Strategic Research on Green Buildings in Teaching Architecture Design in Severe Cold Areas

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Abstract. With a series of standard specifications for energy-saving design and construction issued by the governments, green building has become an important direction for the development of building technology in the future. The climate of the north-eastern part of China is severely cold, so a lot of energy is consumed there, so the energy saving of building is even more severe. The main purpose of this paper is to explore the energy-saving application of teaching buildings in the northeast region in terms of design methods and construction techniques, and carries out energy-saving application, high-efficiency, comfort and green design research from the perspective of building users to promote the sustainable development of the construction industry.

1. The Concept of Green Building
Green buildings are those that maximize energy-saving, environmental protection and pollution reduction throughout the whole life cycle of buildings, create healthy, applicable and efficient spaces for human beings, and are in harmony with nature. The principle of sustainable development put forward by the state is an effective guidance for the construction of modern green and energy-efficient buildings, so that the resources of the construction project have been utilized to the greatest extent during the construction process.

2. Analysis of the Conditions of Teaching Buildings in Severe Cold Regions

2.1. Climate Analysis
The northeast region is located in the severe cold part of China's building thermal design division. From the perspective of green building climate response, climate resources are subject to the following conditions.

2.1.1. Temperature Conditions. Take Changchun as an example: it is the coldest in January, with average daily temperature of -16.5 °C; it is the hottest in July, with the average daily temperature of 23.5 °C; the difference of annual average temperature is 50 °C, and in each month, the difference between the highest and lowest daily temperatures is more than 10 °C. (as shown in Table 1)

From the basic temperature data, we can find that the temperature difference between winter and summer is great, so the outer wall and roof of the green buildings should meet the functions of keeping warm in the winter and insulation in the summer.
Table 1. Monthly average temperature statistics table of Changchun in Jilin Province in the past five years

|                | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Daily Maximum | -10 | -5  | 3   | 14  | 22  | 26  | 28  | 27  | 21  | 13  | 2   | -7  |
| Daily Minimum | -23 | -18 | -3  | 2   | 9   | 15  | 19  | 17  | 10  | 2   | -8  | -17 |

2.1.2. Precipitation Conditions. Most of the north-eastern regions are facing the water-deficient problem. It can be seen from Table 2 that the precipitation in each season is uneven, with 33% of the annual precipitation days and 72% of the annual precipitation gathering in the summer, and the spring and winter precipitation is less, accounting for 7.2%.

Table 2. Changes in average precipitation in major cities in the Northeast China from 1961 to 2010

According to GB 50400—2016 “Technical Specifications for Construction and Residential Rainwater Control and Utilization Engineering”, the formula for total runoff design of rainwater is as follows:

\[ W = 10 \Psi_c h y F \]

In the formula, \( W \) is the total runoff for rainwater (m³); \( \Psi_c \) is the stormwater runoff coefficient; \( h_y \) is the annual rainfall (mm); \( F \) is the catchment area (hm²).

Taking Changchun as an example, its annual average rainfall is 570mm, and the recyclable rainwater which can be reused is up to about 1000m³ per year. Therefore, in the summer, the excessive rainwater can be used for indoor landscapes. It can also be stored as secondary water in the winter after being collected and processed, which is suitable for the concept of green building.

2.1.3. Lighting Conditions. The northeast regions benefit from strong sunlight and abundant solar energy resources. Most of the solar energy resources are available in the regions which are rich in the third resources. The total amount of solar radiation around the year is about 4017-5363MJ/(m²·a), and most regions have stable solar energy resources, which enables the teaching buildings to reuse solar energy resources.

2.2. Functional Conditions of Teaching Buildings

The function, space and layout of the teaching building have their own characteristics. It is the period of use that makes them different from the other buildings. Their periods of use gather in the daytime. Therefore, for their building design, the daytime lighting, summer heat insulation and winter insulation should be the key elements to be considered; also the energy saving in themselves, not only in the teaching periods but also in the winter and summer vacations, should be considered.
3. Design Principles for Green Buildings in Severe Cold Regions

3.1. Saving Resources and Energy
The green buildings are completely different with the traditional ones, due to their application of green energy-saving technologies, and the modern green energy-saving teaching buildings must apply the green energy-saving technologies in all aspects during the construction process; and the energy-saving job cannot be done at the best without the natural energies such as wind and solar energy which can help the green buildings meet the needs of learning and work, and reduce the consumption of electrical energy.

3.2. Green and Environmental Protection
The construction investment and energy consumption of the campus occupy a very large proportion of the entire social resources. Therefore, the implementation of the green building strategies in campus construction can effectively save energy and reduce emissions, and also create a more green and environmentally-friendly learning and living environment for the faculty and students, thereby strengthening the concept of environmentally-friendly and sustainable development and creating positive and broad influences on society.

3.3. Economical Efficiency
Compared with traditional buildings, although green buildings require a lot of investment in the early stage of construction, they do not cost too much during the use, and the post-management work and cost investment can be reduced because of their good construction quality, environmental protection and energy conservation.

4. Application of Green Buildings in Teaching Buildings in Severe Cold Regions

4.1. Reasonable Architectural Form

4.1.1. Building Orientation. When designing the green design of the teaching building, we should first choose a reasonable orientation. The buildings in severe cold regions should adopt the north-south direction as possible as they can. At the same time, it is necessary to follow the overall planning of the campus, referring to the best direction of the winter and summer dominant wind direction and the daily orbit analysis of the local region, so that the building has good natural ventilation in the summer and transition seasons, while avoiding the cold wind in the winter and taking advantage of the natural light effectively.

4.1.2. Building Type. In the cold regions, it takes short time for heat dissipation in the winter, so it is necessary to control the shape factor of the building. The shape factor can be used to visually reflect the amount of heat loss on the outer surface of the building unit area, and it is affected by whether the shape of the building is regular and the size of the building.

\[
\text{Shape Factor} = \frac{\text{external area of the exposing building}}{\text{ratio of building volume}}
\]

Note: Body shape coefficient ≈0.3
The general methods for controlling or reducing the shape factor are as follows:
- Reduce the width of the north-south orientation and increase the length of the east-west direction;
- Appropriately reduce the external surface areas: no too many shapes, cam curve design, decorations, so that the appearance of the building is as regular as possible;
- Increase the height of the building and the length of the long side.
4.1.3. Internal Areas and Atrium. Planar organizations should make use of north-south rooms as their main teaching and office rooms; the standard classrooms are generally placed in the best position on the south side to maximize the use of natural light. The indoor and outdoor transition areas of the building, such as the hot transition areas of foyers and stairwell, are generally in poor thermal environment such as the northwest corner or the northeast corner so that they can act as good temperature buffer zones to improve the thermal comfort of the indoor areas.

As a shared zone inside modern buildings, the atrium carries a variety of public functions such as extracurricular teaching and inter-class activities, and exists in many teaching buildings. For the teaching buildings with atrium in the cold regions, we can make rational use of the natural light, reduce lighting energy consumption by selecting the appropriate scale and shape of the atrium (Figure 1); at the same time we can adjust the comfort of the building by means of hot-pressure ventilation, atrium greening, introduction of water bodies and other methods. (Figure 2).

![Figure 1. Indoor patio ceiling of a college building in Changchun (photographed by the author)](image1)

![Figure 2. Indoor plant and water system of a college building in Changchun (photographed by the author)](image2)

4.2. Enclosure Structure
The enclosure technology is mainly for the walls, doors and windows and roofs of the teaching building with the core function to keep warm, keep put the cold and ventilate.

4.2.1. Walls. Considering the diversified use of walls, the exterior walls of green teaching buildings adopt multiple wall designs. The main basic energy-saving walls currently used include thermal insulation walls, "breathing walls" and sun-protection walls.

The thermal insulation design of the building's exterior walls is suitable for some campus buildings in the cold northern regions. And as to its overall technology, its insulation capacity in the summer is qualified for withstanding the introduction of a certain amount of outdoor heat.

The "breathing wall" is also known as double skinned exterior wall, which is a glass wall. The inner air layer in the double skinned exterior wall is provided with sunshade shutters, which can regulate the indoor solar ultraviolet radiation. In the winter, such a wall minimizes the loss of heat in the room. At the same time, the outer layer of the curtain wall is specially equipped with vents, which can open the ventilation in the summer for the ventilation effect with a large amount of solar radiant heat energy taken away, and the indoor artificial cooling.

The sun protection wall is generally placed on both sides of the building, and it is used to protect the indoor room from the trajectory of the sun. Its main design principle is to add sun protection layer to the wall on both sides of the east and west, improve the resistance of the external enclosure structure to solar radiation, and take away the heat outside the building wall to achieve the effect of external wall sun protection.

4.2.2. Doors and Windows. The external doors and windows of the building are the weak parts of the energy loss of the teaching building, and their energy consumption accounts for a large proportion with the heat loss and air penetration ratio of 32%. Therefore, the design should emphasize the energy-
saving design of the doors and windows. The energy saving measures for doors and windows are as follows:

- Improve the airtightness of doors and windows;
- Reduce the areas of windows and doors on the outer wall, thus reducing the window-wall ratio;
- Improve the thermal insulation performance of doors and windows by selecting good materials and glass materials.

4.2.3. Roof. There are many ways to realize the roof energy-saving design in the teaching building. However, in the extremely cold regions, in addition to the thermal insulation, we also need to consider the ecological design of the roof itself.

Planting roofing is to plant the soil and make some green plants with shallow roots after the roof is waterproof and insulated according to the requirements. It has multiple functions, such as rain and rainwater collection, heat preservation, heat insulation, beauty and environmental protection.

4.3. Renewable Resources

The use of renewable resources plays an essential role in building design and it is essential to the concepts of design of green buildings. We can realize the goals of energy saving and environmental protection in all aspects by comprehensively applying the natural and renewable resources, controlling resource consumption and building energy consumption. Solar energy and recycled rainwater are important renewable resources.

4.3.1. Solar Energy. Solar energy is a natural energy source, and most of the north-eastern region is rich in solar energy resources. The application in building construction complies with the construction requirements of green energy-saving buildings. Solar energy is inexhaustible. The construction workers only need to set up a small area of the spot plate at the roof to fully collect solar heat. People can enjoy hot water and heating, which effectively improves the solar energy. Learning efficiency and office quality in the teaching building.

4.3.2. Rainwater recycling. There is a shortage of water resources in the severe cold regions. It is recommended to set up a rainwater collecting system to collect rainwater from roofs, floors and green zones for green irrigation and road sprinkling within boundary line of land. The rainwater recycling system consists of three main parts: rainwater recycling and processing system, rainwater reuse system and rainwater control system. First of all, in the water supply and drainage design of the green building teaching building, the collection of rainwater is carried out with a PP polypropylene reservoir. Secondly, the irrigation pipe network system is designed to make the processed rainwater flow into the green water pipes directly and serve as landscape water. Finally, the new rainwater control device can provide the disinfected and sterilized rainwater to the teaching building for effective controlling of the process and operation of rainwater.

4.4. Energy-saving Materials

There are four types of new energy-efficient building materials commonly used in green buildings. The first type is recyclable building materials that are optimized and re-made by modern industrial means for buildings. The second type of energy-saving materials is plant-based building materials, which utilizes the degradability and non-polluting characteristics of plants to combine plant components with building materials to reduce the pollution of building materials. The third type of material is carbon fiber material, which is featured with heat resistance and high pressure resistance, and has strong self-cleaning property, which can greatly reduce the cleaning cost of the building in the long run. The fourth type of building materials is a bacteriostatic material which can effectively inhibit the bacteria, thereby providing the users with a stable living environment and promoting the long-term development of green buildings.
5. Conclusion
In this paper, the design scheme of the current green ecological campus teaching building is discussed in the four aspects of architectural form, enclosure structure, renewable resources and energy-saving materials. It turns out that the basic construction of the green teaching building should still be flexible to the local climate and environment, thus forming targeted design countermeasures.

In summary, because the green building design is featured with less investment and significant energy saving effect, and the teaching building is an important place for school education, the concept of green building should be widely applied when designing the comprehensive teaching building.

References
[1] Yao, W., (2017) Green Campus Architectural Design Case and Appropriate Technical Analysis in Cold Regions, Green Building, No. 5: 60-63.
[2] Deng, X.H., (2013) Educational-Building Complex - Development Trend of University Buildings in the 21st Century, New Architecture, 10(11): 18-19.
[3] Yang, L., (2016) Green Building Design - Building Energy Efficiency, Tong Ji University Press, Shanghai.
[4] Li, C., Xi, W.L., Lu, D., Zhi, Y.L., (2016) Study on the Implementation Mechanism of Urban Low-Carbon Planning and Construction Management Based on Green Buildings——Taking Tianjin Eco-city as an Example, 2016 Academic Annual Meeting of Chinese Society for Environmental Sciences, Haikou, Proceedings (Volume I).
[5] Xi, J.P., (2015) A description of the “Proposal of the Central Committee of the Communist Party of China on Formulating the Thirteenth Five-Year Plan for National Economic and Social Development”, http://www.qstheory.cn/dukan/qs/2015-11/15/c_1117135343.htm.