Technical Analysis of Airtightness of Low-Rise Steel Structure Assembled Ultra-Low-Energy Building

Yuhang Hao\textsuperscript{1,5,a}, Yuanyuan Shi\textsuperscript{2,5,*}, Zhihui Bian\textsuperscript{3,5,b}, Shangfei Li\textsuperscript{1,5,c} and Runqiu Yan\textsuperscript{4,5,d}

\textsuperscript{1}Hebei Building Research Engineering Co., Ltd., Shijiazhuang, Hebei, China
\textsuperscript{2}Hebei Building Research Engineering Technology Co., Ltd., Shijiazhuang, Hebei, China
\textsuperscript{3}Hebei Academy of Building Research Co., Ltd., Shijiazhuang, Hebei, China
\textsuperscript{4}Yanshan University, Qinhuangdao, Hebei, China
\textsuperscript{5}Hebei Province Existing Building Comprehensive Transformation Technology Innovation Center, Shijiazhuang, Hebei, China

*Corresponding author e-mail: 1278710408@qq.com, \textsuperscript{a}haoyuhangdayu@126.com, \textsuperscript{b}13903217322@126.com, \textsuperscript{c}271976983@qq.com, \textsuperscript{d}1240267392@qq.com

Abstract. Fabricated steel structure ultra-low-energy building is a new type of building, which is the integration of many new technologies. The air-tightness treatment of low-rise fabricated steel structure ultra-low-energy buildings is one of the key technologies for buildings to achieve ultra-low energy consumption. Through technical analysis of each airtight weak part, the technical measures adopted by the nodes are determined, which provides a reference basis for the popularization and application of low-rise fabricated steel structure ultra-low-energy buildings.

1. Introduction
With the acceleration of China’s urbanization process, the construction industry has been actively developed. Under the background of sustainable development strategy, it has become a new goal of the construction industry to meet the demand of housing construction while reducing the energy consumption of buildings and protecting the ecological environment. Ultra-low energy consumption buildings can greatly reduce building energy consumption, steel structure buildings have strong tensile and compressive performance and can be recycled, and prefabricated buildings can greatly reduce construction pollution on the construction site. The combination of ultra-low energy consumption building, steel structure building and prefabricated building has become a new development direction of the construction industry.

2. Low-rise steel structure prefabricated ultra-low energy consumption building
The structural stability of the steel structure is strong, the construction period is short, the wind resistance performance is good, plus the style is flexible, low carbon, environmental protection. The steel structure is composed of prefabricated i-beams, with the upper and lower columns and transverse beam joints bolted and welded.
Prefabricated building is a building with standardized design, industrial production, assembly construction, integrated decoration, information management, intelligent application, and support for standardized parts and components.

Ultra-low energy consumption building is to establish a reliable envelope structure system through reasonable and effective measures, and select reasonable envelope structure parameters to achieve the goal of ultra-low energy consumption.

The advantages of low-rise steel structure prefabricated ultra-low energy consumption buildings lie in: from the perspective of the whole life cycle of buildings, the design phase adopts ultra-low energy consumption design technology, adopts efficient assembly and energy-saving envelope system, and pays attention to reducing building energy consumption, saving materials and reducing construction period.

The key of low-rise steel structure prefabricated ultra-low energy consumption buildings is to minimize the heat loss of the building. The key technologies include efficient heat preservation and insulation system, non-thermal bridge construction technology, efficient air tightness technology and efficient heat recovery system, etc. The difficulty lies in the overall air tightness treatment technology of the building.

3. Low-rise steel structure prefabricated ultra-low energy consumption building

The overall air tightness of low-rise steel structure prefabricated ultra-low energy consumption building should be dealt with against the building’s external walls, doors and windows, roofing, ground and other weak air tightness links.

3.1. Air tightness of roof panels

The connection method between prefabricated building roof slabs and walls, beams, and columns is similar to that of walls, airtight layer treatment on the basis of ensuring thermal insulation bridge. Holes should be reserved for pipes that go through roof holes, and air tightness treatment should be made at the junction of roof casing and roof. Parapet wall waterproof roll back, forming a tight air tight layer, insulation materials should be wrapped parapet wall, forming a continuous insulation layer, as shown in figure 1.

During the installation of the roof casing, ventilation should be avoided. The waterproof steam diaphragm should be used on the indoor side to realize the continuity of the air-tight layer between the casing and the structure, while the waterproof roll material should be inverted on the outdoor side to achieve the double-layer air-tight layer. Non-combustible heat preservation material is filled between the pipe and the casing, and both ends of the casing are sealed with sealant to achieve the gas tightness of the casing itself.

Through the roof ventilation pipe and roof board contact, the outside paste with aluminum film of self-adhesive modified asphalt waterproof steam insulation coil, the inside paste crack resistant glass fiber and waterproof steam insulation film. The roof panel hole is filled with aerogel to form a tight double air-tight layer, as shown in figure 2.

![Figure 1. Air tightness diagram of parapet wall.](image1)

![Figure 2. Schematic diagram of air tight treatment of ventilation pipe through roof.](image2)
3.2. Air tightness treatment of exterior wall panels
ASA board, ALC board and other prefabricated wall boards can be used for prefabricated buildings with low steel structure.

The gap of the assembled outer wall is mostly located between the wall board and the position of the wall board connection with the foundation. The gap of the wall panel can be filled with foamed polyurethane material. If the gap is too large, polystyrene board material can be used. If the gap is small, the sealant can be used. Waterproof and breathable film can be pasted on the outside to effectively prevent water vapor from penetrating into the wall panel.

When connecting the prefabricated wall panels, attention should be paid to the staggered joints of the wall panels, and special binder should be used for scraping and squeezing to avoid the occurrence of open joints and ensure the overall air tightness of the building. Outside wall board still should use passive room special waterproof separate vapor film, permeate vapor film. The indoor side shall paste the waterproof vapor barrier film, and the outdoor side shall paste the waterproof vapor barrier film, as shown in figure 3. After the airtight layer is completed, the finish layer is processed.

In addition to the special bonding mortar connection in the gap, the connection between the wall board and the floor board should be extended upward for 300~350mm and to the floor board side for 300~350mm to form a complete air-tight layer, as shown in figure 4.

![Figure 3. Wall panel connection node diagram.](image-url)

![Figure 4. Airtight layer processing of connecting nodes of wall board and floor board](image-url)

3.3. Air tightness treatment of door and window
For ultra-low energy consumption buildings, the installation of doors and Windows is the key link of ultra-low energy consumption. For the construction of doors and Windows, passive doors and Windows with ultra-low energy consumption are mainly used, and the heat transfer coefficient of doors and
Windows is less than 1.0W/ (m²•K). For traditional external doors and windows, the load-bearing capacity of assembled wall panels is poor, which is difficult in actual construction, and it is easy for cracks, air leaks, and water leaks in wall panels.

In view of this phenomenon, before installing passive doors and Windows, install C section steel in advance at the entrance of wall board doors and Windows to ensure the bearing capacity of wall board. Paste the waterproof vapor barrier film along the indoor side of the door and window frame, paste the waterproof vapor barrier film along the outdoor side, squeeze the pre-pressure expansion sealing rubber strip into the middle area, to ensure that the cleanliness and flatness of the reserved holes meet the construction requirements. In order to avoid hot bridge phenomenon, the connector can be isolated by rubber sheet, the door and window openings can be fixed by collision anchor bolt, and foaming polyurethane can be filled in the window, as shown in figure 5.

![Figure 5. Schematic diagram of airtight layer treatment of outer window.](image)

3.4. Surface air tightness treatment
In the passive building ground system, heat preservation, air tightness, waterproof and other performance are very critical. After the treatment of the ground base, 4mm SBS modified asphalt waterproof roll should be laid to ensure a lap width of more than 100mm, as shown in figure 6.

![Figure 6. Schematic diagram of surface airtight layer treatment.](image)

3.5. Air tightness treatment at the outside wall
In order to avoid the damage of the air-tight layer caused by the pipe going through the outer wall, the hole through the wall is enlarged to a certain size to be reserved or holed on site, and the casing is installed. The wall panel and casing are filled with aerogel and other sealant materials to ensure air tightness. The interior side wall board and casing are pasted with waterproof vapor insulation film, while the exterior side is pasted with waterproof breathable film. The outside of the vapor insulation layer is pasted with anti-crack mortar glass fiber, and the insulation layer is pasted with rock wool, forming a double-layer air-tight layer and preventing the diffusion of indoor water vapor to the outdoor insulation layer, as shown in figure 7.
Non-combustible insulation material should be filled in the middle of the wall casing and pipeline, and sealant should be filled in both ends of the casing to form the seal of the casing itself, so as to ensure the overall air tightness of the assembled ultra-low energy consumption building.

![Diagram of airtight layer treatment of outer window](image)

**Figure 7.** Schematic diagram of airtight layer treatment of outer window.

4. Conclusion
Low-rise steel structure prefabricated ultra-low energy consumption building is to improve construction efficiency and construction quality, reduce building energy consumption, to achieve the purpose of building energy conservation. Air tightness not only affects building energy consumption, but also affects indoor air quality and building comfort. It is one of the key factors to realize ultra-low energy consumption building. Good air tightness treatment is an important measure to realize low-rise steel structure prefabricated ultra-low energy consumption building, providing a reference for the promotion and application of low-rise steel structure prefabricated ultra-low energy consumption building.

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