Research on Construction Technologies for Building Structure Strengthening

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Abstract: Since the construction industry has been developed continuously, most of existing building structures are subjected to different levels of damage during their long-term use due to reasons such as environment, change and increase of loads and aging of materials, which reduces its safety and working performance. Strengthening building structures has become an increasing attention as a key way to guarantee the structural safety and service life of buildings, therefore construction technologies have also attracted more and more research efforts. This article explores the usefulness of these techniques and analyzes the implementation of certain structural reinforcement technologies, in order to provide a reference for practical building structure fortification projects.

1. Introduction

During long-term use, many factors have effect on building structures such as natural disaster (cases of earthquakes, floods and typhoons), material degradation, growing loads as well as design/construction defects which belong to the structure. To cause cracks, deformation, and reduction of bearing capacity all resulting in a serious threat to the lives and property of the people and the social autonomy. Strengthening and retrofitting existing structures is now a critical challenge for the construction industry to ensure the safety, reliability, and performance of building structures. This is possible through construction technologies that provide strengthening of the building's structure. Hence, it is of great practical importance to research in detail these technologies to support sustainable construction industry development.

2. Value of Applying Building Structure Strengthening Construction Technologies

2.1 Ensuring Building Structure Safety

The safety of the building structure is one of its basic conditions for existence associate with human life, property and a public interest. On the other hand, a structure, particularly exposed to multiple environmental loads over long-life span of time and evolving in an uncertain system environment, can be under combined action of factors which end as a path that tends to a safety hazard. Provision for material degradation is an inevitable process; gradually emerges through time into these issues (e.g. carbonation of concrete, corrosion of steel reinforcement) and resulting mechanical properties degradation. Moreover, any modifications to the outer atmosphere can also pose a risk for structural safety, such as long-term impacts of loads, cyclical changes in temperature and humidity, and gradual alterations in geological settings, which may make the structure become weaker and less stable. Technologies for targeted strengthening of building structures can help address these challenges. By scientifically strengthening the treatment, it is possible to increase bearing capacity working level of the structure in a systematic way; increasing overall strength of the whole structural, and optimizing stress state, fundamentally removing hidden danger [1]. This will not only effectively enhance the stability of building structure under normal use condition(regular column, beam etc.) but also treat those accidental load cases and extreme environmental influences as part of design so that the building structure can guarantee safety and reliability for entire life cycle, which provide a strong guarantee to reach required function.

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2.2 Extending Building Service Life

Buildings, as one of the fixed assets, are important public goods with a service life related to asset utilization efficiency and return on investment. In long-term service, the natural environment and the repeated effect of service loads lead to irretrievable aging and damage of structural materials such as concrete strength attenuation, steel structure corrosion and masonry weathering. These problems are always undermining the quality of the structure and active functional failure. Direct demolition and reconstruction of buildings with degraded performance results in huge capital investment for planning and construction of new buildings, as well as consuming significant amounts of natural resources such as sand, gravel and steel. At the same time, the construction waste generated in demolition works has a great adverse effect on ecological environment surrounding [2]. Through the use of technologies to strengthen building structures, systematic repair and reinforcement of the structural weak links are carried out, restoring mechanical properties of materials and slow aging process in the system that significantly extend the actual service life of buildings. This prevents the waste of resources, minimizes environmental harm, and facilitates holistic use of building assets.

2.3 Meeting Building Function Expansion Needs

As the social economy continues to develop and people's living standards continue to improve, the performance requirements of buildings are changing. A lot of the existing buildings that were built at an earlier time are only usable in initial functional configurations that can not address current usability standards face immediate demands for functional growth or further renovation. This entails strengthening the existing structure to carry new loads, space planning of new functions, service loads, etc. Methods used to strengthen building structures, through scientifically adjusting the form of stress in the original structure, reasonably adding necessary structural components, optimizing the load transfer path of the original structure can effectively improve the adaptability of building structure, make the building structure more smoothly adapt to new functional needs and greatly increase its use value [3]. Meanwhile, functionally expanding and renovating existing buildings also turns out to greatly reduce the occupation of new land resources as well as a lot lower the massive resource consumption and environmental pressure caused by new construction. This method is very consistent with the contemporary idea of sustainable development and has a very good practical significance in saving social resources, protecting eco-environment and promoting urban renaissance.

3. Application of Building Structure Strengthening Construction Technologies

3.1 Section Enlargement Strengthening Method

The section enlargement strengthening is a conventional method that aims to improve load-carrying capacity and stiffness by increasing the flexural cross-sectional size of the original structural member with supplementary concrete and/or reinforcement external to this element. The essence of strengthening with the new member is that through taking advantage of the original member, dispersing loads and reducing stress intensity per unit area as much as possible by using a larger sectional area realize strengthened. This technique can be employed for different elements in concrete structures such as beams, slabs, columns and walls to strengthen members with heavily reduced load-bearing capacity due to insufficient sectional size [4]. Although construction is an extremely technical process, they must typically be treated in the same manner: Prepare the original member surface by thoroughly removing laitance, oil stains and debris; scabble (roughen) to introduce additional surface area in order to ensure that both old and new concrete bond effectively, and can transfer stress at the interface. Then, design and lay the new reinforcement by tying or welding to pre-selected locations on the original member that is clearly aligned with it, making sure that these components work together as an integrated load bearing system. Then put up forms that need to be mounted in a stable and reliable manner of tightly linking seams which are just there will not deform when pouring the concrete causes leak grout, causing impacted strength quality. Finally, fill and cure the concrete. It is also records that along with ambient temperature and humidity as well as type of concrete in three groups (the overall duration of no less than 14 days), the curing period can be take into account [5]. This technique has huge technical benefits: it is relatively easy to construct; the relevant technical system is already mature; and strengthening effects have been successfully verified over a long-term engineering practice, significantly improving the carrying capacity and stiffness of structural members. However, the disadvantages are: increased section size will increase the self-weight of the structure; It may also reduce usable space and affect aesthetics; The construction is divided into multiple stages, which is relatively long cycle; Disrupt normal building use during construction and surrounding traffic.

3.2 External Prestressing Strengthening Method

External prestressing is a type of strengthening method in which arrangement of prestressing tendons outside the structural member applies the predetermined level of holding capacity and stiffness according to adjusting the stress state. What it does is use the reverse load of prestressing tendons to reduce part of the external actions and better stress level in original member to optimize the structure performance. This method is very effective in the reinforcement of flexural members such as beams and slabs, specially with its application for large-span structures where traditional methods do not balance performance enhancement and space conservation requirements because it provides exceptional results [6]. The construction process for this stage involves in series of individual steps: The pre stressing tendons need to be arranged and placed. Reasonably determine the layout position, quantity, and direction of prestressing tendons according to structural mechanical characteristics and strengthening goalso participate in load-bearing. Install the anchors, and then fix it. Anchors should be consistent with prestressing tendons and tension method, and have a strong enough strength, reliability to transfer the prestress stability. Tensioning and applying the prestress is where it becomes essential. Carefully follow the design-specified tensioning sequence to control stress, and avoid damage to the structure in stages caused by instant changes in stress during this process (gradual increase of the design value through staged tensioning). Following the tensioning process, timely and thorough anticorrosion treatment for the prestressing tendons and anchors should be performed by applying coatings, wrapping etc. to isolate them from corrosive media outside in order to mitigate rust degradation of the performance. This approach provides a notable benefit: it is able to increase the bearing capacity and rigidity of the structure significantly without requiring an increase in sectional size or self weight of members, while simultaneously reducing structural deflection and crack width thus improving serviceability. But there are also limitations: The construction process requires a high level of technical precision, and professional construction teams and equipment are needed; the anti-corrosion treatment of tendons and anchors is complex, with long-term maintenance costs relatively high, but the durability of protective measures in environments with complex conditions needs special attention.

3.3 Bonded Steel Plate Strengthening Method

This bonded steel plate strengthening method consists of bonding the original structural member with steel plates using adhesive and turning them into a composite system to increase load-bearing capacity and stiffness. The core principle is to use the bonding action of adhesive to transfer stress and enable the steel plate participate in load-bearing so as to make up for the deficiency in strength of original component. This process is also applicable to various members in concrete structures, including beams, slabs, columns and walls — as it works well in such cases with low sectional load-bearing capacity or insufficient reinforcement. There are specification requirements that have to be followed during the construction process. Step1: surface treatment of the original member: thoroughly remove impurities, such as concrete cover, laitance and oil stains to achieve a sound concrete substrate exposure and then ground up the substrate properly so that enhances its roughness [7]. The second step is steel plate processing and treatment: the steel plate according to the design size of cutting, and then remove surface scale, grinding processing, so that the adhesive can be bonded more firmly. The third step is adhesive Application & Steel Plate Bonding: the adhesive is applied evenly on the steel plate and member surface, then the steel plate is positioned and bonded immediately (clamps or bolts are used to bond) so that it presses down into very tight contact (voids are avoided, drumming). Finally, carry out curing. When curing, external force applied to the steel plate is not allowed because adhesion requires time to cure and reach designed bond strength. The advantages of this approach are obvious: simple construction processes, short construction period, little effect on the usable space and aesthetics of the building, and strengthening results that can be ensured to meet the requirements. But there are shortcomings: the quality of glue and workmanship has a great influence on strengthening effect. However, the adhesive itself may perform poorly under extreme environmental conditions (high temperature or humidity), which may weaken the strengthening effect. Thus, careful selection of materials and construction quality conformity is essential for application in such environments.

3.4 Carbon Fiber Reinforced Polymer (CFRP) Sheet Strengthening Method

CFRP sheet bonding method is a technique in which carbon fiber sheets are bonded to the surface of the original structural member through adhesive with the aim to use high strength and high elastic modulus of CFRP, so that it can increase load-bearing capacity and stiffness capacity. The essence of it is utilizing the mechanical performance of the carbon fiber materials to make up for the strength shortcoming of original structures that could result in an integrative load-bearing system via global adhesive action during bonding. This method is characterized by light weight, high strength, corrosion-resistance and ease in construction. It is applicable for the strengthening of various concrete structural members in the zones that require high criteria regarding self-weight structural and esthetic ability.

The process of construction should be standardized. Step I Surface Treatment: Repairs such as leakages, honeycombs and surface imperfections in the original member, are followed by grinding the surface to provide a flat and sound substrate [8]. Second comes the primer: it makes the adhesive stick better to the concrete, has to go on evenly, and must curer. Second, bond the CFRP sheets: cut them as per design requirements (fibers direction and the lap lenticel should be designed)Apply to members tightly without air bubbles or wrinkles. Finally, apply protective coat (top coat) → The protective coat does form a layer to prevent the CFRP sheets are damaged by erosion of the external environment. 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 have important influencing factors on structural safety, limitation of the service life and functional expansion of building structures. The technology related to external tensile member for bridge reinforcement mainly includes the section enlargement method, external prestressing method, bonded steel plate method and CFRP sheet. In practical engineering, appropriate methods must be chosen based on the situation. As the technology keeps advancing, structure enhancement systems are also evolving and improving. The future strong structure is characterized by the use of new strengthening materials and intelligent strengthening technologies, exploration efforts toward green and environmentally friendly processes of reinforcement will be a major development trends in the field. At the same time, management at all levels such as implementation and design supervision of buildings needs to be strengthened in building structure upgrading plans; Ensure quality safety for projects to keep regular construction activity for the development of a sustainable industry.

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