

Case Analysis of Glass Curtain Wall Project Outside a Building

Yongqu Gong^{1,2}, Qiang Xu^{1,*}

¹College of Civil Engineering, Tongji University, Shanghai, China

²Shanghai Zhongjian Eighth Engineering Diversion Decoration CORP. LTD, Shanghai, China

Email address:

15021300001@163.com (Yongqu Gong), xuqiang@tongji.edu.cn (Qiang Xu)

*Corresponding author

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Abstract: Taking Nanjing Zhongjian Mansion as an example, the choice of curtain wall type is analyzed and the organization of the construction of the project is analyzed in details. The key measures of the quality assurance of glass curtain wall are discussed from the angle of construction. In this case analysis, the glass curtain wall engineering quality control of specific and curtain wall engineering quality control features have been study.

Keywords: Curtain Wall, Glass Curtain, Glass Canopy

1. Introduction

The project is located in C23 block of Xianlin University Town, Qixia District, Nanjing City, covering an area of 21778.92m². The project covers an area of 19953.58 square meters of usable land and 1825.34 square meters of green land. Total floor area of about 789.743 million square meters, 10 floors above ground, 1 basement, height of 47.95 meters, the

podium height of 17.85 meters, divided into two parts office and commercial, including office 47225.78 square meters, commercial 11792.74 square meters. Architectural modeling using the overall form, meaning "Jade building", the unique architectural image will be in the construction of the installation works Limited to establish a distinctive image of the headquarters, will become an important landmark in the University City Center building.[1] The overall effect is shown in Figure 1.



Fig. 1. Nanjing Zhongjian Building Project.

2. Determination of Curtain Wall Type

At the beginning of this project, the type of glass curtain wall is chosen at first, and it is mainly chosen between the modular curtain wall and the framework curtain wall. From the design considerations, if the unit curtain wall, structural design and waterproof design will consume more manpower and resources, the framework of the curtain wall is much easier in the design, and waterproof design is also easier. From the quality considerations, modular curtain wall needs to complete all the manufacture, processing and assembling work in the factory. At the same time, the framework curtain wall can complete all assembling work at the site, but the quality of modular curtain wall is relatively easier to control. In view of the construction period, the frame type Curtain wall must be completed after the completion of the main civil construction and unit-type curtain wall and civil construction can start alternately. From the cost considerations, the consumption of material in manufacturing modular curtain is huge. Sometimes it can be even several time higher than the framework curtain wall. So, compared with framework curtain wall, the cost of modular curtain wall is twenty percent higher. However, due to the high requirements of construction quality in Nanjing Zhongjian Tower project, it is determined to use modular curtain wall after comprehensive consideration.

3. Main Construction Steps

3.1. The Measurement and Settling of Line

The steps of measuring and setting up the curtain wall are as follows: Measuring datum point → projecting datum point → main line bouncing → intersecting point arrangement → outer control line arrangement → interlayer elevation setting → interlayer outer control line size close → interlayer outer line review → Measure the structural deviation.

3.2. Embedded Parts Installation

Installation of embedded parts of the construction process is as follows: steel plate processing → on-site drilling → installation of bolts, embedded parts → on-site testing.

In steel plate cutting processing galvanized steel sheet is sued for cutting and drilling, all embedded parts are included in the four bolt holes, for some of the opposite parts of the

welding operation. Drill has to be according to the design requirements (bore, depth) and it should be ensured that the bit and the main body mounting surface are perpendicular. After the drilling is completed, immediately use the blower, brush and other tools to clean the holes in the residual dust to ensure that the hole wall position does not contain any dust. The medicament tube is then placed in the hole and pushed to the bottom of the hole. [2]

After completion of the above process, the installation of the anchor bolt is carried out. The installation tool and the drill connected with anchor bolt suppress the drug tube, start electric drill (drilling speed of about 750r / min) and push the bolt into the hole to the installation depth. During the push and rotation of the anchor, the tubing is broken, the resin, hardener and quartz particles are mixed and filled into the gap between the bolt and the borehole wall. Once the bolts are screwed in, check the installation dimensions and fine-tune them immediately. During the gel time (check the product data), do not remove the mounting tool to ensure that the anchor bolt is untouched. After the gel time, you can remove the installation tool, but in the hardening time (search product information), it should not touch the screw. Then the reagent is completely cured and the angle code is installed. After the curing of drugs, the angle code is to be fixed. 0°C to 10°C; 10°C to 20°C; 20°C or more, the corresponding solidification can be installed angle code time: 5h; 1h; temperature of the installation time: 30min; 20min, damp pore curing time doubled. Figure 2 and Figure 3 shows the installation of the anchor and the embedded part. [3]

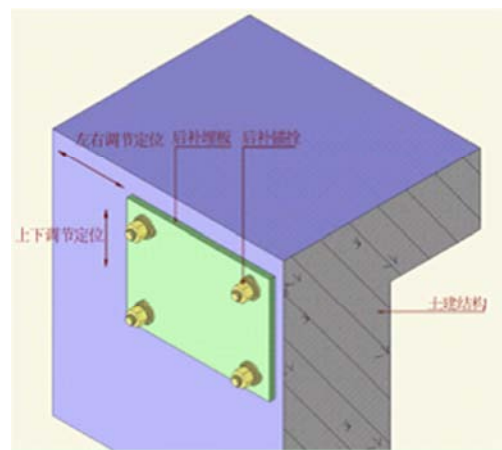


Fig. 2. Anchor bolt installation diagram.

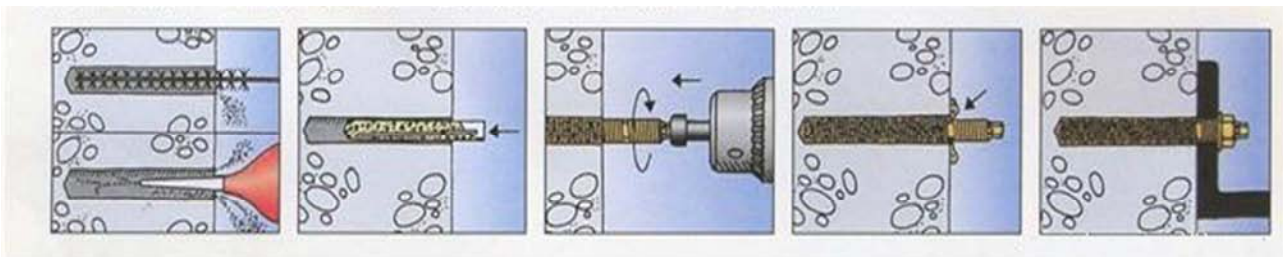


Fig. 3. Embedded components installation diagram.

After the completion of the construction, the embedded parts need to be tested, because the buried base is concealed therefore it should not have any quality problems or else there will be a major wall construction accident.

3.3. Semi Hidden Frame Glass Curtain Wall

Semi-hidden frame glass curtain wall construction process is as follows: embedded parts check, measuring pay-off → support installation → column, beam installation → glass installation → plastic injection → finishes clean.

The main beam is connected with bearings by stainless steel bolts, and then bearings is fixed with embedded pieces by welding. The deviation of elevation in main beams is adjusted to no more than 3mm according to the axial line and elevation of the main beam. The deviation of front and rear axis is adjusted to no more than 2mm. The deviation of left and right axis is adjusted to no more than 3mm. The adjacent two girder installation elevation deviation of not more than 3mm. The curtain wall bearing of each floor is detected by gradienter after installation. The horizontal error between adjacent bearing should be consistent with the standard. The deviation of inside and outside axis is not more than 2mm. The deviation of left and right axis is no more than 3mm. Bearing the welding construction to be certified equipment to ensure good operation. Steel and welding consumables which have not been approved by quality or are unqualified shall not be used for welding. Welding joints should be equipped with special inspection, weld width should be not less than 8mm, the weld should not have bubbles and broken phenomenon. Welding is completed, the self-test qualified and qualified after the Commissioner of supervision of inspection, supervision and inspection engineers qualified to enter the next process after the signing of the construction process. [4]

Column installation process follows the order from top to bottom strictly. Firstly, all columns are connected with corresponding connectors. Then the connector and the main embedded board are connected. During the construction, it should be ensured that the column installation deviation is less than 3 mm, the axial deviation is less than 2 mm and the lateral deviation is less than 3 mm. In the same column, the maximum elevation deviation is controlled within 5 mm, the deviation between two adjacent column is controlled within 2 mm. In beam installation, firstly all beams at both ends of the connecting rod in the columns should be at predetermined position to ensure that the installation is strong enough and there is no evident seam. Control the level of the two adjacent beams horizontal deviation of 1 mm or less, layer by layer from bottom to top installation, only when the upper layer meets the quality requirements then installation should continue to be installed.

After the completion of column and beam installation comes the stage of glass installation. Before installation, clean the dirt and dirt on the surface of glass to avoid the contact between glass and other components. Make sure that there is a gap between the glass and the bottom of the groove and that two or more positioning pads are located in the lower part of

the glass. The positioning pad width and the slot width are adapted, but it should be greater than 100 mm in length. In the glass around the package it should be ensured that the tape is flat enough to control the length of the strip than the border within the slot about 2%, set in the corners of the fracture.

adhesive taper around the glass should be flat enough. The length of adhesive taper should be controlled to be 2% longer than the length of slot inside the framework. Fractures should be set at the corner. Silicone sealant is used in sealant installation and the process follows the guidance of sealant installation strictly. In the injection of plastic, the construction thickness should not be less than 3.5 mm, minimum width should be 7 mm. When the depth of the seal groove is encountered, in the bottom position through the polyethylene foam material for packing.

3.4. Glass Canopy

Glass canopy construction process is as follows: Measurement of pay-off → installation of the main steel → bearing installation → glass installation → glue. Measurement of pay-off, the main steel structure installation and bearing installation process will not repeat them here, the main analysis of glass installation and glue process.

The project will transport the glass to the installation area by means of mechanical handling and transport it to the working platform by means of a crane and a mechanical sucker. Due to the modular glass curtain wall, if slot is in the upper part of glass, the upper part is push into the slot first; if slot is in the bottom part, glue needs to be put into slot first, and then the glass slowly falls into the slot. Then the glass is firmly fixed by foam-filled rods to resolutely avoid swinging and shaking phenomenon. For the glass in the middle, the glass and the steel jaws are positioned and fastened. After the glass installation is complete, adjust the gap in six directions to ensure that the deviation is within plus or minus 2 mm, and then tighten the fastener. Once the installation of five pieces of glass is completed, and overall adjustment and flatness detection is done before the completion of the above process glue.

Glass canopy glue from top to bottom, the first transverse horizontal sequence. This process is divided into different parts which are mentioned as follows: (1) clean the edge of the glass before sealant installation; (2) after pasting masking tape, the sealant installation must be done in one day; (3) spillover should be avoid during sealant installation; (4) the horizontal and Longitudinal interface position should maintain balance to ensure smooth drainage at the location of glue. [5]

4. Quality Control Measures

4.1. Quality Control of Raw Material and Construction Technology

Raw materials are key to the construction as they are the reflection of the final construction quality of curtain wall. In order to make the smooth progress of the glass curtain

wall project, advanced construction processes are applied to have strict control on quality of the material. In the construction process the regular supply of materials should be achieved. Time lines should be closely monitored along with the construction quality. In order to avoid the "lack of experience" and affect the quality of the project, we must first adopt the "model", which means to achieve the construction sequence from part to whole to ensure the best result.

In this project, for the hidden parts, the special attention should be given to the construction of silicone structural adhesive. When the silicone structural adhesive is cured, the plate should be immediately finished. Especially for concealed works, the completion of each sub-project, immediately start self-inspection and mutual inspection, and then be able to continue to carry out the next stage of work.

4.2. Personnel Management

Personnel is the most important aspect in the construction process. It can be an advantage or disadvantage to any construction project. In Nanjing Zhongjian Building project, the objectives are reflected into a number of indicators, and then the targets are assigned to the construction team. It is purely the responsibility of the team to achieve the targets within the time and quality framework defined. In the curtain wall project, the project leader has set some strict quality control indicators, in accordance with the requirements of customers to develop quality management system. In the course of the project, through the "project manager for the management of the core, the total work for the technical core", establish a clear responsibility for the quality management system. [6]

4.3. Fire Protection Measures for Curtain Wall

In the Nanjing Building in the curtain wall project, the use of advanced fire technology, either it the process or material selection they all are very sophisticated, so as to improve the fire protection of the curtain wall. Fire treatment is mainly used in the curtain wall and floor slit position, and the use of thick rock wool with galvanized steel, to achieve full-length isolation.

First install the fire-resistant pallets (1.5 mm galvanized steel), and then install fire cotton. Fire pallets are fixed with self-tapping screws. Fire cotton installation process is as follows: size measurement → → fixed → detection → hidden acceptance. To design as the basis for reference, while the actual size of the fire cut rock wool surface, and then installed in the fire plate. This installation procedure must be avoided during rainy days; wet conditions will reduce the fire effect. After the installation of fire cotton is completed, use wire to seal it. The project also installed insulation cotton, and used two different methods of installation, on the one hand will be installed in the main wall insulation cotton outside, on the other hand will be installed in the frame. The installation of the insulation cotton follows the installation of the plate.

4.4. Curtain Wall Lightning Protection Measures

In order to avoid the side wall lightning stroke, in the construction to ensure that when the elevation of more than 30 meters, the exposed flash and the entire building lightning protection system is connected. Lightning protection performance of the curtain wall in accordance with GB50057, lightning installation process by the embedded part of the laying and skeleton installation of two steps: lightning installation along with the embedded parts together, by connecting the steel and embedded parts, the main mine bar tight To vertical welding with vertical aggregate, and to achieve electrical connectivity. The vertical aggregate is connected by means of a connector while a sealant is injected into the gap to secure it firmly. During window installation, ensure that the windows are diagonally connected to the building's overall lightning protection system via copper braid.

4.5. Curtain Wall Anti Corrosion Measures

Anticorrosion treatment of this project is divided into three parts, which is the anti-corrosion of material itself, the anti-corrosion of the layers between materials and the anti-corrosion of fasteners. Which refers to that the material is galvanized steel, combined with sand blasting. For the exposed steel, the surface fluorocarbon coating; anti-corrosion between the material is to prevent the different metal potential value of the unnecessary electrochemical corrosion, to tackle this issue this project has different metals with isolation between the gasket; Fasteners used in this project are of high-quality stainless steel to avoid corrosion.

4.6. Anti Deformation Measures of Curtain Wall

If the glass curtain wall is exposed to strong winds and large temperature difference for a long time, or it is suddenly attacked by earthquake force, it may be deformed to varying degrees. In order to avoid deformation of the curtain wall, all the plates of the project are floating, more conducive to the release of excess stress. But also in the vertical column between the 20 mm expansion joints, can deal with temperature deformation.

5. Construction Quality Testing

5.1. Testing Standards

This test piece consists of two floors with two corners and a width of (1812 + 1876 + 1920) mm, which can be used as a test specimen for the construction of the building with the maximum wind load value. High 9870mm. Construction testing based on the complete test according to US standards, but the project supervision insisted it must meet international testing standards, so the final combination of the project using the international standard and the United States standards for the detection of physical properties. At the same time, the quality inspection work will also be in accordance with GB / T 15227-2007 and GB / T 18250-2000 the two Chinese standards. [7]

5.2. Detection Process

Nanjing Zhongjian Building glass curtain wall works mainly in the following aspects of testing: air tightness, water tightness (dynamic and static are measured), preload and pre-test, wind pressure performance, three-direction deformation performance (x, y, z-axis, the two directions), can open part of the test.

5.2.1. Some Tests Can Be Turned on

This project was tested twice in total, and the first test was carried out before the other tests, before the wind pressure test and the interlaminar displacement test. Test process is as follows: unlock, fully open and closed lock. Through two open and close tests, it is proved that the performance of opening fan hardware meets the requirements. And after other tests, the fan will remain in the normal state.

5.2.2. Preloading and Pre-testing

Preload and pre-test indicators for the application of 50% P3, that is, +1500 Pa / -1750 Pa. The positive and negative pressures of 50% P3 were applied to the specimens for 10 seconds, respectively. The test results showed that the specimens did not show any damage under positive and negative pressure.

5.2.3. Air Tightness Testing

According to international standards for airtight performance testing, the detection process temperature 27.5°C, the local atmospheric pressure 101.64kPa. In accordance with international standards for air-tight performance test results are shown in Table 1.

In accordance with US standards for airtight performance testing, the temperature 24°C, the local atmospheric pressure 101.23 kPa. The differential pressure during the test was 300 Pa. At this time, the measured partial air permeation amount was 0.01 m³/min•m, and the total air permeation amount was 0.01 m³/min•m².

In order to avoid the impact of weather conditions on the test results, a gap of one week was given before testing. At the second test, the atmospheric temperature was 19°C and the local atmospheric pressure was 101.66 kPa. Likewise, when the test pressure difference is equal to 300 Pa, the measured openable partial air permeation amount is equal to 0.01 m³/min•m, and the total air permeation amount is equal to 0.01 m³/min•m².

Two air tightness tests were carried out, the first test results show that the glass curtain wall works well when airtight, the pressure difference was of 300 Pa in the case of minimal air infiltration. It can be seen that the construction time of the unit plate is reasonable and the effect of the seal is good. The second test was carried out after the wind pressure and interlaminar displacement tests, although in this, the test piece under a lot of wind pressure joints displayed expanding trend in the existence of sealant, but the results also show that gas leakage is very low, that shows that the curtain wall works well when sealed

5.2.4. Watertight Performance Testing

Watertight performance as per the national standard corresponds to five requirements. It is to ensure that the opening part of the pressure equals to 1123 Pa in the case of no serious leakage, which must ensure that the fixed part of the 2247 Pa pressure without serious leakage. In the US standard, the static watertight performance test specify that the test piece must be held at a pressure differential of 720 Pa for 15 minutes with no leakage. The dynamic watertight performance test specifies that the specimen should be at an equivalent static pressure difference of 720 Pa of the wind pressure under no significant leakage.

Table 1. GB tightness performance test results.

project	+qA	-qA	+qL	-qL
Infiltration	0.02	0.02	0.02	0.02
grade	4	4	4	4



Fig. 4. Leakage conditions.



Fig. 5. Gasket deformation, bearing sliding.

In accordance with the national standard for watertight performance testing, the position of the bottom of the sash and the level of patchwork location has a certain leakage, as shown in Figure 4. After inspection, it was found that the bottom of the sash has number of lock points due to which the leakage occurred. The test piece height of 3063 mm, but only the use of single-controlled three-point linkage lock in the water tightness test, it resulted in penetration of rain from its gap. The original single-controlled three-point linkage lock replaced by six-point linkage lock after the problem is resolved, detection is normal.

The phenomenon of water seepage in the horizontal patchwork is mainly because the foam rubber inside the beam fracture and the drainage holes were set too high, making the cavity filled with water without discharge. Only when the water inside the cavity reaches a certain height it can be discharged. In response to this problem, the construction team has removed the foam rubber and re-open drainage hole, so that it is located at the bottom of the beam. Repeated testing showed that there was no leakage afterwards. [8]

5.2.5. Wind Pressure Performance Testing

a. GB wind pressure performance testing

In the national standard wind pressure performance test, select the test index $P3 = +3000 \text{ Pa} / -3500 \text{ Pa}$. GB must be 40% $P3$ in the case of the main force to ensure that the curtain wall components relative to the surface normal deflection $\leq f_0 / 2.5$. Then, repeated pressure test, and the role of $\pm P2$, the curtain wall test shows no significant damage. At the same time, the requirements of the role of $\pm P3$, the main force components of the relative surface normal deflection \leq permissible deflection f_0 , absolute surface normal deflection meet: aluminum components: $\mu \leq \{L / 180, 20 \text{ mm}\} \text{ min}$; glass panel: μ Short edge / 60.

In this test, the deflection measuring point arrangement fully considered the component type, the maximum separation and different cross-section profiles and finally determined to take a corner combination column. A large combination of columns, two plates within the column, a composite beam, 1 plate within the beam and 2 pieces of glass used as the main force components measured deflection and have a representative, can represent the entire curtain wall project wind pressure capacity.

Through the national standard testing, the selection of the curtain wall specimen is not damaged. At the same time, the deflection of the main force components is within the specified value, the beam deformation is very small and can be almost ignored, the test pieces met the national standard testing standards.[9]

b. American standard anti wind pressure performance testing

GB wind pressure performance testing was conducted immediately after the US standard for wind pressure performance testing. The test procedure is as follows: The positive and negative pressure difference of 75% $P3$ ($+2250 \text{ Pa} / -2625 \text{ Pa}$) and 150% $P3$ ($+4500 \text{ Pa} / -5250 \text{ Pa}$) are applied to the specimen for 10 seconds. Through the above steps, American Standard requires the test specimen to meet the following requirements: 150% $P3$ bearing displacement of not more than 3 mm, the permanent deformation of frame components does not exceed the component span of $2/1000$, bearing residual displacement of not more than 1.5 mm, no severe permanent deformation of the frame, glass or sheet, no bond failure along the glass or sheet edge. During the test, the aluminum gasket of the support was deformed to a great extent at the pressure difference of -5000 Pa . Meanwhile, the joint slit of the bearing sliding unit was opened and the damage was shown in Figure 5.

In response to this problem, the friction force between the gasket and anti-skid grain of bearing is immediately accounted by designers, and the object of calculation is complete mechanical friction. The results show that the strength of the aluminum gasket used in this project is low, when the gasket tightening bolts to achieve torque value of about $140 \text{ N} \cdot \text{m}$ around the gasket on the phenomenon of nuts appear on the gasket only nut and bearing anti-slip pattern position friction, resulting in a wide range of gasket deformation, bearing sliding. In order to improve the strength of aluminum gasket,

and in the installation of the wall thickness of 4 mm steel gasket, which makes the aluminum gasket and bearing full contact compression, the maximum use of friction. After the installation of the steel gasket, the test specimen is not damaged, and the residual deflection of the main force member, the displacement value of the bearing and the residual displacement of the bearing are within the limit value, and the detection reaches the American standard.

5.2.6. Interlayer Displacement Performance Testing

Plane deformation performance testing is to achieve the three national standards. According to the amount of layer displacement $\Delta = 2700 \text{ mm}$, the curtain wall test pieces is horizontally moved back and forth 3 times. Through this test, the specimen does not appear without damage. The bottom of the curtain wall unit test panels are lifted in the vertical direction about 20 mm, the lower unit plate is classified as in situ, the test successfully completed. Then, according to the vertical displacement $\Delta = 20 \text{ mm}$, the middle of the curtain wall test pieces used in the vertical installation of steel cross-up and down movement, reciprocating the operation 5 times. Through the test, the specimen did not appear damaged.

Reduce the lower unit plate requirements of the curtain wall test all the lower unit plate in the vertical direction are reduced by 20 mm. In the first step, the vertical mechanical jacks are evenly arranged on the reaction steel frame to lower the steel frame of the simulated floor. When the lower unit plate is lowered, the horizontal seam at the top of the lower plate is widened. The bottom of the horizontal stitching narrow. In this test, the plate at the top of the displacement of more than 20 mm, but the bottom is only 15 mm, through testing it was found that the difference between the top and bottom of the large difference in the amount of foam is too tight combination of beams, resulting in low compression, Jack under strong pressure, making the bottom of the beam deformed. By re-calculation, in the reduction process, the height of 26 mm foam rubber must be compressed to 6 mm, while the hollow rubber instead of solid rubber, the final plate its successfully reduced.

6. Conclusion

- (1) The quality control measures of the curtain wall are introduced, and the quality control measures of the glass curtain wall are validated in the follow - up testing process.
- (2) Nanjing Zhongjian Building curtain wall engineering performance testing though, but the watertight performance, wind pressure performance and reduce the lower unit plate detection process in these three areas found some problems, through the design and construction of the two links, the problem can be resolved.

At present, China's glass curtain wall design and construction technology and world-class level there is a gap. In this paper, the technical specifications of the glass curtain wall and the actual construction process of attention to matters of analysis, combined with practical problems in the project to discuss the expectations of other colleagues that have some reference.

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