DESIGN STRATEGY OF ENERGY-EFFICIENT PUBLIC BUILDINGS IN COLD REGION OF CHINA

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ABSTRACT

For the purpose of improving living environment in chill region of China, reducing building energy consumption and carbon dioxide emissions, this paper studies general layout, shape, plane, and envelop of public buildings in depth, and puts forward corresponding design strategies on the basis of systematical analysis on geographical features, climate characteristics, economic level, technology condition and construction patterns of chill region in China. Approaches discussed in this paper include location and orientation, layout and functional zoning of general public buildings, energy conservation properties of envelope structure. The study provides a reference to energy-efficient public buildings design in chill region of China.

Keywords: Chill region, Energy efficient building, Public building, Design strategy

1. INTRODUCTION

The winter in cold region of China is long and cold, while summer is short and cool, so the energy consumption of building heating is huge. Some data shows that the heating energy consumption accounts for 11.5% of total energy consumption of China. According to test result, the air pollution is serious in the northern city during the heating period: SO₂ increases by 5 to 6 times, N₂O and CO increases by 2 times. Meanwhile, the health status of residents drops by 2-3 levels comparing with the non-heating period. Therefore, it is urgent to research on energy-efficient building design and technology, so as to bring comfort, health, energy conservation and environmental concern to the building construction of chill-area in China.

2. DESIGN STRATEGIES

2.1 Rational Arrangement of Buildings

2.1.1 Full Utilization of Solar Energy

The building orientation depends on local climatic conditions and characteristics. Research results show that east-west oriented multi-storey building consume 5.5% more than north-south oriented ones (same number of layers, outline dimensions, building envelope, window and wall area ratio) [¹]. Take Harbin for example, the solar radiation taken on south wall is 3095 W / m²•day in January, 1193 W / m²•day on east and west, and 673 W / m²•day on north [²]. Therefore, to maximize solar radiation in winter, south, south by west and south by east is the best orientation in chill regions of China. In addition, local topography and other geographical
environment must be taken into consideration. Take full account of urban road systems, community planning, the relationship between group building and site condition.

2.1.2 Prevent Winter Winds and Improve Summer Ventilation

Natural wind increases heat conduction and convection, and benefits ventilation. However in winter of chill region, it increases the building heating consumption. Due to unfit building layout, wind speed could be very high in some spot of the district. It not only seriously affects the outdoor activities of residents in winter, but also has a negative impact on building energy saving: increases the building's cold air infiltration and reduces indoor thermal environment quality. Therefore, winter wind prevention is essential for buildings in chill region.

Proper wind environment design should be a scientific layout planning process based on local wind speed and direction in different seasons, aiming at wind proof in winter and ventilation in summer. The design should exploit higher wind speed area and wind shadow area formed by buildings, analyze wind speed requirements of different people with different activities in different season, and create comfortable environment for outdoor activities. The long axis of buildings in chill regions should avoid being orthogonal with the local prevailing winter wind, or try to minimize the incident angles between prevailing winter wind and the long side of the building to reduce exposure area to prevailing winter wind and cold current. At the same time, choosing direction and location of the gate wisely can avoid high speed winds in micro circumstance. Wind barriers (such as trees, wind block walls, etc.) should also be set according to the direction and velocity of winter wind.

2.2 Control of Building Shape Coefficient

Building shape design should not only consider appearance, but also focus on the relationship between architecture and environment and try to minimize the influences of buildings to the environment, and promote building energy saving. Therefore, on the premise of functional and aesthetic requirements, the shape coefficient of buildings should be reduced as low as possible. Data shows that with the increment of 0.01 on shape coefficient, energy consumption will increase by about 2.5% [3]. The shape coefficient is among the most important factors on building energy consumption in chill region. From the perspective of reducing building energy consumption, shape coefficient should be controlled at a lower level. Thus, buildings in chill region should adopt centralized layout, increase depth, and make compact orderly space, in order to keep warm.

2.3 Function Zoning Combined with Thermal Zoning

Spaces should be zoned according to thermal environment, on the premise of proper function zoning.

Building functions and the users’ activities in different rooms differ. Therefore, the indoor thermal requirement of these rooms is diverse. In the design process, the proper zoning should be based on the thermal environment needs of users. To concentrate rooms with similar thermal requirements in the layout is conducive to the respective control on different zones. Rooms with lower temperature requirements (such as stairs, bathrooms, storage rooms, etc.) could be concentrated together to the thermal-adverse part of building, leaving main rooms with higher temperature requirement in warmer area. This will optimize energy consumption.

North-facing rooms receive little sunlight in chill region in winter, which is adverse for conservation, while the south-facing rooms can capture a lot of solar radiation through the day. This difference results in two different temperature zones under the same heating condition: north zone and south zone. In the layout, it is clear that the major activities should be arranged in south zone, and the auxiliary rooms in north zone. This brings sunshine to mainly used rooms; meanwhile, the utility of auxiliary rooms, which require a lower temperature, will not be affected on the north side.

2.4 Proper Building Entrance Design
The entrance is one of the openings of building and the most frequently used one in winter. The main target in entrance design should be to reduce convective heat loss. The entrance should be designed to avoid outdoor cold air from blowing into the building, and to minimize possible heat loss out of the room at the same time.

2.4.1 The Position and Direction of the Entrance

The position of entrance in building depends on the function layout. Entrance, which is the hub of building, usually locates in function centre of building. It is the bridge and transition between indoor and outdoor space. The entrance is not only the "key point" connecting inside and outside, also an "air inlet". Its special location and function determines its status on energy saving. Building entrance in chill region should avoid facing the dominant winter wind in order to reduce cold air infiltration and building energy consumption.

2.4.2 Form of Entrance

From the energy saving perspective, the entrance design in chill region should pay attention to cold air infiltration and insulation measures. There are several approaches for that purpose:

(1) Entrance Hall (Fig. 1)

An entrance hall can improve the thermal property of the building. Firstly, the hall itself can play the role of temperature buffer zone between external and internal environment to improve the insulation level comprehensively. Secondly, it can prevent cold wind from entering the building directly and reduce the convection heat loss enhancing by wind pressure.

(2) Wind-Proof Porch (Fig. 2)

Wind-proof porch is suitable for buildings that orient differently from the direction of prevailing winter wind. Apparently, the smaller the angle is, the better its effect on wind proofing works.

2.5 Emphasize Insulation Design in Construction Details of Building Envelope

Insulation is a significant feature of low-carbon building in severe cold climate. A large proportion of building energy consumption in chill regions is due to thermal conduction of envelop. The lost heat is consistently replenished by heating system. Thus, quality of envelop directly affects overall consumption. To add conservation properties to envelop can notably reduce daily costs on heating and improve indoor thermal comfort. There are several steps to improve the insulation level of building fabric as stated below:

2.5.1 Choose Suitable Building Materials and Construction Methods
On the premise of fulfilling structural safety requirements, choose insulation material with smaller U-value, lower density and better strength for buildings in severe cold region. Exterior insulation is preferred; however interior insulation and cavity walls are not excluded. Since the interface between insulation layer and structural layer tends to dew, vapor proof layer is suggested to prevent inside humidity while using interior insulation.

2.5.2 Enhance the Water & Humidity Proof Property of Envelop

Humidity inside construction will result in the porous material absorbing water and losing its insulation effect with an increased U-value. In the chill climate, these amounts of water will freeze into ice below freezing point and reduce the insulation level to a further degree. Moreover, this will cause frost hazard and threaten the safety and durability of building construction. To avoid humidity and water, proper drainage strategies should be taken. But also, water-proof layer, vapor resistant and proof layer should be addressed on the side near to water and vapor source. Dense material should be set on the damper side within a compound construction.

2.5.3 Avoid Thermal Bridge

To satisfy the structure requirement, elements with high U-values are often used in building’s external fabric, for example, concrete beam, polar, slab of balcony, canopy and expanded floor, etc. These elements have lower insulation levels than the main body and thus form a thermal bridge and lose heat more easily. To prevent and alleviate the effect of thermal bridge could be done from the following aspects. Firstly, avoid construction materials with high coefficient of heat conductivity running through the walls from inside to out. Secondly, partial insulation treatment can be applied to these materials, such as an additional layer of insulation material to cut off heat flow.

2.5.4 Prevent Cold Air Infiltration

Air infiltration could be caused by temperature difference or wind pressure. To prevent cold air infiltration, one should eliminate the air leakage in external envelop. For instance, use abundant mortar; optimize the construction of doors and windows; improve the quality of installment; employ sealing details on gaps, etc. Improving air tightness of windows could be done in the following ways: use air tight materials to improve insulation between frame and wall, frame and frame, frame and glass; adopt larger pieces of glass to reduce junction area; reduce movable parts on the premise of adequate ventilation in summer.

2.5.5 Limit the Size of Windows and Doors

Windows have much larger U-values than that of walls. Bigger area of windows will result in higher heating demand of building. On the premise of fulfilling indoor day light level and ventilation requirements, it is crucial in severe cold climate to limit the size of glazing to a reasonable value to minimize energy consumption. In the same way, the size of doors should be reduced to the minimum value without compromising its function.

2.5.6 Design the Ground Floor Properly

Among elements of building envelope, the thermal property of ground floor has a direct influence on human health. Cement is widely used in severe cold climate now for its durability, consolidated, low-cost, and easy to work with. But the thermal property of cement is not satisfying because of its good heat conductivity. According to measurement, the heat loss of people on the cement floor which is 23°C equals to that on a wood floor which is 18 °C [4]. The ground floor of building in cold climate should be designed with proper insulation design.

In chill region, the ground area ranged from 0.5m to 1.0m away from the exterior walls consumes large amount of heat due to its extra low temperature, which could fall below the dew point temperature. The area wastes energy, causes hygiene problems, and reduces durability. Thus insulation layers should be set there.
Concluding from above, integral insulation is recommended for the ground floor in chill region, and its heat resistance must reach local energy saving standard. The method can also avoid cracking issues caused by setting insulation layers partially.

3. CONCLUSIONS

In summary, besides fundamental functions of building, the design of low-carbon building in chill region must take local climate features and geography conditions into consideration, and adjust measures to optimize layout, zoning, shape, and envelop.

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5. REFERENCES