Exploration of Anti-leakage Construction Technology for Concrete Structures in Building Engineering

Hao WU

Chizhou Jiantou Engineering Management Co., Ltd., Chizhou, Anhui, 247100, China

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Abstract: In recent years, with the continuous increase in the number of building engineering projects, leakage problems in concrete structures have become increasingly common, gradually emerging as a topic of public concern and discussion. This paper focuses on the leakage issues of concrete structures in building engineering. It first analyzes the common leakage locations and their hazards, then examines the causes of leakage, such as design flaws, non-standard construction practices, ineffective material management, and structural deterioration. Subsequently, key technical points for anti-leakage measures, including waterproof concrete and critical joint treatments, are provided. Finally, quality control and management measures for all participating parties during various construction stages are clarified, aiming to offer reference for the practical work of relevant personnel.

1. Introduction

In construction projects, if anti-leakage design and construction are not effectively implemented, the overall waterproofing performance will be compromised. During later quality inspection phases, core indicator tests for leakage are bound to fail. The scientific application of anti-leakage technology is highly significant for building engineering. A rigorous construction process deployment coupled with control of process parameters can effectively inhibit leakage, avoid related financial waste, and also reduce maintenance complexity and financial investment throughout the building's entire life cycle.

2. Common Locations and Hazards of Leakage in Concrete Structures of Building Engineering

2.1 Common Leakage Locations in Concrete Structures of Building Engineering

Firstly, the roof is a critical node. The junctions between the roof parapet wall and the roof slab, the surroundings of roof drains, and the roots of roof vent pipes are prone to cracking due to stress concentration in the concrete. Additionally, issues like imperfect overlaps or local damage during waterproofing layer construction are common, allowing rainwater to seep into the structure through gaps [1].

Secondly, exterior walls are vulnerable areas. If concrete pouring around window and door openings, sealed scaffold holes, or junctions of exterior wall decorative lines is not dense, if sealing is improper, or if temperature deformation later causes sealing materials to age, rainwater can infiltrate the wall interior through gaps.

Finally, special structural points in basements require attention. Locations such as basement post-poured strips, construction joints, and the junctions between the base slab and exterior walls have high construction process requirements. Inadequate concrete vibration, insufficient curing of post-poured strips, or misalignment of waterstop installation can allow groundwater to penetrate through these weak points under pressure.

2.2 Hazards of Leakage in Concrete Structures of Building Engineering

Firstly, leakage can compromise structural safety. Long-term water erosion causes internal

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reinforcement corrosion. The expansion of rust cracks and spalls the concrete cover, weakening the bond between reinforcement and concrete and reducing the load-bearing capacity of the structure. In severe cases, it may lead to deformation of components like beams, slabs, and columns, further threatening the overall stability of the building [2].

Secondly, leakage affects functionality. Leakage in exterior walls of public buildings can cause internal wall mold growth and decoration layer peeling, affecting aesthetics and user experience. Basement leakage can lead to dampness in equipment rooms and storage areas, damaging mechanical and electrical equipment or stored goods, also impacting the normal use of the building. Finally, leakage increases economic losses and shortens lifespan. Leakage necessitates frequent repairs, generating additional maintenance costs and potentially affecting project schedules due to repair-related downtime. The long-term action of water accelerates concrete carbonation, damaging the integrity of the concrete structure and shortening the overall service life of the building.

3. Causes of Leakage in Concrete Structures

3.1 Systematic Defects in Design Scheme

Oversights in the design phase are the source of leakage risks. The construction drawings for some projects lack sufficient detail, failing to clearly specify the types and performance indicators of waterproofing materials, leading to a lack of precise basis for material selection. Furthermore, unreasonable node design is prominent [3]. For example: insufficient roof flashing height, or the absence of an overhanging slope on parapet copings, causing rainwater to seep along wall gaps. Additionally, defects in drainage system design are common. Lack of proper slope planning for areas like balconies and cantilevered slabs, and inadequate consideration of roof slope and insulation layer thickness, can create local water ponding areas, accelerating the aging and damage of the waterproofing layer. Moreover, insufficient design investigation of site geological and hydrological conditions, and failure to adjust basement roof waterproofing structures based on overburden height, result in actual waterproofing levels not meeting usage requirements, creating pathways for groundwater infiltration.

3.2 Non-standard Implementation of Construction Techniques

Lack of quality control during the construction process in some building projects increases leakage risk. Some projects lack targeted special anti-leakage plans, omitting treatment measures for critical leakage locations and deviating from standard requirements. Insufficient technical skill of operators is a significant contributing factor [4]. For instance: uneven application of waterproof coatings in bathrooms with local insufficient thickness, failure to set standard rounded transitions at internal corners of bay windows, all factors that weaken waterproofing effectiveness. Simultaneously, poor coordination of interfering works often causes secondary damage. Failure to implement protective measures for finished waterproofing layers after installation leads to material damage by subsequent trades without timely repair. Furthermore, acceptance procedures become mere formalities, with incomplete photographic evidence for sign-off acceptance and lack of records for waterproofing material thickness testing, allowing quality defects to go undetected and uncorrected.

3.3 Failure in Whole-cycle Material Management

Quality control of waterproofing materials spans the entire process from procurement and storage to construction. In some projects, incoming material inspection is not strict, failing to distinguish testing parameters according to standards; new waterproofing materials are used without identification documents. Additionally, improper storage environments directly affect material performance. Water-based waterproof coatings suffer performance degradation if frozen or subjected to freeze-thaw cycles; sheet membrane materials age and deteriorate if stored beyond their shelf life. Furthermore, there is insufficient material compatibility during the construction stage [5]. For example: mismatched dimensions between window sub-frames and structural openings lead to poor sealing effectiveness, creating leakage paths. In some projects, relevant personnel may deliberately lower standards and procure substandard materials with inadequate anti-seepage performance, leading to cracking and leakage shortly after application.

3.4 Structural Deterioration Effects

Inherent defects in the concrete structure and subsequent deformation are internal factors for leakage. Voids like honeycombs and surface voids formed due to inadequate vibration during construction provide pathways for water penetration. Meanwhile, surface cracks caused by thermal stress are also common. Inadequate compaction before final setting of concrete, or rapid surface water evaporation during curing leading to shrinkage cracks; improper handling of special nodes like post-poured strips and construction joints makes them prone to gaps due to concrete shrinkage, compounded by issues like misaligned waterstop installation or insufficient curing periods, easily becoming points of leakage. Moreover, during long-term use, the continuous effects of differential settlement and temperature/humidity changes cause initial micro-cracks to gradually expand, eventually breaching the waterproofing layer and causing leakage.

4.Key Points of Anti-leakage Construction Technology for Concrete Structures in Building Engineering

4.1 Holistic Control of Waterproof Concrete Construction

Waterproof concrete is the core foundation of the anti-leakage system, requiring structural self-waterproofing through raw material synergy and process optimization. On one hand, material selection must emphasize compatibility. Cement should preferably be of a type with low heat of hydration and excellent impermeability. Aggregates must ensure continuous grading to reduce internal pores. Admixtures should be rationally selected based on impermeability requirements: water reducers are primarily used to improve workability and reduce water content, while expansion agents can establish pre-compressive stress through shrinkage compensation, inhibiting crack formation at the source [6]. Simultaneously, during pouring, layered operation must be emphasized to ensure uniform transmission of vibration energy, thus avoiding pore channels formed by insufficient vibration. The curing stage requires continuous moisture supply to maintain a normal hydration environment, preventing internal stress imbalance caused by rapid surface water evaporation, ultimately ensuring the formation of a complete and dense impermeable concrete structure.

4.2 Key Points for Sealing and Protection of Critical Joints

Construction joints, expansion joints, and post-poured strips, as structural weak points, require sealing protection through optimized structural design and precise execution. Construction joints should be located away from areas of high stress concentration, while optimizing their form can reduce leakage paths at the interface between old and new concrete. Before construction, surface laitance and impurities must be thoroughly removed, and then bond strength enhanced through an interface bonding layer to eliminate potential interface gaps [7]. Furthermore, protection of expansion joints requires establishing a dual sealing system. Waterstop selection must be compatible with the displacement characteristics of the joint. The synergistic action of embedded and external waterstops forms a three-dimensional defense. Fillers within the joint must possess both elasticity and sealing properties to continuously block water penetration paths during structural deformation. Post-poured strip construction requires mastering the pouring timing, determining the construction time based on structural settlement or thermal deformation patterns. Concrete with shrinkage compensation capabilities should be used, effectively filling the gap through enhanced strength and impermeability.

4.3 Special Protection System for Pipelines and Embedded Parts

Leakage prevention for penetrating pipes and embedded parts requires establishing a special protection system involving interface sealing and structural reinforcement. Penetrating pipes require isolation protection using waterproof sleeves. Sleeves prevent direct contact between the pipe and the structural wall, while waterstop rings enhance the impermeability at the sleeve-concrete interface. The gap between the pipe and the sleeve should be filled with layered sealing materials, forming a graded anti-seepage structure to block water penetration along the gap. Furthermore, protection of embedded parts must emphasize surface treatment and structural reinforcement. Before installation, corrosion must be thoroughly removed to ensure bonding stability with concrete. Waterstop structures should be designed around embedded parts to form a seepage barrier. Simultaneously, during concrete pouring, special attention must be paid to the compaction around embedded parts to avoid voids forming leakage channels, fundamentally blocking water penetration along the interface between the embedded part and the concrete.

4.4 Targeted Protection for Roof and Exterior Wall Nodes

Leakage prevention for roof and exterior wall nodes requires designing protection schemes tailored to the specific leakage risks of different nodes, through characteristic adaptation and process intensification. The core of sloped surface protection is the synergy between drainage and the waterproofing layer. Slope design must ensure smooth drainage paths, avoiding long-term water erosion of the waterproofing layer. Simultaneously, node design should reduce stress concentration in the waterproofing layer. For example, a rounded transition at the parapet root can reduce the probability of waterproofing layer damage. Furthermore, waterproofing layer fixing and sealing must form a complete closed loop to prevent water penetration along the edges. Additionally, exterior wall protection must balance compactness and interface sealing. Sealing of scaffold holes requires layered operation to ensure density, avoiding internal pores caused by uneven pouring. Protection of external window openings requires establishing a multi-level sealing system, forming an anti-seepage defense through the synergistic action of fillers, sealants, and waterproof mortar, combined with drainage structure design to prevent rainwater backflow, ensuring node protection aligns with the overall impermeability performance of the exterior wall.

5. Quality Control and Management of Anti-leakage Construction

Firstly, the construction unit needs to assemble technical and quality inspection resources to conduct a joint review of design drawings, focusing on verifying the feasibility of the waterproofing scheme and the standardization of node design. Any identified issues should be promptly fed back to the design unit for correction. Simultaneously, the project department must conduct special briefings for construction teams on key technologies, comprehensively introducing technical parameters, quality control points, and risk warnings for the anti-leakage works, ensuring construction personnel fully grasp the quality requirements [8]. Furthermore, during the inspection of raw materials and components, the construction unit needs to collaborate with the supervision unit, conducting sampling inspections of cement, aggregates, waterproofing membranes, waterstop plates, etc., according to national and industry standards, preventing unqualified materials from entering the construction process.

Secondly, during the construction process, the supervision unit must implement whole-process standing supervision over all stages including concrete mixing, transportation, pouring, vibration, and curing, ensuring construction techniques comply with specifications. Simultaneously, the supervision unit needs to strengthen standing inspections for key parts and processes like construction joints, expansion joints, and post-poured strips, focusing on verifying the implementation of waterstop measures and maintaining self-inspection records. Furthermore, after the completion of each process, the construction unit must conduct self-inspection. Only after passing self-inspection can they report to the supervision unit for acceptance. The next process can only commence after acceptance by the supervision unit.

Finally, during the project acceptance phase, the client unit should lead the supervision and construction units in testing the waterproof performance of the concrete based on technical standards and design documents. Methods like water ponding or water spray testing can be used. If quality non-conformities are found during acceptance, the construction unit, as the rectification responsible party, should designate specific responsible persons, formulate a special rectification plan, and implement it within a deadline. Upon completion of rectification work, after the supervision unit approves the rectification report, the client unit should lead the final review and confirmation.

6. Conclusion

Anti-leakage measures for concrete structures in building engineering are a core link in ensuring project quality, directly related to structural safety, functionality, and service life. From avoiding design defects at the source, standardizing construction techniques, and strengthening whole-cycle material management, to implementing full-process quality supervision, it requires collaboration among clients, designers, contractors, and supervisors, integrating technical points and management requirements throughout. Only by building a robust anti-leakage defense with systematic thinking and precisely mitigating risks at all stages can leakage hazards be effectively reduced, genuinely enhancing the overall quality and durability of the project.

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