Optimization Design and Construction Suggestions of Low-energy Passive Building

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Abstract: With the rapid development of construction industry, people pursue energy saving and consumption reduction in the building industry based on the concept of sustainable development. Under this background, the low-energy passive building has come out and attracted the continuous attention of the world. As a low-cost design method, it has low energy demand, pays attention to the regional ecological environment, and pursues the high efficiency of design and construction. It has been effectively applied in China's building industry. This work mainly discussed the design of low-energy passive building and construction deployment, and clarified the idea of optimization design and site construction optimization deployment, so as to make the low-energy passive building design and construction reach the standard of low-energy building design, realize the fine management in construction, and lay the foundation for the promotion of low-energy passive building technology.

1. Introduction

As a spatial structure integrated into human life, urban culture and ecological environment, architecture has long corresponded to the label of high energy consumption. Based on the concept of social sustainable development and the reality of resource shortage, the current low-energy passive building has been introduced which adopts passive technology as the main point, and pursuits comfortable and healthy indoor environment [1]. The introduction of the low-energy passive building into the building industry has the advantages of energy saving, economy and comfort, and promotes the green and sustainable development of the building industry. The application value of low-energy passive building is always based on the optimization design and scientific deployment of low-energy passive building construction.

2. Overview of Low-energy Passive Building

The definition of low-energy passive building is not unified in the academic circle. It was first defined by German scholars BoAdamson and WolfgangFeist, that is, the building that adopts various energy saving technologies to minimize the building's heating and cooling requirements and makes full use of renewable energy and indoor living heat to achieve a comfortable living environment. In the *Technical Guidelines for Passive Ultra-low-energy Green Buildings* of China in 2015, the passive building was defined as the building that uses envelope structure with thermal insulation performance and good air tightness, adopts efficient heat recovery fresh air technology to minimize building heating and cooling needs, makes full use of renewable clean energy to adapt to climate characteristics and natural conditions, provides comfortable interior space with minimum energy consumption and meets the basic requirements of green building [2]. To sum up, low-energy passive building is a new energy saving building, which can achieve the appropriate indoor living environment only through the design of the building itself. It is no longer equipped with heating and cooling facilities, and there is no "active" energy supply, which represents the ecological concept and building standard of low-energy, comfort and health.

3. Low-energy Passive Building Design

3.1 Design ideas

It mainly adopts passive means to plan and design the heat gain and heat loss in building energy consumption. It is necessary to clarify the two boundaries in the design. The first boundary is the building energy demand boundary, which performs energy exchange with the outdoor environment, such as solar radiation and indoor heat, and the energy exchange between envelope and outdoor environment. The energy demand on this boundary is defined as the load, that is, the energy (cold, heat, electricity) needed to meet the building function and maintain the indoor environment. The second boundary is the building energy use boundary, on which the energy systems such as electricity, heating and air conditioning provide the fossil energy consumed by the energy needed by the building [3]. The low-energy passive design strategy involves the lighting, water use, air conditioning, heating and other aspects of the building. The core is to minimize the daily demand for resources and energy. Under different social environment and climate conditions, the design strategy also has the corresponding emphasis. The ultimate effect is to maximize the environmental income, and "demand minimizing" and "supply optimization" are the two most important contents. On this basis, the low-energy passive building assists in the utilization of renewable energy, improves the utilization efficiency of energy, and achieves the purpose of resource recycling, symbiosis and reuse.

3.2 Design framework

The design framework mainly contains three levels: the first level refers to the passive energy saving design through the way of building planning and design, and the key point of this method is to make vegetation, terrain, humidity, temperature, wind, sunlight and other natural environmental factors be directly used or avoided by the building body through perfect planning and the most appropriate architectural design. Passive technologies used in the conventional sense measures usually have natural lighting, natural ventilation, heat, heat storage of the envelope, shading, heat insulation and heat preservation, so it can reach the building even without auxiliary energy consumption under the precondition of machinery. Users also can obtain high comfort of life experience and maximize the purpose of saving energy. The second level is the active energy-saving design method relying on the fresh air system with heat recovery and the indoor air monitoring system [4]. The principle is to make up for the lack of passive design through the auxiliary effect of the mechanical system, and then improve the comfort experience of users. The core is to maximize efficiency by using as little energy as possible. The third level is to develop and utilize new energy systems to solve the problem of insufficient fossil fuels. Although the use of renewable energy also belongs to the category of active technical means, renewable energy is mostly renewable and almost endless. The focus is to ensure the sustainable energy while ensuring a low-carbon and environmentally friendly living environment. Mature technologies include ground source heat pumps, wind power and solar energy.

4. Quality Control in Low-energy Passive Building Construction

4.1 Quality control of the construction process in the external thermal insulation structure

According to relevant literature, under the requirements of 50% energy saving standards, the heat consumption of external walls accounts for 41% of the heat consumption of buildings, and the heat consumption of windows accounts for 35% of the total heat consumption. Therefore, to reduce the energy consumption of buildings, the energy saving of the wall must be considered. The thickness of the passive house design is generally recommended to be 150mm to 300mm. According to the current area calculation method in China, the external building insulation area is counted as the construction area. For typical high-rise residential buildings, the additional thermal insulation area required for passive ultra-low-energy buildings accounts for about 2%-4% of the calculated construction area. Construction quality control should be adopted established process: basic treatment - hanging vertical, paste ash cake - ash leveling layer - partition - bounce line - first layer of insulation insulation layer treatment - second layer of insulation insulation layer treatment - paste anti-crack surface layer -

adhesive face plate - hook seam filling construction - panel cleaning and maintenance. These processes are likely to cause the base treatment, panel, wiring, patch and seam steps. Construction technicians should pay attention to some problems. For example, the base treatment is not in place, the base surface is not cleaned; the base is too smooth, the paste is not firm since the wool processing is not done on the insulation layer; the bonding mortar is not fixed since the base treatment is not dried; the bonding layer is not found in the insulation layer, resulting in uneven force and falling off [5]. For another example, the grassroots strength does not meet the requirements. The panel paste does not reach the strength of the insulation layer, resulting in the load of the insulation layer and the base paste system is much greater than the adhesion viscosity of the base and the original base, therefore, the insulation layer paste system will fall off. Additionally, the thermal insulation layer paste does not conform to the construction process. The workers do not rub repeatedly, and the bonding mortar is not spread flat, resulting in the bonding mortar not fully into the groove; the panel is empty and drums, and cracks are not re-pasted, causing the panel to fall off easily. These problems should be strictly avoided in construction.

4.2 Quality control of roof insulation structure construction process

Generally, parapets and various pipes are set on the roof, both of which are fully considered in the insulation design. In order to achieve a better heat insulation effect, the roof is generally required to be 240mm-300mm thick during the construction. Considering that the parapet and ventilation duct are weak areas to ensure continuous insulation, the metal cover plate using high strength bolts and structure is set up in the parapet and ventilation duct for this weak area, so as to achieve better durability, solve the problem of durability and heat insulation of the structure highlighting the roof. In the quality control, the pipe through the roof parts shall meet the relevant requirements. The reserved hole is required to be greater than the outer diameter of the pipe and meet the insulation thickness requirements. The pipe extending outside the roof shall be provided with a sleeve for protection, and the insulation layer shall be provided between the sleeve and the pipe. The pipeline, equipment base and embedded parts passing through the structural plate are required to complete the heat break bridge treatment measures and pass the acceptance, before starting the construction of roof insulation.

4.3 Quality control of the construction process of the ground thermal insulation structure

The basement, as the lower floor of the building, also needs to consider the insulation problem. In the construction, the basement exterior wall with less than 500mm above the ground level is required to bind the continuous waterproof layer. The water insulation layer with water and moisture resistance, corrosion resistance and high compression strength shall be laid as a waterproof and impact resistant insulation layer, such as foam glass plate and extrusion plate. When the basement space is a non-heated room, the buried depth of the external wall insulation layer is equal to the ground elevation of the indoor building on the first floor below the outdoor floor; the universal thermal insulation layer is made at a place above 500mm in the ground level, and a metal partition of about 1m is set at the junction between the shock insulation layer and the universal thermal insulation layer. The interior and outer walls of the basement extend down the vertical direction for more than 1000mm. The thermal insulation layer inside the basement exterior wall extends upwards more than 1000mm vertically.

5. Summary

Based on the development demand of energy conservation and emission reduction in the construction industry, the attention to low-energy passive buildings should be increased in the architectural design and construction, and the building should be promoted and applied. The design link must be field investigated and comprehensively considered to ensure the rationality of the design planning and minimize the construction rework. In the construction, it is necessary to strengthen the quality control, and pay attention to the details and construction difficulties in each construction link, so as to implement the design and construction of low-energy passive buildings, and the building industry will develop in a super-green and low-energy direction.

References

[1] Harkouss, F., Fardoun, F., & Biwole, P. H. (2018). Passive design optimization of low energy buildings in different climates. Energy, 165, 591-613.

[2] Chen, X., Huang, J., Yang, H., & Peng, J. (2019). Approaching low-energy high-rise building by integrating passive architectural design with photovoltaic application. Journal of Cleaner Production, 220, 313-330.

[3] Wang, Z., Xue, Q., Ji, Y., & Yu, Z. (2018). Indoor environment quality in a low-energy residential building in winter in Harbin. Building and Environment, 135, 194-201.

[4] Abdallah, A. S. H. (2021). Passive air cooling system and solar water heater with Phase Change Material for low energy buildings in hot arid climate. Energy and Buildings, 239, 110854.

[5] Li, H., Wang, S., & Cheung, H. (2018). Sensitivity analysis of design parameters and optimal design for zero/low energy buildings in subtropical regions. Applied energy, 228, 1280-1291.