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Application of TPO Waterproof Membrane in Metal Roof System

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Abstract

On the basis of analyzing the current situation of waterproofing for steel structure roofs, this paper introduces and analyzes the TPO polymer waterproofing membrane for the super large metal roof of Hangzhou Convention and Exhibition Center from material selection to node construction. Choosing appropriate waterproofing membranes, a reasonable waterproofing construction plan, professional construction, and paying more attention to waterproofing measures at nodes, on the basis of self waterproofing of metal roofs, can form a closed and self-contained waterproofing layer with the added waterproofing layer, in order to achieve better waterproofing effects.

Keywords

Large Public Buildings; Metal Roof; TPO Waterproof Membrane.

1. Introduction

In recent years, China's exhibition industry has emerged as a new force, showing a vigorous and dynamic development trend. A preliminary exhibition pattern has been formed, with the Beijing Tianjin wing, Yangtze River Delta, and Pearl River Delta as the main exhibition economic belts, and second and third tier inland cities jointly developing. From the perspective of industrial scale, China's exhibition industry has developed rapidly and continuously improved in level, becoming a booster and new highlight of the national economy.

Based on the Hangzhou Convention and Exhibition Project, research on key technologies for the construction of large-span metal roofs (including design deepening, efficient rainwater design, anti-seepage, wind resistance, construction hoisting, and efficient rainwater), apply them to the first phase of the Hangzhou Convention and Exhibition Project, and refine the summary to standardize and standardize it, providing reference and reference for the construction of large-span exhibition halls in China.

2. Project Overview

The Hangzhou Grand Exhibition Center project is located in Nanyang Street, Xiaoshan District, Hangzhou City, Zhejiang Province; The total construction area is 643200 square meters, including 219700 square meters of underground construction area, 4235000 square meters of above ground construction area, and 203000 square meters of metal roof area. The project consists of 6 single-layer exhibition halls and 2 double-layer exhibition halls, totaling 8 exhibition halls. The length and width of a single standard exhibition hall are 207mx95m, the height of a single-layer exhibition hall is 25.9m, and the height of a double-layer exhibition hall is 41.9m.

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3. Current Situation and Analysis of Waterproofing for Steel Structure Roofs

Most of the roofs of public buildings in China use steel or aluminum magnesium manganese vertical locking edge metal roof systems. Traditional metal self waterproof roofs, although able to provide a beautiful shape, have excessive hardness and poor flexibility in metal sheets, which cannot achieve waterproof sealing, and leakage problems have always been the shortcomings of metal roofs. The metal roof system belongs to the structural waterproofing and drainage system, and both external water and condensate water may invade the interior. Most of the leakage on metal roofs is caused by external water, and the roof gutters, detailed nodes, and other areas are the most vulnerable to leakage hazards.

To ensure the reliable waterproof performance of the building roof system, design, construction, and management are indispensable. The functional integrity of the construction level of the enclosure system is the basic guarantee, high-quality waterproof materials and the tightness of detailed nodes are necessary requirements, and construction is a crucial part of achieving design concepts and requirements.

4. Waterproofing of the Roof of Hangzhou Grand Exhibition Center

4.1 Standard Construction Methods for Metal Roof Structures

The roof of this project adopts a combination of aluminum zinc pressed steel plate vertical locking edge roof panel and TPO waterproof membrane in two waterproof forms. The vertical locking edge roof panel is the first waterproof system, mainly achieved through structural waterproofing; The TPO waterproof membrane laid between the sound insulation layer and the fixed support is the second waterproof system, mainly relying on the waterproof performance of the material and the tightness of the construction.

Table 1. Table of Standard Construction Methods for Metal Roofs [1]

Serial Number	Standard construction of metal roofs
1	Decorative layer: 3mm thick aluminum veneer, fluorocarbon spraying
2	Decorative layer: 60 * 60 * 3mm aluminum alloy keel, 6063-T6, fluorocarbon spray coating
3	Decorative layer: 2.0mm thick stainless steel fixture, material SUS316
4	Roof panel: 0.8mm thick 66/418 PVDF coated aluminum zinc pressed steel plate
5	Waterproof layer: 1.2mm thick TPO waterproof membrane (P-type)
6	Insulation layer: 70mm+70mm thick insulation rock wool, staggered laying (unit weight ≥ 180Kg/m3, 6 rock wool nails/m^2)
7	Secondary keel: 30 * 164 * 70 * 4mm thick cross shaped hot-dip galvanized steel keel, Q235B
8	Moisture proof layer: 0.3mm thick polyethylene vapor barrier film
9	Supporting layer: 1mm thick aluminum zinc plated profiled steel plate YX25-210-840 type
10	Sound absorption layer: 50mm thick glass wool (unit weight 32Kg/m3)
11	Dust layer: flame-retardant fiberglass dust blanket
12	Suspended ceiling layer: 0.8mm thick perforated aluminum zinc plated profiled steel plate YX35-190-760 (aperture not less than 5mm, opening rate 25%)

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4.2 Selection of Waterproofing for Metal Roofs

According to the "Technical Standards for Building Metal Envelope Systems Engineering" JGJT 473-2019, there are three types of polymer rolls for the secondary waterproof layer of metal roofs: TPO, PVC, and EPDM. During the design process, the metal roof environment is simulated, and the metal outer plate of the metal roof absorbs solar radiation heat, causing the temperature of the roof panel to be very high in summer, reaching nearly 80 ℃. Generally, the space under the metal plate is relatively enclosed, Therefore, the high temperature of the roof panel causes the lower space to maintain a higher temperature, resulting in slower heat dissipation and a significant impact on the waterproof layer set on its lower side. In addition, large-span steel structures may undergo significant deformation during use, so the selection of waterproofing membrane materials needs to be comprehensively considered from multiple aspects such as high temperature aging resistance, resistance to base deformation, lap joint treatment of membrane materials, and detailed waterproofing treatment.

4.2.1 Analysis of Thermal Aging Performance of Coils

The long-term high temperature environment places high demands on the stability of the coil. The thermal aging performance of the roll material becomes the first important factor affecting the waterproof effect. Based on relevant national standards, the thermal aging performance (heat resistance) of three common polymer waterproofing membranes was analyzed, as shown in Table 2.

Table 2. Comparison of thermal aging performance of three types of polymer waterproofing membranes [2].

Variety of coil materials	Heat aging conditions	Mechanical performance retention rate%, ≥		Low temperature flexibility/℃
		Maximum tensile force	tensile strength	
TPO	115℃, 672h	90	90	-40
PVC	80℃, 672h	85	85	-25
EPDM	80℃, 168h	80	-	-35

The TPO with the best thermal aging performance is tested at 115 ℃ for thermal aging

After 672 hours of testing, the mechanical performance retention rate is above 90%, and its low tenderness The performance is also optimal, at -40 ℃.

4.2.2 Analysis of Roll Material's Ability to Resist Deformation of the Base Layer

Polymer waterproofing membrane is generally used for metal self waterproofing roofs using mechanical fixation method. The membrane is laid empty and can resist structural deformation under normal use. The mechanical properties of three commonly used polymer waterproofing membranes for adapting to deformation of the base layer are shown in Table 3.

Table 3. Comparison of mechanical properties of three types of polymer waterproofing membranes for adapting to deformation of the base layer

Variety of coil materials TPO	Mechanical	
	Elongation at maximum tension (P-type)%, ≥	Elongation at break (H-type)%, ≥
TPO	15	500
PVC	15	200
EPDM	15	450

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The maximum tensile elongation of reinforced coils used for large surfaces is 15%, which is significantly different from the fracture elongation of homogeneous coils used for detailed node treatment. The fracture elongation of homogeneous coil material is the highest at TPO, which is 500%. However, the detailed nodes of the steel structure roof are the places where the roof is subjected to complex forces and has the greatest accumulation of deformation. Therefore, the quality of the fracture elongation of homogeneous coil material is crucial.

4.2.3 Comparison of Seam Treatment for Roll Materials

The lap joints of TPO and PVC polymer rolls are both welded using hot air, without open flame construction, with high reliability. The strength of the weld seam is higher than that of the roll itself, ensuring that the lap joint does not leak water. However, the relatively mature lap joint connection of EPDM rolls is treated with adhesive, which is complex to construct. Most domestic adhesives used in China have poor durability. The comparison of the peel strength of three types of roll seams is shown in Table 4.

Table 4. Comparison of Peeling Strength of Three Types of Roll Seams

Variety of coil materials	Comparison of joint peeling strength	
	Lap joint treatment method	Joint peeling strength/(N/mm), ≥
TPO	hot-air welding	3.2
PVC	hot-air welding	3.0
EPDM	Mostly adhesive	2.0 or membrane damage

TPO does not contain plasticizers, so there is no risk of shortened lifespan due to accelerated migration of plasticizers at high temperatures.

Based on the above analysis, TPO polymer waterproofing membrane is the optimal choice for waterproofing metal roofs in such public buildings.

5. Construction Precautions for TPO Waterproof Membrane

5.1 Technological Process

After the installation of rock wool and sound insulation layer is completed: clean the base layer → lay TPO roll material → mechanically fix the roll material (if the roof panel support is installed in a timely manner, there is no need for specialized mechanical fixing of the roll material in the corresponding area) → hot air welding of the roll material.

5.2 Base Treatment

Before construction, the base layer should be inspected to ensure that it meets the requirements for laying TPO rolls. The connection between steel plates should be smooth and continuous, without any sharp protrusions, to avoid piercing or cutting the coil material.

5.3 Laying and Fixing of TPO Waterproof Membrane

During construction, the roll material should be pre laid, and the naturally relaxed roll material should be arranged on the base layer according to the contour, flat and straight, without distortion. After the coil is laid and unfolded, it should be left for 15-30 minutes to fully release the internal stress of the coil and avoid wrinkling during welding. Lay adjacent rolls and form a ≥ 80 mm overlap along the length of the rolls, with a minimum width of 25 mm for hot air welding. The roll material is fixed by the fixed support of the roof outer panel that follows the subsequent construction, so the roof outer panel is required. The construction of fixed supports and roll materials should be coordinated to

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prevent the roll materials from being lifted by the wind. At skylights, deformation joints, roof pipes, etc., it is required to use gaskets or pressure strips to fix the roll material.

5.4 Hot-air Welding

Use an automatic or handheld hot air welding machine to weld TPO coils with hot air. Attention should be paid to conducting trial welding every day when starting work. Welding machine temperatures that are too high or too low cannot guarantee weld quality. In addition, the quality of the welding machine also directly affects the quality of the weld seam

Table 5. Hot air welding and coil laying

	
Hot air welding of waterproof roll materials	Waterproof membrane laying completed

5.5 TPO Polymer Waterproofing Membrane Finished Product Protection

TPO is a flexible waterproof membrane with slightly weaker resistance to mechanical damage and burns. After the completion of the TPO waterproofing and insulation system construction in this project, the upper metal roof system construction needs to continue, and attention must be paid to protecting the completed TPO roll waterproofing layer.

1) When storing materials and items on the roof, fine wood boards, multi-layer boards, or other hard boards should be laid on the waterproof membrane. When handling materials and items on the roof, they should not be dragged on the roof waterproof layer to avoid scratching or scratching the waterproof layer;

2) Remaining materials such as screws and rivets left on the roof should be cleaned up in a timely manner to avoid damaging the waterproof membrane;

3) Smoking is strictly prohibited on the roof to prevent discarded cigarette butts from scalding the waterproof layer.

6. Detailed Practice of TPO Waterproofing System for Metal Roofs

The metal roof composite TPO waterproofing system can effectively compensate for the leakage hazards that are difficult to eliminate in the metal self waterproofing roof system by leveraging the adhesion, sealing, and adaptability to base deformation of flexible rolls. However, simply laying a layer of TPO waterproofing membrane on the large surface of the roof cannot achieve a one-time solution, especially for large-span irregular roofs with high waterproofing difficulty. The specific waterproofing methods for specific nodes are worth exploring.

6.1 Improvement of Waterproof Performance at the Penetration Point of the Support Screw

In the metal roof system, there are two mainstream materials for profiled metal sheets:

Corresponding supports: ① Aluminum alloy profiled outer plate and T-shaped aluminum support, ② profiled steel outer plate and steel support; This project adopts butyl rubber pad steel support as the supporting structure of the metal roof.

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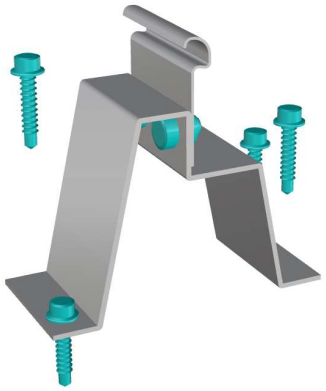

Fig. 1 Detail of butyl rubber pad steel support

Ordinary supports are fixed to the transfer purlins below by self tapping screws penetrating waterproof membranes, serving as a stress channel for transmitting wind loads to the main structure. Under the action of wind exposure, the metal roof outer panel will drive the fixed support to generate high-frequency vibration. The support at the fixed screw and the base waterproof membrane are difficult to tightly adhere, and gaps are prone to occur, thereby forming leakage hazards.

The solution to this problem is to add a 2mm thick butyl tape with creep resistance between the support and TPO waterproof membrane to tightly bond the two together, which can reduce the risk of leakage hazards mentioned above.

6.2 Waterproofing Method for the Closure of the Gutter

The metal roof of the Hangzhou Grand Exhibition Center project adopts a 3mm stainless steel plate gutter, and the gutter keel is a square steel pipe. The connection method between the two segments of the gutter is butt argon arc welding; The detailed node treatment between stainless steel gutter and TPO coil is particularly important.

Fully stick a layer of TPO waterproof membrane in the gutter and flip it over to the roof for hot air welding with the large TPO membrane, and handle the closure of the membrane at the water outlet to form a continuous waterproof surface for the entire roof system. Even if there is water leakage on the roof, it can be discharged to the gutter by flowing through the TPO membrane surface to prevent leakage and avoid the possibility of the gutter being filled with water and backflowing.

7. Conclusion

TPO polymer waterproofing membrane, as the latest generation of polymer waterproofing membrane, has many outstanding advantages such as superior chemical and physical properties, weldability, environmental friendliness, and ease of construction, especially the tightness of detailed node treatment, which is gradually being recognized by owners and designers.

However, the leakage treatment of its detailed nodes still needs to be explored, and how to avoid the leakage of support nodes caused by strong wind induced vibration still needs to be solved in practice.

Acknowledgments

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