

Research on Construction Technologies for Building Structure Strengthening

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Abstract: With the continuous development of the construction industry, existing building structures often suffer varying degrees of damage during long-term use due to factors such as the natural environment, load changes, and material aging, affecting their safety and serviceability. Construction technologies for building structure strengthening, as crucial means to ensure structural safety and extend building service life, are increasingly gaining attention. This article discusses the value of applying these technologies and analyzes the application of specific structural strengthening techniques, aiming to provide a reference for practical building structure strengthening projects.

1 Introduction

During long-term use, building structures are affected by numerous factors, such as natural disasters including earthquakes, floods, and typhoons, as well as material degradation, increased loads, and design/construction defects inherent to the structure itself. These lead to issues like cracks, deformation, and reduced load-bearing capacity, seriously threatening people's lives, property safety, and the public interest. To ensure the safety and reliability of building structures and improve their performance, strengthening and retrofitting existing structures has become an important task in the construction industry. Construction technologies for building structure strengthening are key to achieving this. Therefore, in-depth research into these technologies holds significant practical importance for promoting the sustainable development of the construction industry.

2 Value of Applying Building Structure Strengthening Construction Technologies

2.1 Ensuring Building Structure Safety

The safety of a building structure is the core prerequisite for its existence, directly linked to life, property, and the public interest. During long-term use, structures are subject to the combined effects of multiple factors leading to potential safety hazards. Material degradation is an inevitable process; over time, issues like concrete carbonation and steel reinforcement corrosion gradually appear, causing a decline in the structure's mechanical properties. Furthermore, changes in the external environment also threaten structural safety, such as the long-term cumulative effects of loads, repeated fluctuations in temperature and humidity, and slow changes in geological conditions, all of which can weaken the structure's load-bearing capacity and stability. Effective building structure strengthening technologies can address these issues targetedly. Through scientific strengthening treatment, the load-bearing capacity of the structure can be systematically enhanced, its overall stiffness increased, and its stress state optimized, thereby fundamentally eliminating potential safety risks ^[1]. This strengthening not only keeps the structure stable under normal use conditions but also improves its ability to resist accidental loads and extreme environmental impacts, ensuring the building structure remains safe and reliable throughout its entire life cycle, providing a solid guarantee for the realization of its functions.

2.2 Extending Building Service Life

Buildings, as significant fixed assets, have a service life directly related to asset utilization efficiency and investment return. During long-term service, erosion by the natural environment and the continuous action of service loads cause structural materials to gradually age and decay, such as

concrete strength attenuation, steel structure corrosion, and masonry weathering. These issues continuously weaken the overall performance of the structure and accelerate the process of functional failure. If buildings with degraded performance are directly demolished and rebuilt, it not only requires huge capital investment for the planning and construction of new buildings but also consumes large amounts of natural resources like sand, gravel, and steel. Simultaneously, the construction waste generated during demolition can seriously impact the surrounding ecological environment ^[2]. By applying building structure strengthening technologies, systematic repair and reinforcement of the structure's weak links can be carried out, effectively restoring the mechanical properties of materials and delaying the aging process, thereby significantly extending the actual service life of the building. This approach avoids resource waste, reduces environmental damage, and enables the sustainable utilization of building assets.

2.3 Meeting Building Function Expansion Needs

With the continuous development of the social economy and the gradual improvement of people's living standards, the functional requirements for buildings are constantly evolving. Many existing buildings, constructed earlier, have initial functional configurations that can no longer keep up with current usage standards, facing urgent needs for functional expansion or renovation. This inevitably requires targeted strengthening of the original structure to meet the new demands of new functions in terms of structural load-bearing capacity, spatial layout, service loads, and more. Building structure strengthening technologies, through scientifically adjusting the structure's stress form, reasonably adding necessary structural components, and optimizing the load transfer path of the original structure, can effectively enhance the adaptability of the building structure, allowing it to cope with new functional needs smoothly, thereby significantly increasing the building's use value ^[3]. At the same time, functionally expanding and renovating existing buildings can greatly reduce the occupation of new land resources and lower the massive resource consumption and environmental pressure caused by new construction. This approach highly aligns with the current concept of sustainable development and holds very positive practical significance in saving social resources, protecting the ecological environment, and promoting urban renewal.

3 Application of Building Structure Strengthening Construction Technologies

3.1 Section Enlargement Strengthening Method

The section enlargement strengthening method is a traditional technique that involves adding concrete and reinforcement outside the original structural member to increase the cross-sectional size and enhance load-bearing capacity and stiffness. Its core principle is utilizing the new materials to work compositely with the original member, dispersing loads and reducing stress intensity per unit area through the increased sectional area, thus achieving strengthening. This method is suitable for various components in concrete structures like beams, slabs, columns, and walls, particularly for strengthening members where insufficient sectional size leads to significantly low load-bearing capacity ^[4]. Construction must follow a strict technical process: first, treat the surface of the original member by thoroughly removing laitance, oil stains, and debris, then roughen (scabble) the surface to enhance the bond between new and old concrete by increasing roughness, ensuring effective stress transfer at the interface. Next, configure and place new reinforcement according to the design, fixing it to preset positions on the original member by tying or welding, ensuring accurate positioning and integration with the original structure into a holistic load-bearing system. Then, erect formwork, which must be installed firmly and reliably with tight seams to avoid deformation and grout leakage during concrete pouring that could affect strengthening quality. Finally, pour and cure the concrete. The curing duration is determined based on the concrete strength grade and environmental conditions, usually not less than 14 days, to ensure concrete strength meets standards ^[5]. This method offers significant technical advantages: simple construction process, mature technical system, and reliable strengthening effects verified by long-term engineering practice, greatly improving the load-bearing capacity and overall stiffness of structural members. However, it

has limitations: the increased sectional size directly adds to the structural self-weight, may reduce usable space, and affect aesthetics; moreover, it involves multiple construction stages, has a relatively long cycle, and may disrupt normal building use and surrounding traffic during construction.

3.2 External Prestressing Strengthening Method

The external prestressing strengthening method involves arranging prestressing tendons outside the structural member and applying prestress to adjust the structural stress state and enhance load-bearing capacity and stiffness. Its core mechanism is using the reverse load generated by the prestressing tendons to offset part of the external actions, reducing the stress level in the original member, thus optimizing the overall structural performance. This method is highly effective for strengthening flexural members like beams and slabs, and performs particularly well in strengthening large-span structures, effectively addressing issues where traditional methods struggle to balance performance improvement and space preservation in such structures [6]. The construction process requires multiple precise steps: first, arrange and install the prestressing tendons. Based on the structural mechanical characteristics and strengthening objectives, determine the layout position, quantity, and direction of the prestressing tendons accurately to ensure their effective participation in structural load-bearing. Then, install and fix the anchors. The selection of anchors must match the type of prestressing tendons and the tensioning method, and they must possess sufficient strength and reliability to ensure stable prestress transfer. Applying and tensioning the prestress is the critical step. It must strictly follow the design-specified tensioning sequence and control stress, gradually reaching the design value through staged tensioning to avoid damaging the structure due to stress sudden changes during the process. After tensioning, comprehensive anti-corrosion treatment for the prestressing tendons and anchors must be promptly applied, isolating them from external corrosive media through coatings, wrapping, etc., to prevent performance degradation caused by rust. This method offers significant advantages: it can greatly increase the structure's load-bearing capacity and stiffness without increasing member sectional size or self-weight, while also reducing structural deflection and crack width, improving serviceability. However, limitations exist: the construction process demands high technical precision and requires specialized construction teams and equipment; furthermore, the anti-corrosion treatment for tendons and anchors is complex, long-term maintenance costs are relatively high, and the durability of protective measures needs particular attention in environments with complex conditions.

3.3 Bonded Steel Plate Strengthening Method

The bonded steel plate strengthening method involves adhering steel plates to the surface of the original structural member using adhesive, forming an integral load-bearing system with the original member to enhance its load-bearing capacity and stiffness. Its core is utilizing the adhesive's bonding action to transfer stress, allowing the steel plate to participate in load-bearing and compensate for the strength deficiency of the original member. This method is suitable for strengthening various components in concrete structures like beams, slabs, columns, and walls, and is particularly effective for strengthening members with insufficient reinforcement or low sectional load-bearing capacity. The construction process must strictly follow specification requirements. The first step is surface treatment of the original member: thoroughly remove impurities like the concrete cover, laitance, and oil stains to expose the sound concrete substrate, then grind the substrate to increase surface roughness and enhance the bond strength between the adhesive and concrete [7]. The second step is steel plate processing and treatment: after cutting the steel plate to design dimensions, descale and grind its surface to ensure effective bonding with the adhesive. The third step is applying adhesive and bonding the steel plate: evenly apply the adhesive to both the steel plate and the member surface, then immediately position and bond the steel plate, securing it with clamps or bolts to ensure tight contact and avoid voids (drumming). Finally, carry out curing. During curing, applying external force to the steel plate is strictly prohibited to ensure the adhesive fully cures and achieves the design bond strength. The advantages of this method are clear: simple construction process, short construction period, minimal impact on building usable space and

aesthetics, and effectively guaranteed strengthening results. However, limitations also exist: the quality of the adhesive and the construction (workmanship) greatly influence the strengthening effect. Under harsh environmental conditions like high temperature or humidity, the adhesive's performance can be easily compromised, potentially reducing the strengthening effect. Therefore, application in such environments requires special attention to material selection and construction quality control.

3.4 Carbon Fiber Reinforced Polymer (CFRP) Sheet Strengthening Method

The CFRP sheet strengthening method involves bonding carbon fiber sheets to the surface of the original structural member using adhesive, utilizing the high strength and high elastic modulus of the CFRP to enhance the member's load-bearing capacity and stiffness. Its core is using the mechanical properties of the carbon fiber material to compensate for the strength defects of the original structure, forming an integral load-bearing system through the adhesive's bonding action. This method features light weight, high strength, corrosion resistance, and convenient construction. It is suitable for strengthening various concrete structural members and is particularly applicable in scenarios where requirements for structural self-weight and aesthetics are high. The construction process must follow standardized procedures. First, perform surface treatment: clean and repair defects like cracks, honeycombs, and surface imperfections on the original member, then grind the surface to ensure a flat and sound substrate^[8]. Next, apply primer: the primer enhances the bond between the adhesive and concrete, must be applied evenly, and allowed to cure. Then, bond the CFRP sheets: cut the sheets according to design requirements, pay attention to fiber direction and lap length during bonding, ensure tight adhesion to the member surface, and avoid air bubbles or wrinkles. Finally, apply protective coat (top coat): the protective coat forms a layer to prevent the CFRP sheets from being damaged by external environmental erosion. The advantages of this method are significant: the material is lightweight and high-strength, does not increase structural self-weight or sectional size, construction is convenient and fast, impact on building usable space and aesthetics is minimal, and it offers good corrosion resistance and durability. However, this technology also has limitations: CFRP sheet material cost is relatively high; the construction process requires strict environmental conditions and process precision; it must be operated by professional personnel to ensure strengthening quality, otherwise improper construction can easily affect the overall strengthening effect.

4 Conclusion

Construction technologies for building structure strengthening play significant roles in ensuring structural safety, extending building service life, and meeting functional expansion needs. The section enlargement method, external prestressing method, bonded steel plate method, and CFRP sheet method are all commonly used technologies in current construction projects, each with its characteristics and scope of application. Suitable methods must be selected based on specific circumstances in practical engineering. With technological progress, building structure strengthening technologies continue to develop and innovate. In the future, the development and application of new strengthening materials, the promotion of intelligent strengthening technologies, and the exploration of green and environmentally friendly strengthening processes will become development directions in this field. Simultaneously, management across all stages—design, construction, supervision—needs strengthening in building structure strengthening projects to ensure project quality and safety, supporting the sustainable development of the construction industry.

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