Journal of Materials, Processing and Design (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jmpd.2024.080202
ISSN 2516-0923 Vol. 8 Num. 2

Optimization of Waterproofing Construction Techniques and Materials

Liyang Yuan[1,a,*]

[1]Jiujiang Zhongya Enterprise Management Co., Ltd, Jiujiang, Jiangxi, 332005, China
[a]305461680@qq.com
[*]Corresponding author

Keywords: Waterproofing Construction, Waterproofing Materials, Optimization Design, Construction Control

Abstract: Water leakage in building structures remains a significant challenge in construction projects. Addressing how to mitigate leakage issues during the construction process to ensure functional building performance is an area worthy of research. Existing studies typically focus on waterproofing or leak prevention at specific locations. This paper undertakes corresponding research based on a specific project, aiming to ensure comprehensive waterproofing and leak prevention across the entire project while considering cost reduction and adherence to construction schedules. Research findings demonstrate that optimizing waterproofing practices and materials can yield significant economic benefits. With optimized waterproofing methods and materials, construction procedures are streamlined, construction efficiency is enhanced, construction timelines are shortened, and the quality of waterproofing construction is effectively ensured. The waterproof practices and optimization methods of waterproof materials used in this paper can be used as a reference for other projects to achieve the goal of reducing costs and increasing efficiency in the entire industry.

1. Introduction

Water leakage in building structures is a significant challenge in construction engineering. Addressing how to mitigate leakage issues during the construction process to ensure functional building performance is a direction worthy of research. To improve the quality of waterproofing for metal roofs in public buildings, Liu [1], based on engineering cases, analyzed the performance and economic costs of different materials in metal roof waterproofing systems. They conducted in-depth research on waterproofing practices for detailed nodes such as gutters, skylights, and upright lock edge supports, effectively ensuring the stability and reliability of metal roof waterproofing systems. To enhance the waterproofing performance of substation building roofs, Jin et al. [2] proposed a series of effective measures to prevent roof leakage by selecting waterproofing materials, optimizing waterproofing designs, and improving construction techniques. To improve the quality of waterproofing construction, Wan et al. [3] designed an optimization technique for controlling the construction quality of building engineering roof waterproofing, with engineering practices demonstrating favorable effects of the optimized technique on construction quality control.

Addressing the challenge of numerous joint seams in prefabricated building exterior wall panels leading to waterproofing difficulties, Zhao [4] optimized the waterproofing process for exterior wall panels of prefabricated buildings, effectively improving the waterproofing quality at key nodes. Through a study of prefabricated exterior wall waterproofing structures in domestic and international prefabricated buildings, Zhang et al. [5] explored standardized design of prefabricated exterior walls, material selection for waterproofing design, structural analysis of prefabricated exterior wall waterproofing structures, and optimization of construction procedures to ensure the waterproofing performance of prefabricated building exterior walls. Considering the importance of basement waterproofing, Feng [6] clarified optimization techniques for waterproof membrane construction and techniques to prevent detachment during construction of waterproof membranes on exterior walls. Based on the principles of pre-laid anti-adhesive construction technology for polymer self-adhesive waterproof membranes, Xia [7] analyzed its application in waterproofing construction of underground floor slabs in high-speed railway station buildings, covering aspects such as construction preparation, base treatment, pre-laid anti-adhesive construction of waterproof membranes, waterproof treatment of special areas, and finished product protection. To address leakage issues in basements, Jiang [8] proposed multiple defensive waterproofing practices to meet project waterproofing requirements. Mathea Wojciech [9] proposed that construction units in residential construction basement waterproofing and anti-seepage construction should continuously strengthen waterproofing by reasonably applying mortar plastering layers and concrete materials. The proportion of waterproofing materials also greatly influences their waterproofing performance. Chen et al. [10] studied the effects of proportioning on the flowability and bonding strength of K11 waterproofing slurry, proposing optimal ratios suitable for engineering applications. Due to complex terrain leading to inadequate waterproofing performance of tunnel waterproofing boards, Chen [11] proposed a series of optimized waterproofing construction measures, achieving effective tunnel waterproofing results.

Existing research on waterproofing and leakage prevention in building structures typically focuses on specific locations [12]. However, as architectural forms in China become more stringent, the imperative need to reduce costs and increase efficiency in projects becomes more prominent. Investigating how to ensure comprehensive project waterproofing and leakage prevention, while reducing related construction costs and ensuring construction schedules, is a direction worthy of research. This paper undertakes corresponding research based on a specific project, aiming to provide reference for similar projects.

2. Project Overview

The project is managed under EPC (Engineering, Procurement, and Construction) contract, utilizing a fixed unit price model set at 1798 yuan/m2. During the bidding and estimation phase, the project showed minimal profit margin and significant risk of loss. Unforeseen cost risks and management complexities underscore the critical importance of design optimization. Under the EPC model, the total price per square meter of building area is all-encompassing, where every penny wasted or saved directly impacts the project's financial outcome. The four major underground components (excavation earthwork, pile foundation engineering, excavation support engineering, waterproofing engineering) are often focal points and challenges during construction, serving as the primary source of profit. Considering factors such as quality, schedule, and cost, it is crucial to identify early on the construction challenges, points of difficulty, and potential loss factors to fully leverage the advantages of the EPC management model. This approach aims to turn losses into profits and maximize overall project benefits. The local construction practices at the project site are relatively traditional, and the local quality supervision departments are keen to introduce more advanced construction techniques and materials for demonstration and wider adoption.

Traditional waterproofing methods for various underground civil engineering structures typically involve adhering or loosely laying waterproof membranes on substrates, often leading to gaps between the waterproof layer and the structural body. Once the waterproofing layer is compromised, water can seep through uncontrollably, making it challenging to locate leakage points and resulting in considerable difficulty in repairs. In severe cases, this can lead to the complete failure of the waterproofing system. Moreover, rigid protective layers are required on top of the waterproof materials, adding to the complexity of construction with numerous procedural steps. The construction process also involves significant use of auxiliary tools and materials, constraining the construction pace due to procedural requirements.

3. Overview of Original Design Contents

Basement Floor Waterproofing Method: The waterproofing methods for primary and secondary levels reference the floor 3 (D1-4) in page 9 of 13CJ40-1, and the floor 1 (D2-3). The waterproofing materials consist of 1.5mm self-adhesive polymer-modified asphalt waterproof membranes and 2.0mm uncured rubberized asphalt waterproof membranes.

Basement Exterior Wall Method: The waterproofing methods for primary and secondary levels reference the side wall 3 (D1-4) in page 10 of 13CJ40-1, and the side wall 1 (D2-3) in page 9. The waterproofing materials consist of 1.5mm self-adhesive polymer-modified asphalt waterproof membranes and 2.0mm uncured rubberized asphalt waterproof membranes; additionally, 2.0mm self-adhesive polymer-modified asphalt waterproof membranes are used.

Basement Roof Waterproofing Method: All waterproofing levels are rated at level one. The waterproofing methods reference the roof 2 (D1-8) in page 11 of 13CJ40-1.

4. Technical Optimization Main Contents

4.1. Overall Approach

As a construction project under the EPC management mode, it is essential to start from the design phase to control construction costs, reduce on-site construction difficulties, and enhance the construction quality of the design. Fully leveraging the advantages of EPC management, drawing lessons from successful experiences of the general contractor during construction is crucial.

During construction, emphasis is placed on adopting new technologies, techniques, and materials to achieve technological innovation. Advanced production processes are employed to replace traditional construction methods, thereby improving construction quality while reducing costs. This approach is essential for securing a competitive position in the intense market competition.

4.2. Technical Solutions

The waterproofing methods have been revised as follows:

For basement floor waterproofing, refer to the floor 8 (F1-15) in page 17 of 10J301-1. The waterproofing material is 1.2mm high-molecular self-adhesive membrane.

For exterior wall waterproofing, refer to the exterior wall 10c (F1-18) in page 20 of 10J301-1. The waterproofing material consists of 1.2mm cementitious penetrating crystalline waterproof coating and 1.5mm polyurethane waterproof coating.

For basement roof waterproofing, refer to the roof 2 (ZF-10) in page 24 of 10J301-1. The waterproofing material includes 1.2mm high-density polyethylene geomembrane and 2.0mm polyurethane waterproof coating, polyester non-woven fabric filtration layer, and a 10mm thick low-grade mortar isolation layer.

4.3. Key Construction Techniques

4.3.1. High Molecular Self-adhesive Membrane Waterproofing Roll Material

The basement floors in this project utilize high molecular self-adhesive membrane waterproofing roll material.

4.3.2. Flat Sheet Construction Process

As depicted in Figure 1, the flat sheet construction process primarily includes the following steps: surface preparation → baseline snapping → laying of high molecular self-adhesive membrane waterproofing roll material → roll material overlapping → detailed node treatment → self-inspection, repair, acceptance → reinforcement binding → concrete pouring.

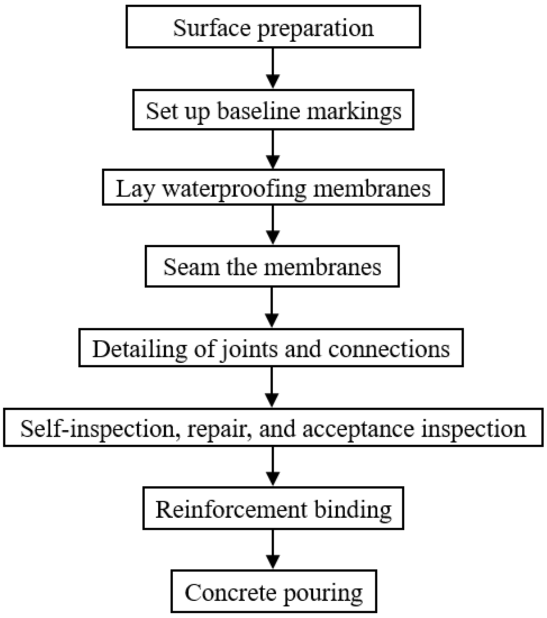

Figure 1: Flat Sheet Construction Process Diagram

4.3.3. Facade Sheet Construction Process

As illustrated in Figure 2, the facade sheet construction process primarily includes the following steps: leveling the base layer of the enclosure structure facade (or installing wooden boards) → inspecting and cleaning the facade base layer → positioning and snapping lines for sheet installation → laying high molecular self-adhesive membrane waterproofing roll material and mechanically fixing it → overlapping the sheets → detailed node treatment → self-inspection, repair, acceptance → reinforcement binding → concrete pouring.

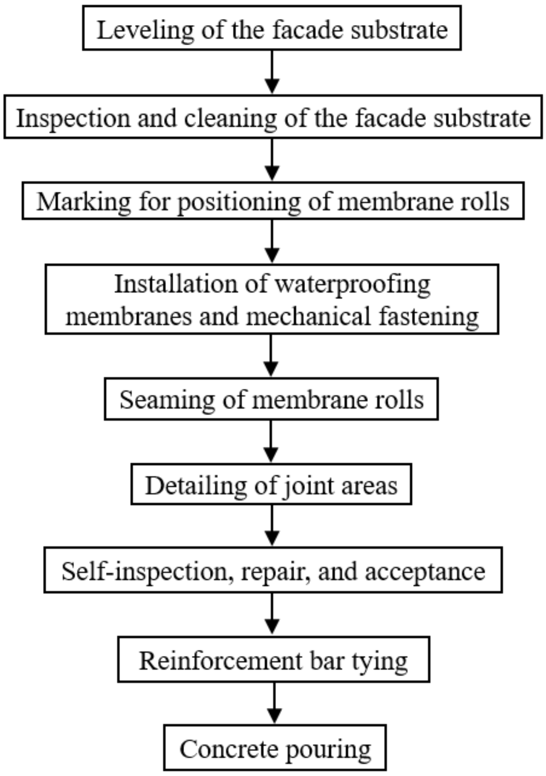

Figure 2: Facade Sheet Construction Process Diagram

4.3.4. Installation of Flat Sheets

1) Surface Cleaning

After the completion of pouring the concrete cushion layer, clean the concrete surface of residues and other debris, ensuring the work area is free from water accumulation and is clean and tidy.

2) Marking Lines

3) Bonding Sealant Application at Corners

4) Laying the First Sheet on the Flat Surface

When laying the first sheet, construction personnel position it according to the marked lines on the base surface. It can ensure the smooth high-density polyethylene film faces the base layer, and the weather-resistant granule layer faces the construction personnel. Operating personnel carefully adjust the sheet's position.

Adjacent sheets overlap with a width of 70mm along the long edge of the first sheet. Workers should remove the isolation film at the intersection before overlapping, ensuring the lower part of the overlap area is clean, dry, and free of dust. Once the two sheets are overlapped, they will continue the installation continuously, applying firm pressure during the roller overlap to ensure a strong bond. They will repeat these steps until the entire flat sheet installation is completed.

5) As shown in Figure 3, overlap the short edges of the sheets.

6) Seal the overlaps on both the flat and vertical surfaces with sealing adhesive.

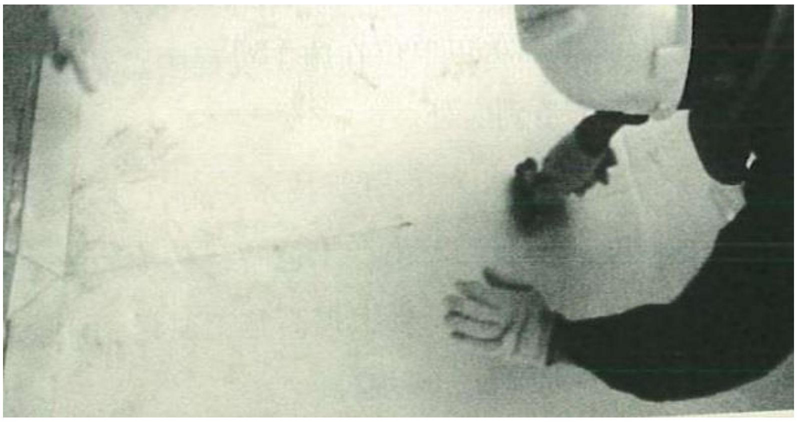

Figure 3: Overlap of Short Edges on Flat Surface

4.3.5. Installation of Facade Sheets

As shown in Figure 4, when installing sheets on the facade, workers align the sheets according to the marked lines on the base layer of the enclosure structure wall. This will ensure the smooth high-density polyethylene film faces the enclosure structure, while the weather-resistant granule layer faces the structural concrete wall. Workers will use mechanical fixation to secure the sheets to the support surface of the enclosure structure wall. The nailing should be positioned 5mm from the outer edge of the sheet's self-adhesive edge. Depending on site conditions, mechanical fixation should be applied approximately every 500mm along the long edge of the sheet. During installation, workers remove the isolation membrane from the surface of the self-adhesive overlap edge on the long side and ensure all nailing points are covered by the overlapping edge of adjacent sheets. They will immediately after overlapping, use a pressure roller to ensure a secure seal.

Figure 4: Installation of Facade Membrane

Based on site conditions, the installer mechanically fixes the membrane approximately every 500mm along the short edges, with nail positions 5mm from the membrane's outer edge. After completing the nailing operation, as depicted in Figure 5, the installer uses prefabricated self-cut strips (polymer self-adhesive film without sand cut into strips 80mm wide) or sealant at the overlapped sections of the short edges. The installer ensures that all nailing points are covered by the overlap edge of the lower sheet.

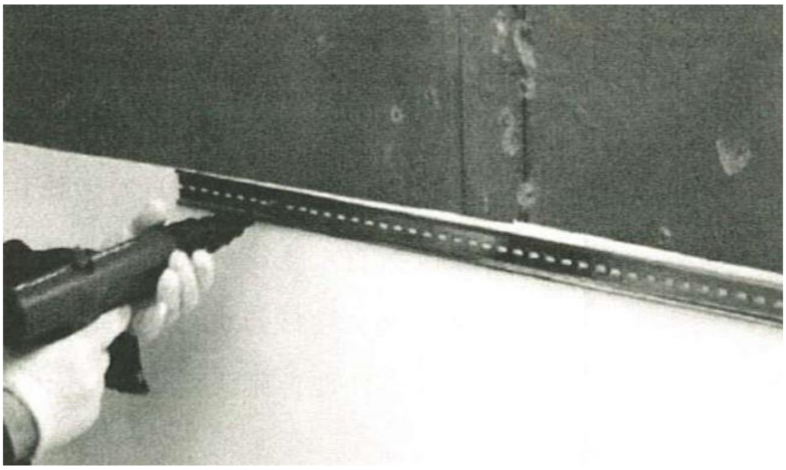

Figure 5: Securing of Compression Strip

4.3.6. Waterproofing Layer Repair

Before tying steel reinforcement mesh, supporting formwork, and pouring concrete, the construction team carefully inspects the waterproof membrane for any damage. Any identified damage should be promptly repaired to prevent potential leakage issues. When repairing damaged areas, the repair crew cuts a piece of membrane no smaller than 150mm×150mm, overlaps it onto the damaged area, and uses prefabricated self-cut strips or sealant to repair and seal it, ensuring integration with the original waterproof layer.

After completing the membrane installation, concrete should be poured as soon as possible. Before pouring concrete, measures should be taken to ensure the surface of the membrane is clean and free of debris, achieving effective bonding between the membrane and the concrete.

During the concrete pouring process, the construction team handles the area with care to prevent damage to the membrane waterproof layer caused by human error.

4.3.7. Protection Measures for Finished Products

After the completion of the waterproofing layer, attention should be paid to protecting the finished product to prevent damage to the self-adhesive membrane waterproofing layer. During the construction and acceptance of the waterproofing layer, no personnel wearing spiked shoes are allowed to walk on the waterproofing layer. Unauthorized personnel should not enter the site, and it is strictly prohibited to stack debris or push carts on the waterproofing layer. The project management team strengthens education for relevant construction personnel to raise their awareness of finished product protection and takes corresponding measures to effectively ensure the waterproofing performance of the waterproofing layer.

1) Finished product protection is crucial to the success of waterproofing projects. To achieve ideal results in waterproofing projects, special attention must be paid to finished product protection.

2) During waterproofing layer construction or when the waterproofing layer is completed but the protective layer is not yet in place, it is the critical period for finished product protection. During this period, sharp objects must not impact or puncture the waterproofing layer.

3) After the completion of the waterproofing layer construction, it is strictly prohibited to randomly puncture holes or drill for installing machinery and equipment on the waterproofing layer. If holes or drilling on the waterproofing layer are unavoidable, prior consent must be obtained from the waterproofing company, and appropriate repair work must be arranged promptly.

4) If damage to the waterproofing layer is observed during use, relevant parties should be

notified promptly to arrange timely repairs.

5) Spitting and defecating in unauthorized areas are strictly prohibited.

6) After the completion of the waterproofing layer construction, timely inspection should be conducted, and upon passing inspection, the protective layer should be promptly installed. Unprotected waterproofing layers must not support heavy machinery or transport equipment.

7) During waterproofing layer construction, all operators must wear soft-soled shoes. Wearing spiked shoes on-site is strictly prohibited to prevent damage to the waterproofing layer. Prompt repairs should be made if any damage to the waterproofing layer is discovered.

8) When pouring the concrete protective layer, the iron legs of concrete transport carts must be covered with rubber membranes and securely fastened.

4.3.8. Rainy Season Construction Measures

(1) Progress scheduling: Schedule progress during weather conditions that provide better assurance of quality.

(2) Key points for rainy season construction:

1) Arrange construction tasks during the rainy season carefully to minimize losses caused by rain delays.

2) In case of confirmed rainfall forecasts or signs of rain, protective measures such as waterproof covering should be applied to partially constructed base layers to prevent water immersion as much as possible.

3) For base layers that have been rained on, adequate drying time is necessary before resuming waterproofing construction.

4) Construction is strictly prohibited during rainy days, and work must not proceed during wind speeds of level four or higher.

5) Ensure proper storage of materials to reduce transportation during the rainy season, and implement a series of technical measures such as lightning protection and leakage prevention.

6) Develop detailed technical measures for rainy season construction and ensure comprehensive implementation. Strengthen safety education for construction personnel to prevent accidents.

4.3.9 Other Waterproofing Techniques

Common practices include the application of cementitious penetrating crystalline waterproof coatings for basement exterior walls, polyurethane waterproof coatings, and the construction method involving 1.2mm thick high-density polyethylene geomembranes for basement ceilings.

4.4. Implementation Results

Through the optimization of waterproofing construction techniques and materials, and the adoption of new processes, materials, and technologies, the construction costs of the project have been reduced by nearly ten million yuan, while simultaneously shortening the construction period.

5. Key Technological Advantages

1) Pre-laid waterproof membranes permanently bond with structural layers, eliminating any potential for water seepage between them. Even if localized damage occurs to the membrane, water remains confined to a small area, thereby enhancing the reliability of the waterproofing layer.

2) Polymer waterproof membranes exhibit excellent tensile strength, tear resistance, and impact resistance. They possess unique puncture resistance and self-healing properties after puncture, allowing construction activities such as rebar binding on the waterproof layer without

compromising its effectiveness.

3) The special polymer bonding layer between cement slurry and the membrane undergoes a wet-curing reaction. Bond strength increases with the compressive strength of concrete, forming a new waterproof layer that fully integrates with the concrete surface during its initial setting period.

4) Special polymer wet-curing adhesive does not require external force; it bonds securely upon contact with cement slurry, even on uneven surfaces, ensuring strong adhesion.

5) Waterproof performance remains unaffected by settlement of the main structure, effectively preventing groundwater infiltration.

6) No need for leveling layers; minimal requirements for substrate condition. The waterproofing system is unaffected by weather and substrate moisture, offering distinct advantages for construction during the rainy season and under tight deadlines.

7) The waterproofing material allows for cold application, is non-flammable, non-toxic, odorless, environmentally friendly, and free from fire hazards, ensuring safety and environmental protection.

6. Benefit Comparative Analysis

6.1. Economic Benefits

As shown in Table 1, optimizing waterproofing construction techniques and materials can generate economic benefits of approximately 11.59 million yuan. This clearly demonstrates favorable economic outcomes.

Table 1: Calculation of Economic Benefits

Item	Reference to drawings	Contract Price (RMB)	Optimized Benefits (RMB)
Original Design Waterproof Method	13CJ40-1	33125015.94	11588692.66
Improved Waterproof Method	10J301	21536323.28	

6.2. Social Benefits

This project represents the first prefabricated residential initiative in the local area, integral to the national strategy for industrializing the construction sector. It is a focal point of residential industrialization vigorously promoted by the local government, which holds high expectations for the project. The project actively promotes advanced construction techniques and materials during its execution, which further stimulates rapid development in the local construction market.

6.3. Technical Summary

The original waterproofing methods involved numerous construction steps, extensive auxiliary tools and materials, and a slow construction cycle. By adopting high polymer self-adhesive waterproofing membranes, after completing the base layer casting, waterproofing materials are directly laid, requiring additional layers only at short joint ends to ensure seam sealing. The membranes are overlapped and sealed by rolling, with film removed along the long edges. No protective layer is needed after membrane application, allowing direct steel reinforcement binding and concrete pouring. Exterior wall waterproofing has been simplified to waterproof coatings, reducing handling at junctions and membrane detachment during wall application. This approach boosts efficiency and guarantees construction quality.

7. Conclusion

Based on actual project implementation and ensuring project timelines, optimizations in basement floor, basement ceiling, and exterior wall waterproofing and materials have been executed to enhance economic benefits and ensure construction quality. The main conclusions drawn are as follows:

(1) Optimizing basement floor waterproofing to 1.2mm high polymer self-adhesive membranes from 1.5mm self-adhesive polymer-modified bitumen membranes + 2.0mm non-curing rubberized asphalt membranes, optimizing basement exterior wall waterproofing to 1.2mm cementitious penetrating crystalline waterproof coatings + 1.5mm polyurethane waterproof coatings from previous methods, and optimizing basement ceiling waterproofing have effectively enhanced waterproofing construction quality.

(2) Significant economic benefits have been achieved through waterproofing method and material optimizations.

(3) Optimizing waterproofing methods and materials has reduced construction steps, improved efficiency, shortened construction periods, and effectively guaranteed waterproofing construction quality.

References

[1] Liu, D. J. (2024). Optimization Study of Waterproofing System for Super Large Metal Roof of Public Buildings. Railway Construction Technology, (06), 197-201. (In Chinese)

[2] Jin, L. F., Jin, Y. C., Fang, G. C., et al. (2024). Optimization Design and Control Measures of Waterproofing Engineering for Substation Roof. Northeast Electric Power Technology, 45 (05), 55-58. (In Chinese)

[3] Wan, T. Y., Che, X. Q., Liu, H. F., et al. (2023). Optimization Technology for Construction Quality Control of Roof Waterproofing in Construction Engineering. Engineering Machinery and Maintenance, (06), 152-154. (In Chinese)

[4] Zhao, J. L. (2023). Research on Waterproofing Technology Optimization of Prefabricated Building Exterior Wall Panels. Journal of Jiangsu Vocational College of Architecture and Technology, 23 (04), 22-25. DOI: 10.19712/j.cnki.jsjyxb.2023.04.020. (In Chinese)

[5] Zhang, Y. W., Li, H. F., Huang, Z., et al. (2024). Study on Prefabricated Exterior Wall Waterproofing Structure in Prefabricated Buildings. Guangdong Building Materials, 40 (07), 107-109. (In Chinese)

[6] Feng, C. Y. (2024). Optimization of Difficulties in Joint Detachment of Waterproof Membranes for Basement Exterior Walls. Urban Architecture, 21 (06), 201-204. DOI: 10.19892/j.cnki.csjz.2024.06.50. (In Chinese)

[7] Xia, C. (2024). Application of Pre-laid Anti-sticking Process in Waterproof Construction of Basement Floor in High-speed Railway Station Buildings. Sichuan Cement, (06), 124-126. (In Chinese)

[8] Jiang, L. (2024). Application of Multiple Defensive Waterproof Schemes in Basement Leakage Repair in Housing Construction Projects. China Building Waterproofing, (06), 53-56. DOI: 10.15901/j.cnki.1007-497x.2024.06.013. (In Chinese)

[9] Mathea Wojciech. (2021). Construction Machinery Construction Risk Assessment Based on Artificial Intelligence Algorithm. Kinetic Mechanical Engineering, 2 (2): 1-8.

[10] Chen, L. Z., Liu, Y., Peng, H. H., et al. (2024). Optimization Study on Construction Performance of K11 Waterproof Slurry. China Building Waterproofing, (04), 11-15+24. DOI: 10.15901/j.cnki.1007-497x.2024.04.004. (In Chinese)

[11] Chen, J. T. (2024). Optimization of Waterproof Board and Construction Joint Construction Technology in Complex Terrain Tunnels. China Building Waterproofing, (04), 41-45. DOI: 10.15901/j.cnki.1007-497x.2024.04.010. (In Chinese)

[12] Zhao, X., Geng, D., Cheng, Z., Bai, Z., Long, M., Chen, Y., Lu, Q., Ying, W. (2023). Study on the Performance of Active Embedded Steel Wire Knot Form in Silicone Graphene Composite Thermal Insulation Structure Integrated System. Buildings, 13 (3), 705. https: //doi.org/10.3390/buildings13030705.