are northerly and northeasterly winds, and the dominant wind directions in summer are southwesterly and southerly winds. The climate is relatively hot and humid.[2]

The selected base faces the south, with slopes in the northeast corner, the site’s own microclimate is formed between the mountains and rivers, the south wind in summer blows across the lake, and the north wind in winter is blocked by the undulating terrain, which makes the whole site in a more
suitable and stable climate. There is an old tree in the base, and the environment of the base itself has a
certain impact on the building's ventilation method and air conditioning energy consumption.

3. Scheme conception and energy saving design

3.1. General idea
Due to the influence of the terrain orientation and the basic regulations of Wuhan, the design of this
building chooses a north-south orientation, which can allow the summer wind to enter the room and
facilitate air circulation and heat exchange. In winter, due to the blocking of mountains in the east, the
cold wind can be effectively avoided. The shape of a building is closely related to energy-saving
design. Different building shapes will cause different solar radiation heat received by the building. In
order to save energy, the building should be compact in design to make the most of natural light and
ventilation[3].

Considering the characteristics of the comprehensive base, lighting, ventilation, and solar radiation,
this building adopts a rectangular shape. The body is as compact as possible while reducing the
external surface area. Due to the existence of ancient trees in the base, comprehensive consideration of
heating and ventilation decided to make the building enclose the ancient trees to form an atrium, and
the building was partially designed with three floors. The building as a whole faces the southwest
direction, introducing the lake and water into the building, and a small part of the building is
embedded in the southwest slope. The main entrance and garage are designed on the west side near the
road.

3.2. General layout design
Necessary functional zoning of the general plan is the prerequisite for determining the location of a
single building. Good functional zoning and green design can also save energy. The proposed building
size is 9m×16m, and the main shape is rectangular. There are three floors, facing north and south. Set
up road passages such as primary and secondary entrances and exits, vehicle entrances and exits.

Greening land mainly includes land for planting areas such as trees and lawns. By planting trees
and green plants, a natural barrier can be formed, which can guide the wind direction and beautify the
environment. The roof and building facade can also be designed for greening. There is an old tree
within the construction land, and the protection of the old tree should be considered during
construction.

The building faces the lake to the south, and a landscape platform is designed outside. The platform
is connected to the building and points to the lake surface. The second floor of the building is also
designed with a landscape platform, which not only increases the viewing surface but also plays a role
in shading. A small part of the building is embedded in the slope on the northeast side of the building.
One is to consider the thermal insulation design and the other is to introduce the mountain landscape.
The main entrance on the west side of the building is paved with sidewalk masonry roads, and the
accessible slope on the east side is designed with a pavilion for rest. Pave the road with cement, and
plant trees on both sides of the garage.

3.3. Building function design
The flow of the building should be concise and clear, and the whole can be designed around ancient
trees, forming a chimney effect in the center of the house, while using the self-purification ability of
plants to bring fresh air to the room. The living room, master bedroom and other rooms that need a lot
of light are arranged in a unified south direction, and the sun is used to the greatest possible extent to
achieve the purpose of passive energy saving. Terraces or sun visors are arranged on the second and
third floors south to play a role in shading. The second-story roof adopts the cast-in-place reinforced
concrete planting roof, which has good thermal insulation performance and can achieve the function of
recycling rainwater[4].
3.4. Energy saving calculation and building optimization

3.4.1. Computer simulation.
After the initial design of the building combined with the geographical environment, computer technology is now used to simulate the lighting and shading performance of the building, and the simulation results are used to further optimize the building’s energy saving[5].

Ecotect software and the sunflower plug-in in grasshopper, as a sustainable building analysis tool, can perform various energy-saving visual analysis of building models. They are widely used by domestic and foreign green building designers with high accuracy. Therefore, these two softwares are used in this simulation.

3.4.2. Energy saving calculation of building maintenance structure.
In addition to combining the local climate with lighting, shading, and ventilation, residential buildings can be designed for energy conservation in terms of roofing, exterior walls, doors and windows and other maintenance structures based on the geographical climate of Wuhan to improve livability and energy efficiency.

- **Body shape factor.** The body shape factor can indicate the heat transfer and heat consumption of the building maintenance structure. The building has a surface area of 487 square meters, a building volume of 1013 square meters, and three floors. The calculated building shape factor is \(0.48 \leq 0.55\), which meets the requirements.

- **Roof.** Two roofs are used in this design, the roof roof adopts cast-in-place reinforced concrete planting roof, and the rest roof adopts inverted XPS insulation roof. The planted roof has good thermal performance and can absorb toxic gases in the atmosphere. In addition, the planted roof can intercept about 70% of rainwater, reducing the discharge of urban sewage. The rooftop landscape also contributes to enriching the fifth facade of the building. Calculate the heat transfer coefficient of the cast-in-situ reinforced concrete planted roof to determine whether it meets the energy-saving design requirements. Roof type (top-down): planting soil layer (200.00mm) + honeycomb plastic water retaining and drainage spacer (12.00mm) + rigid waterproofing Layer (40.00mm) + white ash mortar isolation layer (10.00mm) + coil (coating) layer (4.00mm) + cement mortar leveling layer (20.00mm) + thermal insulation layer (25.00mm) + cement mortar leveling layer (20.00mm) + roof panel (100.00mm), thermal resistance value \(\Sigma R=2.29(\text{m}^2\cdot\text{k})/\text{w}\), thermal inertia \(D=4.73\), roof heat transfer resistance \(R_o=2.45(\text{m}^2\cdot\text{k})/\text{W}\), roof heat transfer Coefficient \(K=0.40\ w/(\text{m}^2\cdot\text{k})\), which satisfies the requirement of \(K \leq 0.60\) when the figure coefficient>0.40 and \(D>2.50\).

- **Exterior wall.** This design adopts foam plastic insulation wall, and now calculates its heat transfer coefficient. Type of exterior wall (from outside to inside): paint finish layer (10.00mm) + adhesive layer (5.00mm) + welded steel wire mesh frame (8.00mm) + polymer anti-cracking mortar: lime cement mortar (10.00mm) + foam glass (60.00mm) + interface agent mortar: cement mortar
(20.00mm) \pm \text{base wall: reinforced concrete (140.00mm)}, \text{thermal resistance Value } \Sigma R = 1.25 (m^2 \cdot k)/W, \text{thermal inertia } D = 2.48, \text{roof heat transfer resistance } R_o = 0.40 (m^2 \cdot k/W), \text{exterior wall heat transfer coefficient } K = 0.71 \text{ w/(m}^2 \cdot \text{k) }, \text{To meet the requirement of } K \leq 0.80 \text{ when the figure coefficient > 0.40 and } D < 2.50[6].

- Window. This design adopts Low-E insulating glass. The glass variety is 6mm white glass + 12mm air + 6mm sun-shading Low-E glass. Its shading coefficient is 0.41, heat transfer coefficient is 1.706, and SW=0.41[7].

4. Design results display
The following is a display of the results of the proposed design of the residence, including architectural technical and economic indicators, renderings, floor plans and section.

- Total building area: 303.9 $m^2$
- Total land area: 598 $m^2$
- Building density: 24%
- Volume rate: 0.51
- Green area rate: 39%
- Building height: 3.9m

Figure 2. Building renderings.
Figure 3. Technical drawings.
5. Conclusion

Building energy efficiency has become a global trend. It is not only conducive to the sustainable development of buildings and other industries, but also enables residents to live in a more natural and comfortable environment. The proposed design of a small energy-saving house in Wuhan is a preliminary exploration of green building design in cold winter and hot summer areas. The house is optimized through multiple steps such as preliminary design conception, computer simulation, and maintenance structure thermal performance calculations, and finally achieves lower housing energy consumption, to provide people with a more livable environment.

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