

Curtain Wall Design for Taiyuan Wusu International Terminal Terminal III Reconstruction and Expansion Project

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Abstract: The Taiyuan Wusu International Terminal III Reconstruction and Expansion Project, as a national key project, is a future landmark building in Taiyuan City, characterized by large building volume, high passenger flow, and complicated functions. Due to the complexity and specificity of the project, many problems and challenges have arisen. By studying these issues and practical solutions, it has significant implications for the subsequent curtain wall design for airports and transportation buildings construction. Therefore, this article lists the parameters of the curtain wall system used and summarizes some problems and solutions encountered in the actual design process, providing practical construction experience in curtain wall engineering.

1. Background

1.1 Brief Introduction to Taiyuan Wusu International Terminal III Reconstruction and Expansion Project

The terminal area project of Taiyuan Wusu International Terminal III renovation and expansion project includes passenger T3 terminal building, transportation center, parking building, rail transit station, etc; The ground area of the terminal building is about 400000 square meters, the transportation center is about 50000 square meters, the parking building is about 130000 square meters, and the rail transit station is about 90000 square meters. The expansion project will also include the construction of functional supporting facilities such as a second runway, taxiway system, apron system, and freight transportation. The designed capacity of Terminal III in this project (2030) is 22 million passengers (19.6 million domestic and 2.4 million international).

The terminal *III* has a building area of 402282.23 square meters, designed based on a passenger throughput of 32 million in 2035. It has four floors above ground (including mezzanine floors, excluding reserved floors), and only a comprehensive equipment gallery is installed underground. From top to bottom are the observation platform and the reserved commercial mezzanine (with an elevation of 18.50, this floor is reserved); Departure check-in and international departure level (elevation 13.50); International arrival level (elevation 10.50); Domestic mixed flow, baggage claim,

arrival hall level (elevation 6.00); Bus and public transportation, long-distance waiting hall, station apron, equipment layer, luggage handling room layer, etc. (elevation 0.00, station apron layer).

In terms of facade design, the main body of the terminal draws on the construction techniques and symbolic elements of ancient buildings in Shanxi, such as the curves of the Jin Temple's Notre Dame Hall.^[1-2]

1.2 Design objectives in the project

As a landmark project of Taiyuan City and a facade building of the city, the Terminal III renovation and expansion project of Taiyuan Wusu International Terminal undertakes not only the functions of ordinary transportation buildings, but also a business card of Taiyuan City. Shanxi Province is famous for its rich historical and cultural heritage. As the saying goes, "The above ground cultural relics are seen in Shanxi, while the underground cultural relics are seen in Shaanxi." The so-called above ground cultural relics refer to the many well preserved and ancient buildings with a long history in Shanxi Province. And Taiyuan, also the capital of Shanxi Province, is the location of the great collection of ancient buildings in Shanxi.

In order to reflect the cultural characteristics of Taiyuan, this project, as the gateway building of Taiyuan City, is committed to using modern architectural techniques to showcase the beauty of Shanxi's ancient architecture. In terms of shape, the roof uses the classic eave curve, giving a strong first impression. The facade and curtain wall design of the building follows the basic principles of aviation architecture: transparency, cleanliness, and brightness, and strives to reflect the beauty of Jin style and charm in the design of details and materials.^[3]

2. Curtain Wall Design for Taiyuan Wusu International Terminal III Reconstruction and Expansion Project

2.1 Overview of Curtain Wall Design

The curtain wall of the terminal building consists of the main building and the central corridor curtain wall (including skylights and lighting roofs); East and west corridor curtain walls (including skylights and skylights); Pedestrian observation platform; VIP Hall Canopy; Airside overhanging eaves; Protective eaves; The station floor curtain wall and boarding bridge curtain wall are composed.

The scope of curtain walls includes: air and land side glass curtain wall systems, marble curtain wall systems, aluminum panel curtain wall systems, skylight systems, canopy curtain walls, observation platform high bars, and sunshade systems.

To reflect the charm of Shanxi, in addition to the glass curtain walls commonly used in terminal buildings, a large number of marble curtain walls are also used, showcasing Shanxi's history with the thick texture of marble. How to balance the proportion between marble and glass has also become a challenge. After a lot of difficult scheme comparisons, the following principles have been summarized.

1) Priority should be given to ensuring that tourists have a clear view and meet ventilation and smoke exhaust requirements.

2) The decorative level of the main facade for landside tourists entering the terminal building is higher than that of the airside, so the design of the marble curtain wall is more detailed, thicker, and the materials used are also of higher quality.

3) There is a corresponding relationship between the modulus division of marble curtain walls and glass curtain walls, maintaining harmony and unity.

4) The marble curtain wall is concentrated in the lower part of the building, forming a proportional scale similar to the wall body of ancient Tang Dynasty buildings.

5) The marble curtain walls in public spaces and crowded areas extend into the indoor space, providing visitors with a complete visual experience.^[4]

2.2 Curtain Wall System Design

The curtain walls of the terminal building adopt a frame system. Due to the various specifications of the terminal's grid size and complex changes in building volume, the main sections and configurations of the glass curtain wall are 8+1.52pvb+6 double silver Low-E+16Ar+6+1.52pvb+8 fully ultra-white tempered laminated hollow glass. The dimensions vary with the grid and design requirements.

The description of the glass curtain wall system is as follows:

Curtain wall form: vertical exposed and horizontal concealed glass curtain wall system

1) The form of glass curtain wall is a vertical exposed horizontal concealed frame glass curtain wall, with a vertical decorative strip protruding 500mm from the glass surface, and a horizontal concealed frame.

2) The exposed frame of the curtain wall adopts a bridge cut aluminum alloy insulation system, and the hidden frame adopts a fixed distance compression block structure. The length of the compression block is not less than 50mm, and the layout spacing is not more than 300mm.

3) The typical division is 1.8m high * 3.6m wide, with a glass panel consisting of 8+1.52pvb+6 double silver Low-E+16Ar+6+1.52pvb+8 ultra white tempered laminated insulating glass (all 4 pieces of glass are ultra white). The Low-E membrane is located on the 4th side from the outside to the inside.

4) Dual layers of sealant must be used between the vertical exposed frame glass and the insulation strip, and the bite between the outer side of the insulation strip and the profile must also be sealed with sealant. The edge of the buckle cover adhesive strip must be sealed with sealant. The position of the adapter supporting the decorative strip should be equipped with a ternary ethylene-propylene kit, and all waterproof measures must be strictly implemented. At the same time, it is required to clean the gaps before applying sealant. To achieve good adhesion and ensure good waterproof effect, the construction unit needs to provide a detailed construction organization design for the gluing process, please refer to the relevant drawings for details.

5) The interlayer position is sealed with 1.5mm galvanized steel plate and 200mm fireproof rock wool, and steel keel support components are set. The junction position is sealed with fireproof adhesive.

6) The positions of the ground heat dissipation convector groove and electromechanical return air groove adjacent to the curtain wall need to be equipped with a sandwich panel structure of 2mm fluorocarbon sprayed aluminum veneer+insulation rock wool+1.5mm galvanized steel plate or 2mm fluorocarbon sprayed aluminum plate on the back of the glass, and it is necessary to cooperate with the installation and maintenance of the ground heat dissipation convector groove to reserve conditions.

The mable curtain wall system is described as follows:

Curtain wall form: frame type honeycomb mable curtain wall

The typical division is 0.6m high * 1.8m wide, and the curtain wall panel is made of 30mm honeycomb mable with lychee surface treatment. The honeycomb mable adopts a back bolt type aluminum alloy hanging system, and each honeycomb mable adopts a 6-point back bolt. The stainless steel back bolt specification is M8. The color and texture of honeycomb mable will be determined by the architect and owner. The facade adopts a wide and narrow seam effect. The wide seam is 50mm, and the fine seam is 8mm.

The description of the lighting roof glass curtain wall system is as follows:

Curtain wall form: Daylight roof glass curtain wall system

Distribution location: including the main building and the central corridor, including the T-shaped large skylight and 30 small strip skylights in the main building

The curved lighting roof needs to be set out according to the 3D model provided by the design

institute, and fitted with a plane to ensure the finished surface is neat.

1) The lighting ceiling needs to be set out according to the 3D model provided by the design institute to ensure that the finished surface is neat.

2) The glass grid is detailed in the architectural drawings. The skylight glass is equipped with 8 double silver Low-E+16Ar+6+1.52Pvb+6 ultra white tempered laminated warm edge hollow glass (all 3 pieces of glass are ultra white). The connection between the skylight and the metal roof, as well as the connection between the skylight and the gutter, adopts a design without facing seams. Along the drainage direction, there is an open frame system with insulation structure to meet the thermal performance requirements of the skylight, and anti leakage and anti condensation structures are installed, with no less than 3 waterproof measures, Sealant should be applied to the side of the cover strip, and double layers of sealant should be used to seal the glass and aluminum alloy profiles. Condensate or leakage water should be discharged from the inside of the curtain wall to the gutter. If insulation cotton cannot be filled at the junction with the gutter, an external insulation blanket should be used to meet the temperature requirements.

3) The insulation blanket product must be an inorganic high-performance composite insulation material with a large number of curtain wall engineering cases. The performance has been tested by a third party and must meet the following requirements: the design value of thermal conductivity for 2000 hours of accelerated aging is $\leq 0.020\text{W}/(\text{m} \cdot \text{K})$, the combustion performance is Grade A, the trichloromethane content is $\leq 1.0\text{mg}/\text{kg}$, does not contain asbestos, and is compatible with silicone. The product model listed in the testing report must be completely consistent with the model of the proposed product. The fixation method is adhesive or mechanical fixation.

4) The waterproof system must have at least 2 waterproof measures, and the hidden frame adhesive joint must be sealed with double layers of sealant. Please refer to the relevant drawings for the specific construction form.

5) A 4mm thick stainless steel gutter is set at the intersection of the skylight and the traffic center, and double layer TPO waterproof roll is laid on the gutter.

Main materials:

1) Glass panel: 8 double silver Low-E+16Ar+6+1.52Pvb+6 ultra white tempered laminated warm edge insulating glass (all 3 pieces of glass are ultra white)

2) Main rod: 180X60X8mm steel passage for the large skylight, 300x60x8mm steel passage for the central area main rod, made of Q235B material and hot-dip galvanized on the surface;

3) Secondary components: large skylight 80X60X5mm steel passage, made of Q235B material, with surface hot-dip galvanized treatment;

4) Exposed frame pressure plate: The pressure plate is fully length, made of 6063-T6 aluminum alloy profile, with surface anodizing treatment;

5) Open frame buckle cover: made of 6063-T5 aluminum alloy profile, with fluorocarbon spraying treatment on the surface;

6) Lighting roof base: Made of 6063-T5 aluminum alloy profile, with fluorocarbon spraying treatment on the surface;

7) Aluminum clad steel profiles: Made of 6063-T5 aluminum alloy profiles, with fluorocarbon spraying treatment on the surface;

8) Decorative strip: Made of 6063-T5 aluminum alloy profile, with fluorocarbon spraying treatment on the surface;

9) Insulation rock wool: 200mm thick insulation rock wool, with a unit weight not less than $120\text{kg}/\text{m}^3$

The description of the internal shading system is as follows:

Curtain wall form: openable sunshade window

Using aluminum alloy to open the fan profile, assembling 3mm double-sided fluorocarbon sprayed perforated aluminum veneer, fixed on the variable cross-section steel profile, the surface of the variable cross-section steel profile is fluorocarbon sprayed, and the variable cross-section steel profile is welded to the main steel structure. The aluminum alloy opening fans are connected to each other

through aluminum alloy core profiles, and the opening fan hardware is a hidden hinge opening.

The description of the boarding bridge maintenance curtain wall system is as follows:

The boarding bridge is divided into 5 categories, mainly including glass curtain walls, aluminum panel curtain walls, and stone curtain walls.

The specific requirements for curtain walls are as follows:

1) The glass curtain wall adopts a vertical and horizontal concealed construction form, and the exposed frame of the curtain wall adopts a bridge cut aluminum alloy insulation system. The length of the insulation strip is not less than 35mm. The concealed frame adopts a fixed distance compression block structure, and the compression block length is not less than 50mm.

2) Each vertical grid position is equipped with a main steel structure column, and a 200mm space outside the steel structure column is used for installing aluminum alloy columns in the curtain wall system.

3) The typical division of glass and aluminum plate is 1300 * 3600mm, and the glass adopts 10+12A+10 tempered double silver LOW-E hollow ultra white glass; The aluminum curtain wall adopts a close joint system, and the structural layers from the outside to the inside are: 3mm fluorocarbon sprayed aluminum veneer+1.5mm galvanized steel plate+145mm thermal insulation rock wool+1.5mm galvanized steel plate+3mm fluorocarbon sprayed aluminum veneer. The outdoor aluminum panel gap is treated as the outer glue strip+sealant and foam rod. The gaps between the second layer of galvanized steel plate are sealed by glue. The indoor aluminum panel is divided. The indoor side joint location does not need glue treatment, but only needs glue strip sealing. The keel supporting the aluminum panel curtain wall is a steel truss system, and the aluminum panel is made of 3mm fluorocarbon sprayed aluminum veneer.

4) Dual layers of sealant must be used between the vertical exposed frame glass and the insulation strip. At the same time, the bite between the outer side of the insulation strip and the profile must also be sealed with sealant. The edge of the buckle cover adhesive strip must be sealed with sealant, and all waterproof measures must be strictly implemented. At the same time, it is required to clean the gaps before applying sealant to achieve good adhesion, to ensure good waterproof effect. The construction unit is required to provide a detailed construction organization design for the gluing process.

5) The interlayer or beam bottom that needs to be sealed shall be sealed with 1.5mm galvanized steel plate+100mm fireproof rock wool, and steel keel support components shall be installed. The junction position shall be sealed with fireproof adhesive.

6) The stone curtain wall adopts a back bolted aluminum alloy pendant system, and the panel is made of 30mm thick burnt granite. The color will be determined by the architect and owner. The stone division is 1039mm wide * 500mm high. The facade adopts a wide and narrow seam effect, with a wide seam of 20mm wide and 40mm deep, and a fine seam of 8mm wide.

2.3 Significant and Difficult Points in Curtain Wall Design

In order to achieve the above design principles, some difficulties were encountered in the specific design work. In the case of determining the configuration of the terminal building, a large amount of natural smoke exhaust is required. In order to meet the fire protection needs, various smoke control zones and corresponding facades are adjusted to make the layout of smoke exhaust windows uniform and beautiful as much as possible, without sudden changes on the same surface. Some areas that cannot be met can be shared with adjacent smoke control zones by utilizing the connectivity of large spaces, and demonstrated in fire protection.

The node design of marble curtain walls is another design difficulty. Due to the fact that the marble curtain wall is located in the lower half of the building facade, and functionally speaking, there is a large area of the computer room at the 0m floor of the terminal that requires smoke exhaust, as well as many escape walkways and fire exits leading to the outdoors, there are a large number of openings in the marble curtain wall. In order to maintain the thick effect of the marble curtain wall, the marble

curtain wall protrudes 600 millimeters thicker than the glass surface. Therefore, when opening holes in the marble, the side edges of the holes are sealed with marble, and the originally inclined concave convex shaped marble is simplified at the opening. In addition, due to differences in floor elevation, a section of metal skirting was also applied to the grounded part of the marble, hiding the height difference in the skirting.

Finally, in addition to the characteristic marble curtain wall, the proportion of glass curtain walls in Taiyuan Terminal is divided.

The length and shape of the external sunshade, the position and shape of the local internal sunshade, the construction of the glass canopy and pedestrian roof, and countless details all test the patience and wisdom of designers.^[5]

2.4 Summary

This project is a national level large-scale project, and as the airport design of the provincial capital city, its shape design plays a very important role. The airport is not only the transportation center of a city, but also the external face of the city, and the design of the curtain wall has a significant impact on tourists' first impression and usage experience of the terminal. In the curtain wall design work of the third renovation and expansion project of Taiyuan Wusu International Terminal, despite the tight schedule, heavy workload, and shortage of manpower, the designer can still maintain their tireless pursuit of architectural effects, striving to achieve perfection in every detail, not only improving the quality of the project, but also providing valuable reference experience for other projects.

3. Conclusions

This project is a national level large-scale project, and as the airport design of the provincial capital city, its shape design plays a very important role. The airport is not only the transportation center of a city, but also the external face of the city, and the design of the curtain wall has a significant impact on tourists' first impression and usage experience of the terminal. In the curtain wall design work of the third renovation and expansion project of Taiyuan Wusu International Terminal, despite the tight schedule, heavy workload, and shortage of manpower, the designer can still maintain their tireless pursuit of architectural effects, striving to achieve perfection in every detail, not only improving the quality of the project, but also providing valuable reference experience for other projects.

References

- [1] Richman, R. C., & Pressnail, K. D. (2009). A more sustainable curtain wall system: analytical modeling of the solar dynamic buffer zone (SDBZ) curtain wall [J]. *Building and Environment*, 44(1), 1-10.
- [2] Abdallah A S H, Makram A, Nayel M A A. Energy audit and evaluation of indoor environment condition inside Assiut International Airport terminal building, Egypt [J]. *Ain Shams Engineering Journal*, 2021, 12(3): 3241-3253.
- [3] Cuce E, Riffat S B, Young C H. Thermal insulation, power generation, lighting and energy saving performance of heat insulation solar glass as a curtain wall application in Taiwan: a comparative experimental study [J]. *Energy Conversion and Management*, 2015, 96: 31-38.
- [4] Schonig E. Airport-Facade. Ceramics against Radar-Reflections [J]. *Fliesen und Platten*, 1992, 42(7): 80-84.
- [5] Kon O, Caner I. Life Cycle Energy Assessment of European Airport Terminal Buildings According to Glass Facades *New Frontiers in Sustainable Aviation* [M]. Cham: Springer International Publishing, 2022: 101-111.