Energy-saving Design of the Enclosure Structure of Teaching Buildings in Severe Cold Areas

Li sheng Chen
Teaching And Research Office For Architecture, The Tourism College of Changchun University, Changchun City, 130000, China
525802150@qq.com

Abstract. In recent years, the energy saving issue in public educational places has attracted more and more attention from scholars in the society, especially the energy-saving design and construction of teaching buildings in severe cold areas have received widespread attention from scholars from all walks of life. In this paper, it will further analyze the energy-saving design of the enclosure structure of teaching buildings in severe cold areas, aiming to further improve the energy-saving design level of public buildings, so that construction projects can better serve education fields.

1. Introduction
During the normal operation of the building, the enclosure structure is an important part that affects its energy consumption. According to this fact, in the construction process, improving the exterior wall energy-saving technology and window design level have become important tasks in the entire construction project. At present, the exterior wall of the teaching building in the northern region is mainly composed of load-bearing materials. The exterior wall of the teaching building generally uses a composite thermal insulation material composed of cast-in-place concrete, hollow brick and polystyrene board. The windows are basically facing south, and double windows are mostly adopted. In this paper, the author will further design and analyze the energy-saving function of the enclosure structure of the teaching building, aiming to further enhance the energy-saving level of the enclosure structure of the teaching building in severe cold areas.

2. Energy-saving design and thermal engineering design of the enclosure structure
2.1 Design items of the enclosure structure
In the energy-saving thermal engineering design of the enclosure structure of the teaching building in severe cold areas, the area of the enclosure structure in the room should be decreased as much as possible, the shape and structure of the building should be controlled in a reasonable range, and the uneven surface should be reduced to achieve the purpose of energy saving. The exterior protective structure of the teaching building mainly includes roof structure, exterior wall structure, outdoor floor slab, ground structure and exterior doors and windows, where the exterior wall structure and exterior window account for an important proportion. In the energy-saving design of the enclosure structure, it is necessary to select the appropriate energy-saving structure according to the actual conditions of the above parts and the energy consumption of the building in the severely cold area, and to perform accurate thermal calculations to ensure that each part can meet the requirements of China's mandatory
energy-saving standards to ensure that the energy-saving and thermal engineering design for public buildings in severe cold areas can meet reliability requirements.

2.2 Analysis of energy consumption of the enclosure structure

The energy consumption of the teaching building mainly includes the energy consumption of the air conditioning and lighting system, the energy consumption of the heating and ventilation system, and the energy consumption of the enclosure structure system. In particular, the energy consumption of the enclosure structure system in severe cold areas is even greater. In order to achieve the goals of energy conservation, consumption reduction and emission reduction, and reduce the energy consumption of public buildings as much as possible, attention should be paid to energy conservation and thermal engineering design of buildings in severe cold areas.

The energy consumption of the enclosure structure is composed of the heat transfer consumption of the enclosure structure and the air penetration energy consumption in the gap between the door and window. The heat transfer consumption of the enclosure structure accounts for 55% to 80%, the energy consumption of air penetration in the gap between the door and window accounts for 25% to 40%. Table 1 compares the heat transfer coefficient of the enclosure structure under different energy saving standards. From the table, it can be seen that the energy consumption of non-energy-saving buildings is twice that of buildings with an energy-saving standard of 65%. Due to the existence of a large number of non-energy-saving buildings, the energy efficiency of existing buildings is not ideal, and a large amount of heat energy is lost through the enclosure structure.

| Year                        | Exterior wall | Roof | Exterior window |
|-----------------------------|---------------|------|-----------------|
| 1980 (base energy consumption) | 1.25          | 0.80 | 3.26            |
| 2006 (energy-saving standard of 65%) | 0.50          | 0.40 | 2.12-2.18       |

Note: The thermal coefficient of exterior windows with an energy saving standard of 65% varies depending on the area ratio of windows and walls.

Generally, it usually consider the key parts of the enclosure structure for the energy saving. Due to the limitations of the current domestic technical level and economic rationality, the heat transfer coefficient limit of the enclosure structure is determined on the premise of meeting the total building heat consumption index. It should focus on the exterior walls and exterior windows, with due consideration to the roof, while the floor, ground and core panels under the balcony door still use 50% energy-saving standard.

The heat transfer consumption of the enclosure structure for per unit construction area should be calculated according to the following formula:

\[ q_{HT} = (t_i - t_e) \left( \sum_{i=1}^{m} \varepsilon_i \cdot K_i \cdot F_i \right) / A_o \]

- \( t_i \) — The average indoor calculated temperature of all rooms (°C)
- \( t_e \) — The average outdoor temperature during heating period (°C)
- \( \varepsilon_i \) — Correction coefficient of heat transfer coefficient of enclosure structure
- \( K_i \) — Heat transfer coefficient of enclosure structure [W/(m².K)]
- \( F_i \) — The area of the enclosure structure (m²)
- \( A_o \) — Building area (m²)

3. Energy-saving design of enclosure structure

3.1 Exterior wall insulation system
3.1.1 EPS module. High-rise civil buildings can use EPS and concrete one-time cast-in-place exterior insulation system, which is called EPS module. The operation mode of this system is as follows: the corresponding horizontal tank is built on the inside of the building, and the interface mortar EPS board is sprayed on the inside surface, and then it is placed inside the formwork in the exterior wall of the high-rise building. The staff should note that after completing the above tasks, it is also necessary to set the corresponding tracing bolt as firmware. After pouring the concrete, the wall, bolt and EPS board will be combined. After the mold is removed, the EPS board should be leveled, and the anti-crack layer or protective layer is added to decorate it. EPS module is the most commonly used exterior insulation method for high-rise civil buildings in the north.

3.1.2 Advantages of EPS module. For a high-rise teaching building, 100 mm thick rock wool insulation board (Class A) is used as the first layer of exterior wall insulation, with a thermal conductivity of 0.044 and a bulk density of 140 kg/m³. For the floors above the second floor, a 100 mm thick EPS module (Class B1) is used with a thermal conductivity of 0.033 and a bulk density of 30 kg/m³. The fire barrier is made of foamed glass (Class A) and it has a height of 300 mm. The thermal conductivity is 0.052 and the bulk density is 140 kg/m³. It can be seen that the thermal conductivity of the EPS module is lower, so the indoor building has better heat dissipation effect and energy saving effect. (As in Table 2)

Compared with the traditional EPS polystyrene board, the density of the EPS module is increased by 35%, the compression strength is increased by 31%, the thermal conductivity is reduced by 16%, the fused fracture bending load is increased by 25%, and the tensile strength perpendicular to the board surface is increased by 30 %.

Table 2 Comparison of parameters of different exterior wall insulation systems

| Material                                | Level  | Thermal conductivity | Bulk density (kg/m³) |
|-----------------------------------------|--------|----------------------|----------------------|
| 100mm rock wool insulation board        | Class A| 0.044                | 140                  |
| EPS module                              | Class B| 0.033                | 30                   |
| EPS polystyrene board                   | Class B| 0.038                | 45                   |
| Foam glass                              | Class A| 0.052                | 140                  |

3.2 Window settings
Light environment includes sunlight, daylighting, and lighting. The classroom needs sufficient light, which not only aims to ensure the indoor temperature, to ensure the smooth progress of the teaching tasks, but also to adjust the mood of the students, so the window should be set to ensure the lighting range and lighting time. At the same time, it should pay attention to shading and deal with glare, should avoid damage to students' eyesight. We also need to use windows to further optimize the indoor acoustic environment, light environment and thermal environment. As a public place, the teaching buildings should maintain good ventilation and rational layout to prevent the obstruction of sight. The window setting also needs to avoid noise interference, pull the vertical and horizontal distances of the building far from the noise source, or perform a sealed barrier. The most important design item in severe cold areas is that the teaching buildings should have thermal insulation effect.

3.2.1 Energy-saving design of exterior windows. The design for exterior windows include four forms according to different stages:

- Environmental protection structure combination that meets 65% energy efficiency standards of public buildings: the outer window adopts aluminum alloy broken bridge double-layer hollow Low-E (3+12+3) glass, and the heat transfer coefficient is \( U = 1.78 \text{ W/m}^2\text{K} \).
- Environmental protection structure combination that meets 50% energy efficiency standards of public buildings: the outer window adopts aluminum alloy thermal insulation double-layer hollow Low-E (3+12+3) +600 glass, with 600-wide horizontal sunshade, heat transfer coefficient is \( U = 1.66 \text{ W/m}^2\text{K} \).
The most ideal combination of outer protective structure is as follows: the outer window adopts double-layer hollow Low-E (6+12+6, inner insulation film) glass with broken bridge aluminum alloy frame material, with 600-wide horizontal sunshade, heat transfer coefficient is $U = 1.62 \text{ W/m}^2\cdot\text{K}$.

### Table 3 Comparison of different exterior window form parameters

| No. | At the stage | Form of the exterior window | Heat transfer coefficient |
|-----|--------------|-----------------------------|--------------------------|
| 1   | 1980 (base energy consumption) | Aluminum alloy frame ordinary single-layer transparent glass (3 layers) | 5.69 |
| 2   | 2006 (65% energy saving) | Aluminum alloy thermal insulation double-layer hollow Low-E (3+12+3) glass | 1.78 |
| 3   | 50% energy saving | Aluminum alloy thermal insulation double-layer hollow Low-E (3+12+3) +600 glass, with 600 wide horizontal shade | 1.66 |
| 4   | Optimal state | Broken bridge type aluminum alloy frame material double-layer hollow Low-E (6+12+6, inner thermal insulation film) glass, with 600 wide horizontal shade | 1.62 |

In severe cold areas, windows should face south, which is the basic common sense in architecture field, the design should fully consider the area ratio of the window to the wall and the heat transfer coefficient of the window, especially when designing the glass curtain wall with high thermal performance requirements. The double glass has an air intermediate, it can increase the temperature difference between the inner and outer layers glass in more than ten times, can reduce the radiation of cold air, keep the indoor warm, and avoid the loss of classroom heat. The outside and inside wall should adopt different double-glazed glass. In the architectural design, transparent glass and heat-absorbing glass should be used in combination. When there is no heat source indoors, it can receive the heat radiation from the sun, it should adopt heat-absorbing glass, and at the same time, it should use a layer of transparent glass on the outside, which can effectively absorb the energy dissipated to the outside. At the same time, the heat transfer coefficient should be reduced, achieving energy saving and environmental protection. Practice has proved that the fourth type of exterior window has the lowest heat transfer coefficient, so it can achieve the best energy saving effect. (As shown in Table 4)

### Table 4 Comparison of heat transfer coefficients of different exterior window forms

![Heat transfer coefficient chart]

#### 3.2.2 Window setting strategy

- Improve the accuracy of glass, strictly measure the size of windows, reduce the width of window gaps, and avoid air infiltration.
- Improve the airtightness of the outer window, and use sealant or sealing strip to ensure the tightness of the window.
- Scientifically design the window form to reduce the gap.
- Reduce the energy consumption during ventilation, and adopt energy-saving ventilation device to achieve energy-saving effect.

3.2.3 Shading technology of exterior windows. In order to avoid the impact of the direct sunlight on the teaching tasks, it is necessary to carry out shading treatment on the transparent enclosure of the building to reduce the heat radiation in summer, and two modes of fixed shading and active shading can be used. First of all, the fixed sunshade mode has better appearance and is very effective in blocking direct sunlight, but it does not play a corresponding role in blocking scattered and reflected light. It can provide a good shading effect in summer, and it also allows solar radiation and penetration in winter. Active shading refers to shading equipment that can be adjusted and retracted. It can generally be installed outdoors or between two or three layers of glass. It can guarantee to block sunlight radiation, at the same time, it can also allow sunlight to enter according to actual needs, it can meet the sunshade needs in most regions. Therefore, the enclosure shading project should be based on the actual situation of the specific enclosure design, we should reasonably choose shading technology, ensure the stability and adjustability of the internal environment of the teaching buildings according to the specific situations, so that the enclosure engineering can service for the building.

Table 5 Comparison of sunshade window parameters

| The orientation of the teaching building | Area ratio of window to wall | Practice name | Heat transfer coefficient (W/m²·K) | Shading coefficient |
|----------------------------------------|----------------------------|--------------|-----------------------------------|-------------------|
| East                                   | 0.20                       | Broken bridge type aluminum alloy frame material double-layer hollow Low-E (6+12+6 inner insulation film) glass, with 600 wide horizontal shade | 1.65              | 0.75              |
| West                                   | 0.05                       | Broken bridge type aluminum alloy frame material double-layer hollow Low-E (6+12+6 inner insulation film) glass, with 600 wide horizontal shade | 1.64              | 0.75              |
| South                                  | 0.19                       | Broken bridge type aluminum alloy frame material double-layer hollow Low-E (6+12+6 inner thermal insulation film) glass, with 600 wide horizontal sunshade | 1.62              | 0.75              |
| North                                  | 0.05                       | Broken bridge type aluminum alloy frame material double-layer hollow Low-E (6+12+6 inner insulation film) glass | 1.68              | 0.72              |

4. Conclusions
This paper analyzes the energy-saving design of the enclosure structure of teaching buildings in severe cold areas, it focuses on the energy-saving technology on exterior walls and windows of teaching buildings, and puts forward a series of strategies to ensure energy-saving design can be smoothly progressed. Only by continuously improving the technical level, choosing effective energy-saving structures and energy-saving schemes according to local conditions, and strictly implementing the national mandatory energy-saving standards, can energy-saving and environmental protection be
effectively achieved. The author also hopes that this paper will arouse the attention of the researchers in the field, hope they can pay more attention to the design of buildings in severe cold areas, improve the quality of buildings in severe cold areas, and further develop green buildings and energy-efficient buildings.

References
[1] Geng, F., Wu, X.Y. (2016) Simulation analysis of energy efficiency in public buildings in cold regions. Energy efficiency in buildings, 11:60-62.
[2] Zhou, M.R., Kong, J., Ruan, W.Y. (2010) The suitability analysis of external wall external insulation system. Low temperature building technology, 06:116-118.
[3] Dong, Y.Y., Zhang,P.T.,Wu,Z.Z. (2013) On the construction management and quality control of metal and stone curtain wall engineering projects. Construction Economy, 04: 4.
[4] Zhang, L. (2007) China Terminal Energy Consumption and Building Energy Saving. China Building Industry Press, Beijing.
[5] Yan, H.L. (2002) Overview of energy-saving technologies for doors and windows of building envelopes. Energy Saving, 02.
[6] Yang, H.C. (2006) Civil Building Energy-Saving Design Technology. China Building Industry Press, Beijing.
[7] Yang, L.(2016) Green Building Design - Building Energy Efficiency, Tong Ji University Press, Shanghai.
[8] Zhu,S.J.(2017)Research on technology and economy of green building based on new energy-saving building materials. Resource Conservation and environmental protection,1:71-72.