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KEY TECHNOLOGIES FOR WATERPROOFING DESIGN AND CONSTRUCTION OF EXTERNAL WALLS WITH INSULATION DECORATION INTEGRATED BOARDS

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Abstract: External wall systems using modified expanded polystyrene (MEPS) insulation decoration integrated boards (IDIBs) commonly suffer from recurrent defects, including joint water infiltration, leakage at internal and external corners, waterproofing failure at windowsill and parapet coping nodes, and water-penetration pathways formed by mechanical anchors. To address these issues, this study conducts a comprehensive investigation based on on-site construction practices, integrating four key dimensions: waterproofing detailing design, material selection for waterproofing, zonal construction waterproofing control, and specialized anti-infiltration techniques for critical nodes. The proposed approach optimizes the waterproof tongue-and-groove joint configuration, standardizes the sealant application procedure for board joints, and implements dedicated construction details for internal corners, external corners, door/window openings, and parapet coping. Through enhanced waterproofing workmanship, a complete set of construction technologies for IDIB external wall waterproofing is established, specifically tailored for high-rise residential buildings. Engineering practice demonstrates that this integrated waterproofing system effectively blocks rainwater infiltration pathways, eliminates potential leakage risks, and improves the durability of the external thermal insulation system. Furthermore, it reduces long-term maintenance costs and delivers significant economic and social benefits.
Keywords: Modified expanded polystyrene (MEPS); Insulation decoration integrated board (IDIB); External wall waterproofing; Node anti-infiltration; Construction technology

1 INTRODUCTION

Under the national initiatives for low-energy green building development and mandatory waste reduction targets, external wall insulation decoration integrated board (IDIB) systems have emerged as the preferred thermal insulation solution, owing to their integrated thermal and decorative performance, factory-based prefabrication, and minimal on-site wet trades. Among various options, modified expanded polystyrene (MEPS) IDIBs have been widely adopted due to their equivalent Class A fire rating, low thermal conductivity, and moderate cost.

According to the Zhejiang Application Guidelines for Insulation Decoration Integrated Boards, an IDIB system comprises a decorative panel, thermal insulation core, bonding mortar, mechanical anchors, and sealant jointing materials. The entire system is continuously exposed to outdoor wind pressure, rainwater, and cyclic temperature variations. Consequently, waterproofing vulnerabilities are predominantly concentrated at board joints, anchor penetrations, internal and external corners, windowsills, and parapet coping junctions [1-2]. Three major waterproofing challenges are prevalent in current industry practice: (i) conventional mechanical anchors are installed at a density of 6–8 per square meter, creating continuous water-penetration pathways through anchor holes that allow rainwater to infiltrate the insulation layer along the fasteners; (ii) the inherent rigidity and susceptibility to warping of the boards, combined with deviations in wall flatness and verticality, result in uneven joint widths and subsequent sealant cracking or leakage; and (iii) the tongue-and-groove joint configurations at internal corners, external corners, windowsills, and parapet copings are oversimplified, lacking multi-barrier waterproofing provisions, thereby permitting rainwater to penetrate inward along the joints and causing widespread defects such as wall dampness and indoor water ingress.

A review of the literature reveals that domestic research has predominantly focused on bond strength and fire performance of IDIB systems, with limited systematic investigation into waterproofing construction. Han Yijun et al. identified sealant joint failure as the primary cause of external wall leakage [3-4]; however, no standardized construction process was proposed for the complex nodes of residential façades. While certain local standards specify performance indicators for sealing materials, they lack detailed procedural guidance for waterproofing at critical details such as internal corners and parapet copings. Existing technologies primarily emphasize board bonding and fixing, often neglecting additional waterproofing details at anchor holes and termination points. In contrast, overseas composite cladding systems typically employ closed-joint dry-hanging waterproofing configurations, which involve substantially higher costs and are therefore unsuitable for prevailing domestic construction practices. Thus, conducting systematic research on the full-process waterproofing design and key construction technologies for IDIB external walls—tailored to Zhejiang provincial standards and the realities of high-rise residential projects—holds significant practical engineering value.

This study is based on an affordable housing project in Xihu District, Hangzhou. The project has a total floor area of 10736489m², comprising 10 high-rise residential buildings with a maximum building height of 49.05m. The external walls of all buildings adopt the MEPS IDIB system. The technical research framework is structured as follows:

(1) Investigation of the water infiltration mechanism of MEPS IDIB external walls and identification of waterproofing vulnerability points across the entire system.

(2) Establishment of a coordinated waterproofing material selection standard covering substrates, boards, anchors, and sealants.

(3) Development of a standardized waterproof sealing construction process for large-area board joints.

(4) Design of specialized anti-infiltration details and construction sequences for four critical node types: external corners, internal corners, windowsills, and parapet copings.

(5) Implementation of whole-process waterproofing quality control measures and water spray acceptance criteria.

2 WATER INFILTRATION MECHANISMS AND WATERPROOFING VULNERABILITY POINTS

2.1 Water Infiltration Mechanisms

The MEPS IDIB external wall thermal insulation system is composed of the structural wall, leveling layer, bonding mortar, MEPS thermal insulation core, decorative panel, mechanical anchors, and sealant jointing layer. Rainwater infiltration follows three primary pathways:

(1) Board-joint infiltration pathway: Thermal cycling and board deformation induce sealant cracking, allowing rainwater to enter the insulation layer along the board joints. The infiltrated water accumulates within the cavity between the board and the substrate, and prolonged soaking progressively degrades the bond strength of the adhesive mortar, see Figure 1.

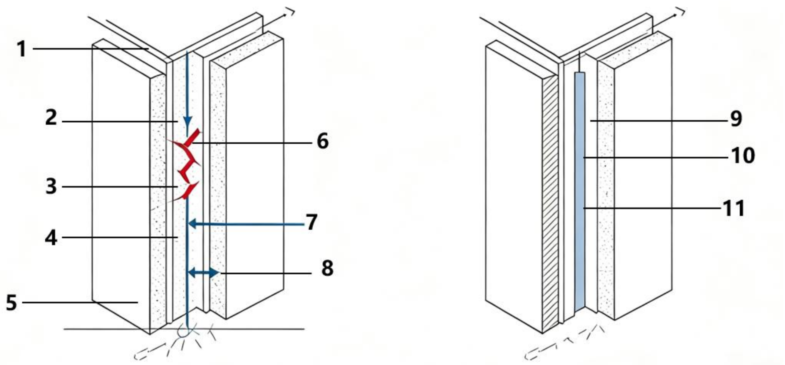

Figure 1 Schematic Diagram of the Board-Joint Infiltration Pathway

1-decorative panel; 2-thermal insulation core; 3-bonding mortar; 4-leveling layer; 5-structural wall; 6-bonding mortar cracking; 7-sealant cracking; 8-water accumulation in cavity; 9-continuous and full weather-resistant sealant bead; 10-thermal stress relief; 11-effective prevention and control

(2) Anchor-induced water-penetration pathway: Plastic or metal anchors penetrate through the boards. When anchor holes are left unsealed, rainwater infiltrates the substrate along the outer surface of the anchor shank and through the annular gap of the drilled hole, see Figure 2.

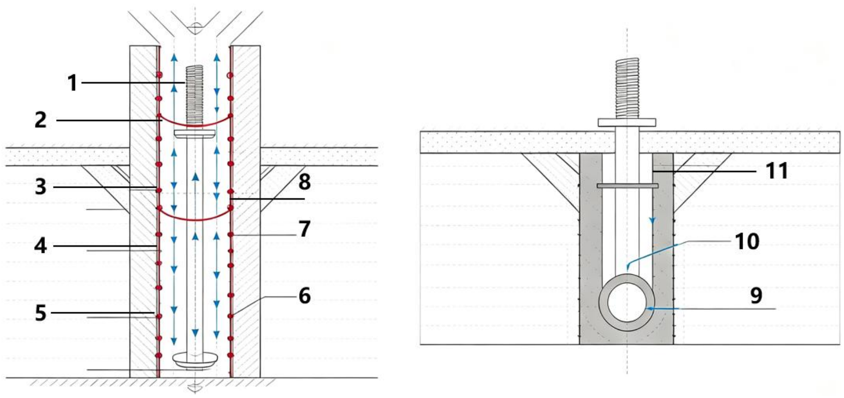

Figure 2 Schematic Diagram of the Anchor-Hole Infiltration Pathway

1-metal or plastic anchor; 2-decorative panel; 3-thermal insulation core; 4-bonding mortar; 5-leveling layer; 6-spot water infiltration; 7-annular gap; 8-unsealed drilled hole; 9-avoidance of spot infiltration; 10-sealing of the drilled annular gap; 11-anchor hole sealed

(3) Node-junction infiltration pathway: Dimensional discrepancies and open tongue-and-groove gaps at the joints of internal corners, external corners, windowsills, parapet copings, and door/window openings—combined with the absence of additional waterproof wrapped-edge layers—permit rainwater to penetrate inward along the structural junction planes, leading to concealed leakage, see Figure 3.

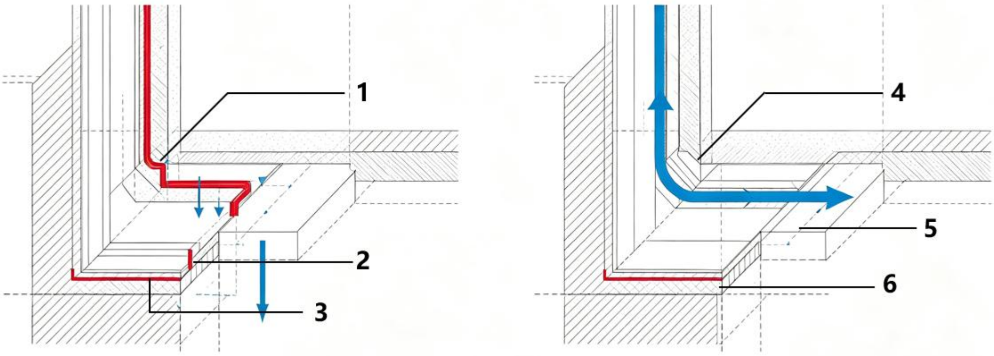

Figure 3 Schematic Diagram of the Node-Junction Infiltration Pathway
1-tongue-and-groove gap; 2-dimensional discrepancy (level difference); 3-no additional waterproofing; 4-wrapped-edge seal; 5-additional waterproofing layer; 6-node-junction sealing and blocking

2.2 Waterproofing Vulnerability Points

(1) Large-area board zones: Horizontal and vertical division joints; anchor penetration holes.
(2) Elevation corner zones: Tongue-and-groove joint seams at external and internal corners of the façade.
(3) Building termination nodes: Upper and lower windowsill interfaces, door/window side frames, parapet coping, plinth, and balcony terminations.
(4) System boundary terminations: Cut-off points of the insulation layer, expansion joints, and junctions between exterior walls of dissimilar materials.

3 WATERPROOFING SYSTEM DESIGN AND MATCHING MATERIAL SELECTION

3.1 Hierarchical Waterproofing System Design

Following the waterproofing design principles of "multi-barrier protection, combined blocking and drainage, and critical-node reinforcement," a three-tier waterproofing system is established [5-6]:
(1) Primary waterproofing (surface-layer water blocking): The exterior decorative panel itself is dense and hydrophobic. Tongue-and-groove joints form the first physical water-blocking barrier. A polymer cement-based waterproof coating is applied to the rear face of the board to prevent moisture penetration into the thermal insulation core.
(2) Secondary waterproofing (joint sealing and water isolation): A foam backing rod + neutral weather-resistant silicone sealant dual-bead system forms a continuous water-isolation layer, sealing all board-joint gaps.
(3) Tertiary waterproofing (additional anti-infiltration at nodes): Critical nodes—including internal corners, external corners, doors/windows, and parapet copings—are reinforced with waterproof wrapped-edge mesh, flashing terminations, and drip details. Anchor holes are individually sealed to create localized enhanced waterproofing.

3.2 Waterproofing Material Specification

In accordance with the Zhejiang Specification DB33/T 1164-2019 and considering the properties of the MEPS core, the technical requirements for primary waterproofing materials are defined as follows [7-9]:
(1) Bonding mortar: Polymer waterproof bonding mortar is adopted. The immersed tensile bond strength shall be ≥0.15MPa. It serves a dual function of board adhesion and substrate water isolation. The strip-bonding method creates a sealed bonding cavity, minimizing water accumulation space.
(2) Joint filler foam rod: Closed-cell polyethylene foam rod with a density of ≤37kg/m³. The rod diameter shall be 2mm larger than the joint width to prevent three-sided sealant adhesion and accommodate thermal movement.
(3) Weather-resistant sealant: Neutral silicone weather-resistant sealant with a movement capability of ≥20-class, UV resistance, and a low-temperature flexibility of 40℃. It must be compatible with inorganic panels and polystyrene cores, causing no corrosion or staining.
(4) Additional waterproofing materials: Alkali-resistant glass-fiber waterproof mesh fabric (160g/m²) and polymer cement waterproof coating, used for wrapped-edge detailing at nodes and anchor-hole sealing.
(5) Proprietary anchor: An integrated plastic anchor with a water-stop disc is used. The disc is equipped with a rubber gasket. After drilling, the hole is filled with waterproof mortar to eliminate the water-penetration pathway.

4 KEY CONSTRUCTION TECHNOLOGIES FOR LARGE-AREA ZONES

4.1 Substrate Pretreatment for Waterproofing Control

When the substrate flatness deviation exceeds 4mm, a waterproof mortar leveling layer is applied. Floating dust, oil stains, and loose concrete must be removed from the wall surface. The substrate moisture content shall be ≤8%, and construction shall proceed only after the wall is fully dried following rainfall. Pre-existing wall cracks are repaired with flexible waterproof putty to prevent inward water transmission through the substrate.

4.2 Key Waterproofing Controls for Board Installation

The board installation procedure incorporates the following waterproofing controls:
(1) Layout and setting-out: Vertical and horizontal control lines govern panel flatness and plumbness, reducing long-term joint deformation and cracking. At external corners, full boards are prioritized to avoid small-piece splicing that would increase leakage joints.
(2) Bonding technique: The strip-bonding method is employed, with a bonding mortar thickness of 3–5mm and a bonded area of ≥80%. Boards are pressed firmly to expel entrapped air, eliminating water-filled cavities between the board and the substrate. Adjacent courses are staggered by half a board length, and vertical joints are fully offset to prevent continuous infiltration channels formed by through-joints, see Figure 4.

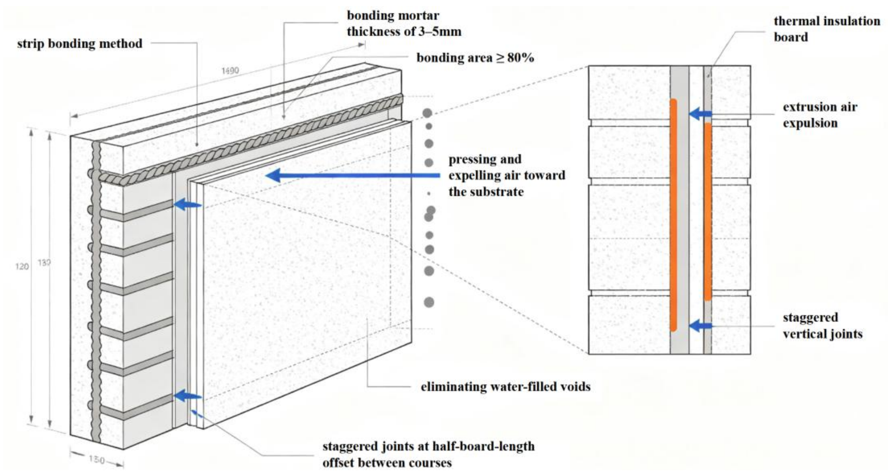

Figure 4 Schematic Diagram of the Board Bonding Technique

(3) Warping prevention: Temporary supports are used during installation to maintain strict tolerances—flatness ≤3mm and corner squareness ≤3mm. This prevents panel warping that would cause uneven joint widths and sealant debonding.

4.3 Waterproofing Treatment for Anchor Installation

(1) Anchor layout: A proprietary anchor with a water-stop disc is installed at a density of 6–8 per m². The drilled hole depth through the leveling layer shall be ≥30mm.
(2) Hole waterproofing: After drilling and dust removal, the hole is filled with polymer waterproof mortar. The anchor is inserted and the rubber gasket is compressed tightly to seal the annular gap.
(3) Post-installation sealing: After anchor fixation, a thin layer of waterproof coating is brushed around the anchor disc to form a localized waterproof barrier, blocking any residual infiltration pathway along the anchor shank.

4.4 Standardized Sealant Application for Division Joints

Joint waterproofing is the core of large-area anti-infiltration and is executed in four steps:
(1) Joint cleaning: A wire brush and air blower are used to remove dust and mortar debris from the joint. The joint must be completely dry.
(2) Foam rod insertion: For a joint width of 6–8mm, a matching closed-cell foam rod is inserted to a depth of 3–5mm below the panel surface, reserving the specified sealant fill space.
(3) Masking tape application: Masking tape is applied along both sides of the joint to protect the decorative panel surface from sealant contamination and to ensure a straight, uniform bead profile.
(4) Sealant application and finishing: Sealant is injected at a steady speed using a caulking gun to achieve a continuous, void-free bead. A finishing tool is used to smooth the bead against both panel edges, ensuring intimate adhesion. The masking tape is removed immediately after tooling. The joint is cured for ≥24h under ambient temperature, and exposure to rain is strictly prohibited during the curing period.

5 SPECIALIZED ANTI-INFILTRATION CONSTRUCTION TECHNIQUES FOR CRITICAL NODES

5.1 Waterproofing Construction for External and Internal Corners

The waterproofing procedure for façade corners is as follows:

(1) External corner waterproofing detail: A 45° miter-cut tongue-and-groove joint is employed. The two board ends are bevel-cut at 45°, with a joint gap of ≤2mm. An alkali-resistant waterproof mesh fabric is wrapped over the insulation-layer joint on the interior side, with a wrapped-edge width of ≥100mm. The exterior board joint is filled with a foam backing rod and finished with a full sealant bead. A metal drip strip is installed on the exterior corner to intercept runoff and prevent rainwater from flowing along the corner face into the joint, see Figure 5.

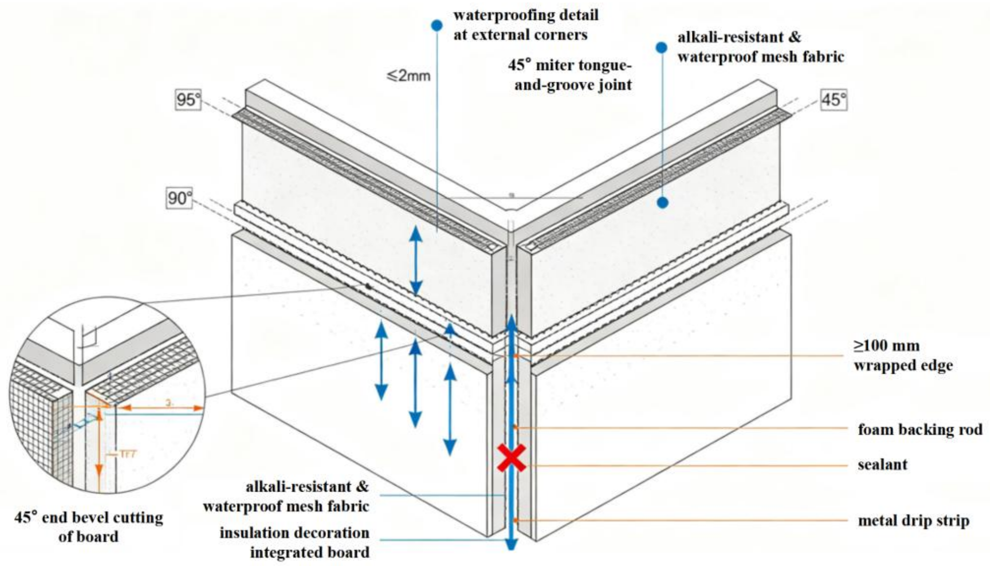

Figure 5 Waterproofing Detail at the External Corner

(2) Internal corner waterproofing detail: A matching L-shaped monolithic panel component is used at internal corners, with a drainage cavity within the tongue-and-groove interface. A waterproof coating is applied to the interior corner surface. The joint is sealed with a widened sealant bead (8–10mm joint width). A bottom water-guiding groove is integrated so that any minor infiltrated moisture can be routed along the groove to the exterior, preventing water accumulation, see Figure 6.

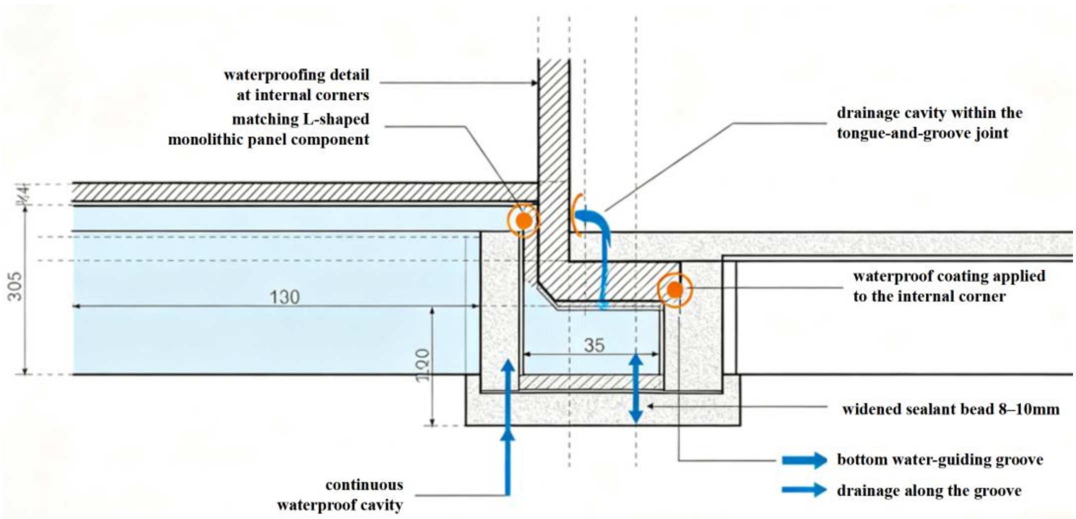

Figure 6 Waterproofing Detail at the Internal Corner

5.2 Windowsill Waterproofing and Anti-Infiltration Technique

The windowsill is a high-risk leakage node. The principle of "top barrier + bottom drainage, dual-seal" is strictly enforced:

(1) The board beneath the windowsill is sloped outward at 2%, and a prefabricated drip groove (depth ≥10mm) is installed to prevent backflow of rainwater.

(2) The upper edge of the windowsill board is turned up to the window frame side with a minimum 100mm wrapped edge. The turned-up area is reinforced with waterproof mesh fabric + waterproof coating.
(3) The gap between the window frame and the IDIB is filled with a foam backing rod, followed by interior and exterior weather-resistant sealant beads (dual-bead system). At the bottom joint of the windowsill, the sealant bead is thickened and a secondary waterproofing layer is added, see Figure 7.

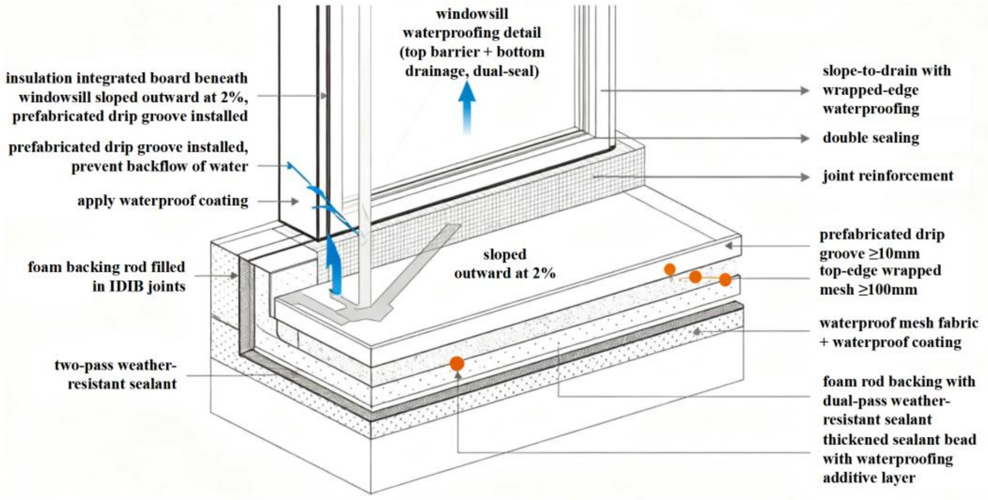

Figure 7 Waterproofing Detail at the Windowsill

5.3 Parapet Coping Termination Waterproofing

The IDIB is turned up to the top of the parapet wall. The coping is formed by cast-in-place concrete with a 5% inward drainage slope:
(1) A flashing waterproofing membrane is installed at the junction between the board top and the coping. The membrane turns down to cover the board by ≥150mm.
(2) All IDIB terminations on the interior face of the parapet are pointed with waterproof mortar, and the termination gaps are fully encapsulated with sealant.
(3) A drip line is detailed at the outer edge of the coping to prevent rainwater from flowing down the parapet sidewall and penetrating the insulation layer, see Figure 8.

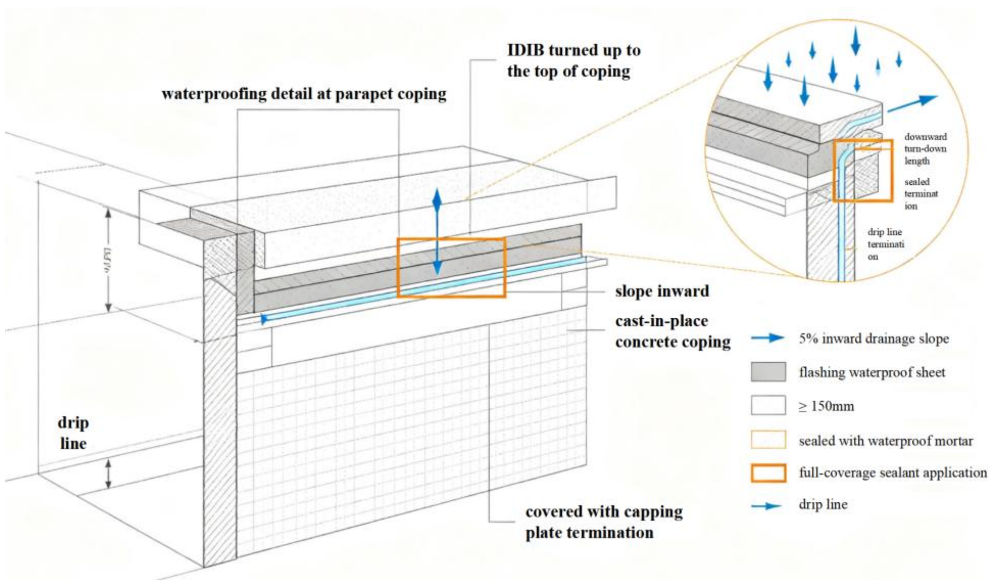

Figure 8 Waterproofing Detail at the Parapet Coping

5.4 Door and Window Opening Side-Frame Waterproofing

The insulation boards around openings are cut to precise dimensions. Through-joints are strictly prohibited at the four corners of each opening. A 200×300mm waterproof mesh patch is applied at a 45° angle across each corner as localized reinforcement. The gap between the board and the frame is filled with flexible foam, and both the interior and exterior sides are sealed with weather-resistant sealant beads. A weep hole is provided at the bottom of the opening to promptly discharge any water accumulated within the joint cavity, see Figure 9.

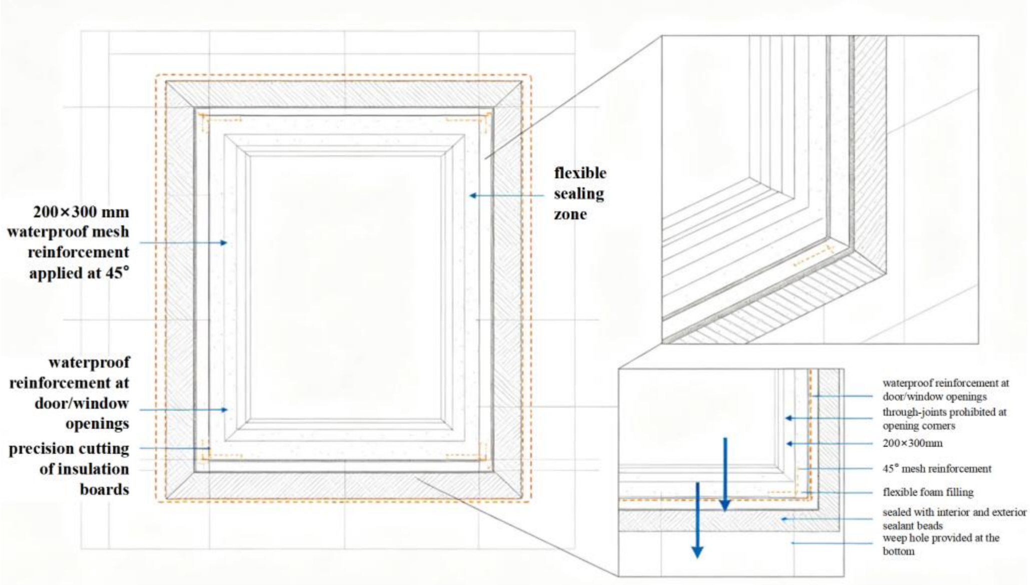

Figure 9 Waterproofing Detail at Door and Window Openings

6 WHOLE-PROCESS QUALITY CONTROL AND ACCEPTANCE OF WATERPROOFING CONSTRUCTION

6.1 Key Points of Whole-Process Control

The whole-process control measures for waterproofing construction are as follows:
(1) Material incoming inspection: All sealants, waterproof mortars, and foam rods shall be submitted for laboratory testing and may only be used upon confirmation of compliance with performance specifications. Waterproofing and sealing operations shall be suspended during rainfall or when the substrate moisture content exceeds the allowable limit.
(2) Pilot-sample guidance: Prior to large-area construction, waterproofing mock-ups for internal corners, external corners, windowsills, and parapet copings are fabricated. These mock-ups must pass joint acceptance inspection by the supervision unit, the owner (client), and the quality supervision authority before the standardized process can be uniformly implemented across the project.
(3) Concealed-work inspection: The following items are treated as concealed works and are subject to formal inspection with photographic records retained: substrate waterproof leveling, anchor-hole sealing, wrapped-edge mesh at critical nodes, and foam-rod filling.
(4) Finished-product protection: During the sealant curing period, impacts on board surfaces and water flushing of walls are strictly prohibited. After completion, sharp objects must be prevented from damaging the sealant beads.

6.2 Water Spray Acceptance Criteria for External Walls

After the complete IDIB system is installed and the sealant has fully cured for 7 days, a sectional water spray test is conducted:
(1) The spray pressure shall be 0.2–0.3MPa, with a minimum duration of 2h per test section. Each inspection lot covers 500m².
(2) The spray coverage shall include all waterproofing nodes—large-area joints, internal/external corners, windowsills, and parapet copings.
(3) Acceptance criteria: No damp marks or water infiltration points on interior walls; no water accumulation or leakage between the board and the substrate; no blistering, cracking, or debonding of the sealant beads.

7 ANALYSIS OF ENGINEERING APPLICATION BENEFITS

7.1 Economic Benefits

(1) With the optimized waterproofing process, thick metal supporting brackets over large areas are eliminated and anchor consumption is optimized, reducing the unit material cost by approximately ¥7/m².
(2) The standardized waterproofing procedure reduces long-term leakage repair costs for high-rise residential external walls by over 90%.
(3) Since waterproofing and board installation are executed concurrently without requiring a separate secondary waterproofing rendering, the construction schedule is shortened and labor input is reduced, see Table 1.

Table 1 Economic Benefit Comparison (¥/m²)

Item	Metal bracket installation (conventional)	Auxiliary anchor installation (proposed)
Material unit price	Metal bracket: ¥35/m; bracket length per m²: 1m	Anchor: ¥4/pc; quantity per m²: 6–8pcs
Labor unit price	Labor installation rate: ¥8/m	Labor installation rate: ¥0.5/pc
Comparative analysis:	Compared with the conventional metal bracket installation method, the proposed construction technique reduces the required bracket installation length, achieving a cost saving of ¥7/m².	

7.2 Social Benefits

(1) The complete waterproofing system enhances the durability of the MEPS IDIB system. The service life of the external wall waterproofing meets the 25 year requirement specified in relevant codes, aligning with the demands of green buildings and the long-term performance of high-rise residential structures.
(2) The incidence of common external wall leakage defects is substantially reduced, improving occupant comfort and lowering post-delivery complaint rates for residential projects.
(3) The process is replicable and scalable to similar high-rise and green low-carbon buildings in Hangzhou and the broader Yangtze River Delta region. It contributes to the advancement of the industry's technical system for IDIB waterproofing construction and has generated research outputs including specialized construction methods, patented technologies, and journal publications.

8 CONCLUSIONS AND FUTURE WORK

8.1 Conclusions

(1) The primary causes of water leakage in MEPS IDIB external wall systems are sealant joint failure, water-penetration pathways through anchor holes, and the lack of multi-barrier waterproofing at building nodes. The established three-tier hierarchical waterproofing system effectively blocks all three rainwater infiltration pathways.
(2) The key construction technologies for overcoming common waterproofing defects include: proprietary anchors with water-stop discs; standardized dual-bead sealing with foam rod and weather-resistant sealant; and specialized wrapped-edge anti-infiltration details at external corners, internal corners, windowsills, and parapet copings.
(3) Verified through both the pilot section and the full-scale application at the Xiaoheshan Affordable Housing Project, the integrated waterproofing system passed water spray tests with zero leakage. It effectively improves the overall quality of the external thermal insulation system while balancing economic efficiency and practicality, making it well suited for IDIB external wall projects in high-rise residential buildings across Zhejiang Province.

8.2 Future Work

Future research may focus on the following directions:
(1) Conduct long-term tracking tests on sealant weather resistance under extreme rainstorm and high wind-pressure conditions typical of high-rise buildings.
(2) Utilize BIM technology to develop 3D detailed layouts for waterproofing nodes at corners, doors/windows, and parapet copings, enabling early optimization of tongue-and-groove waterproofing configurations.
(3) Further develop factory-preformed waterproof tongue-and-groove boards to reduce on-site sealing work and improve the efficiency of prefabricated waterproofing construction.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Zhejiang Provincial Department of Housing and Urban-Rural Development. Technical Specification for External Thermal Insulation Systems of Non-metallic Panel Insulation Decoration Boards for External Walls (DB33/T 1164-2019). Hangzhou, 2019.
[2] China Architecture & Building Press. Technical Specification for External Wall Waterproofing Engineering (JGJ/T 235-2011). Beijing, 2011.
[3] Han Y J, Li B. Research on leakage prevention of external wall insulation decoration integrated boards. Architectural Theory and Technology, 2024.
[4] Chen H B. Research on overlapping technology of waterproof and breathable membrane for external wall insulation integrated systems. Building Science, 2025.
[5] Yu C, Li G, Wang H. Restoration of authenticity in building insulation-and-decoration integrated board in cold regions. Scientific Reports, 2025, 15: 20880.
[6] Sha B, Li G, Xia S, et al. The external thermal insulation composite system with foam ceramic insulation decoration integrated board: statics, mechanical properties, and artificial aging accelerated rate. Journal of the Australian Ceramic Society, 2025, 61(4): 615-636.

[7] Wibowo A P, Saidani M, Khorami M. Enhancing sustainability in construction: investigating the thermal advantages of fly ash-coated expanded polystyrene lightweight concrete. Journal of Composites Science, 2024, 8(4): 157.

[8] Hsu K L. Development of waste expanded polystyrene flexible coating material in concrete waterproofing. IOP Conference Series: Earth and Environmental Science, 2019, 351: 012021.

[9] Prasetiyo W A, Saidani M, Khorami M. Surface modification of extruded polystyrene foams through UV curing and its stable adhesion to mortar. Construction and Building Materials, 2022, 359: 129458.