An Analysis of Optimization Strategies for Exposed Steel Reinforcement in Cast-in-Place Concrete Structures in Building Construction

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Abstract. Currently, the problem of exposed steel reinforcement in cast-in-place concrete structures during construction is particularly prominent. It directly affects the overall quality of building construction projects. Building construction projects are characterized by their large volume and complex structures, making it crucial to strengthen the overall construction quality control. This paper aims to address the issue of exposed steel reinforcement in concrete cast-in-place structures at construction sites. It explores the causes of exposed steel reinforcement in reinforced concrete cast-in-place structures and analyzes the problem of exposed steel reinforcement on construction sites from the perspective of load-bearing concrete spacer blocks. This analysis attempts to optimize existing concrete spacer blocks as a reference for solving the problem of exposed steel reinforcement in cast-in-place concrete technology at construction sites or similar issues.

Keywords: Building construction project; exposed steel reinforcement; concrete spacer block; modularization

1 Introduction

In the era following the COVID-19 pandemic, various industries are confronting a challenging landscape. To ensure their survival, many sectors find themselves ensnared in a period often referred to as the “race to the bottom” era. Therefore, measures to control engineering quality risks in housing construction projects are urgent.

There is a growing demand from all sectors for higher standards of quality in building construction projects. Ensuring construction quality is a fundamental prerequisite for guaranteeing the safety, reliability, and durability of building structures. Any minor issues that arise during the construction of residential buildings can directly impact the overall construction quality. Therefore, prioritizing construction quality in building construction is of paramount significance. Among numerous quality issues, “exposed steel bars” bear the brunt of the red line of engineering quality [1]. In current housing

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construction projects, the exposure of steel bars directly affects the overall quality of the project. Moreover, building construction projects are characterized by their large-scale and intricate structures, which underscores the critical importance of enhancing the overall construction quality control in this sector [5].

The main measure to avoid the quality risk of "exposed steel bars" is to control the protective layer of cast-in-place concrete[3]. The specific measures to control the protective layer of cast-in-place concrete are mostly using concrete cushion blocks. At the construction site, concrete cushion blocks are mainly in the form of points (including different shapes), and finished concrete cushion blocks are used to support the steel bars, achieving the control of the quality risk of "bare steel bars".

2 Summary of Exposed Steel Reinforcement Causes

Civil engineering projects in building construction are inherently complex, involving various industry knowledge and specialized content. Due to numerous influencing factors, concrete cast-in-place structures may experience the phenomenon of exposed steel reinforcement after concrete pouring [2]. The reasons for this issue are summarized as follows (Figure 1):

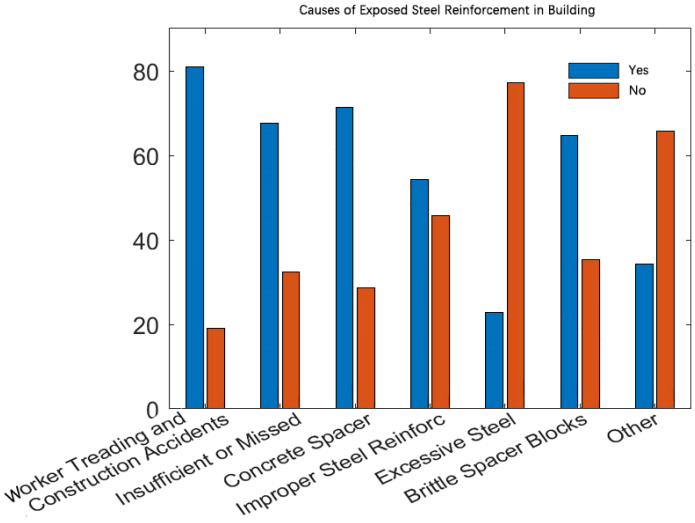

Fig. 1. Causes of Exposed Steel Reinforcement in Building Construction on Construction Sites

During concrete pouring, displacement of the steel reinforcement protective layer blocks due to factors such as worker trampling and construction errors result in exposed steel reinforcement, accounting for 80.95%.

In the process of steel reinforcement binding, inadequate placement or omission of concrete spacer blocks leads to steel reinforcement sagging or moving closely to the formwork, causing exposed steel reinforcement in densely reinforced areas, accounting for 67.62%.

During steel reinforcement binding, the concrete spacer blocks at the bottom of the steel reinforcement, being brittle and subjected to excessive load, may fracture, causing the steel reinforcement to fall and adhere closely to the formwork, resulting in exposed steel reinforcement, accounting for 64.76%.

Insufficient concrete protective layer thickness, concrete leakage during placement, or impact on steel reinforcement by vibrating rods, leading to the displacement of the steel reinforcement and exposed steel reinforcement, accounting for 71.43%.

Inaccurate steel reinforcement dimensions or improper binding of steel reinforcement results in oversized steel reinforcement frames, and local contact with the formwork, accounting for 54.29%.

Small structural or component cross-sections, excessive steel reinforcement density, and stones trapped on steel reinforcement prevent cement mortar from fully surrounding the steel reinforcement, causing exposed steel reinforcement, accounting for 22.86%.

3 Stress Analysis of Concrete Spacer Blocks

Concrete protective layer blocks are generally placed below the steel reinforcement at the bottom of beams and slabs. They provide vertical support for the steel reinforcement at the bottom of the components, ensuring that the thickness of the concrete protective layer meets the design requirements during concrete pouring[4]. Concrete protective layer blocks placed under beams can increase the load-bearing area and address local compression issues. Through the interaction between protective layer blocks and steel reinforcement, they acquire substantial load-bearing capacity.

In terms of site cleanliness, the arrangement of concrete spacer blocks can effectively address the problem of scattered placement. During the construction process, existing concrete spacer blocks are placed according to construction plans, the experience of construction personnel, and convenience[9]. Due to the small volume of concrete spacer blocks and the negligence of site management personnel, workers may place them haphazardly, leading to a cluttered and irregular construction site. Additionally, some protective layer blocks may not be placed under the steel reinforcement, rendering them ineffective (Figure 2).

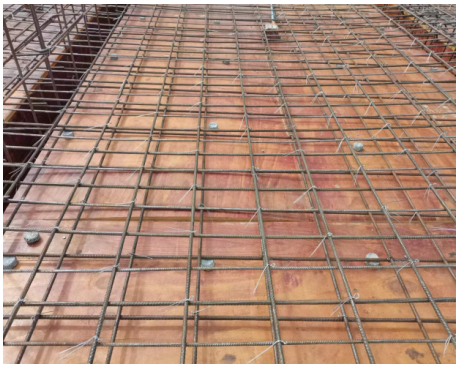

Fig. 2. Disordered Placement of Blocks

3.1 Point Loading

In cast-in-place structural beams, concrete block loading occurs as a result of the gravitational force of the structural steel reinforcement being transferred to the concrete spacer blocks[11]. Concrete spacer blocks are usually scattered in a point-like distribution under the beams' steel reinforcement at construction sites, providing support for the steel reinforcement's weight, thus forming the protective layer (Figure 3).

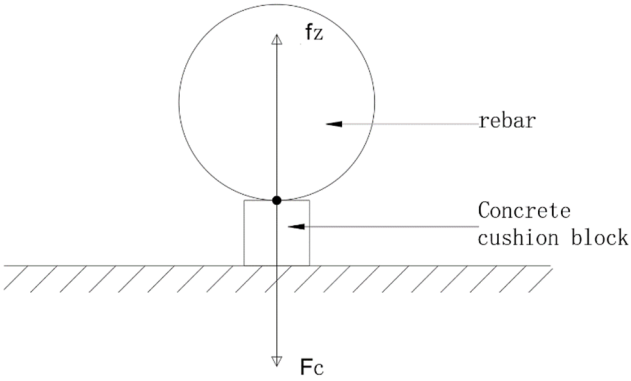

Fig. 3. Point Loading Analysis

Under this configuration, the forces between concrete spacer blocks and steel reinforcement are relatively scattered. The weight borne by a single concrete cushion block is relatively small. Concrete spacer blocks are brittle and have low strength[8]. Under the influence of gravitational force, trampling by construction workers, and pressure from inspectors, concrete spacer blocks can easily fracture. This can lead to inadequate protective layers at the bottom of the steel reinforcement or uneven protective layers, ultimately resulting in exposed steel reinforcement (Figure 4).

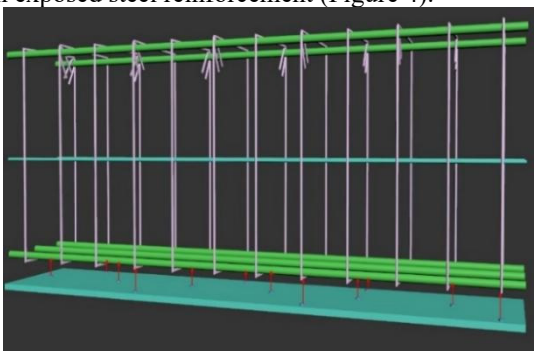

Fig. 4. Point Loading Analysis Diagram

3.2 Linear Loading

Optimized concrete spacer blocks can significantly improve their load-bearing capacity. Concrete spacer blocks bear the weight transmitted through structural steel reinforcement and support the weight of the steel reinforcement through their connections. This arrangement can greatly enhance the load-bearing capacity of concrete spacer blocks (Figure 5).

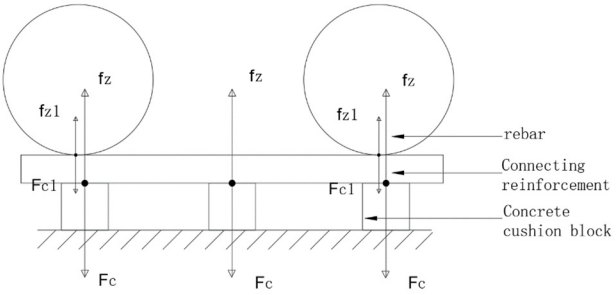

Fig. 5. Linear Loading

In construction sites, the contact force point between the concrete cushion block and the steel reinforcement structure after grouping has changed from the old single point to a linear multi-point, the force is more uniform, and multiple concrete cushion blocks are gathered together, significantly improving the effect of bearing gravity and breaking away from the scattered point-like distribution of existing concrete spacer blocks. They assume a linear distribution with stronger resistance to compression and shear forces (Figure 6).

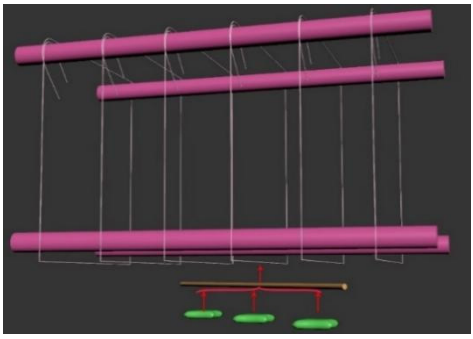

Fig. 6. Linear Loading Analysis Diagram

4 Application of Concrete Spacer Blocks in Cast-in-Place Structural Beams

Concrete spacer blocks are grouped in sets of three and secured to steel reinforcement by using wire ties, forming a concentrated and modularized system. When binding concrete spacer blocks to steel reinforcement, the spacing between concrete spacer blocks

should be as uniform as possible, and the binding should be secure. Otherwise, grouped concrete spacer blocks may experience uneven loading, detachment, displacement, and fracture, increasing the risk of exposed steel reinforcement and uncontrollable engineering quality.

Through on-site tests and imitate, and in accordance with the "Quality Acceptance Code for Concrete Structure Engineering", when using modularized concrete spacer blocks, it is advisable to select steel reinforcement with diameters ranging from 6 mm to 10 mm. Within this range, the protective layer thickness of cast-in-place concrete structures can be controlled within the specified range. Using excessively large steel reinforcement can result in overly thick protective layers, affecting structural height, increasing material waste, and raising costs [10]. Conversely, using overly small steel reinforcement can lead to inadequate load-bearing capacity for modularized concrete spacer blocks, causing steel reinforcement to settle and increasing the risk of exposed steel reinforcement (Figure 7).

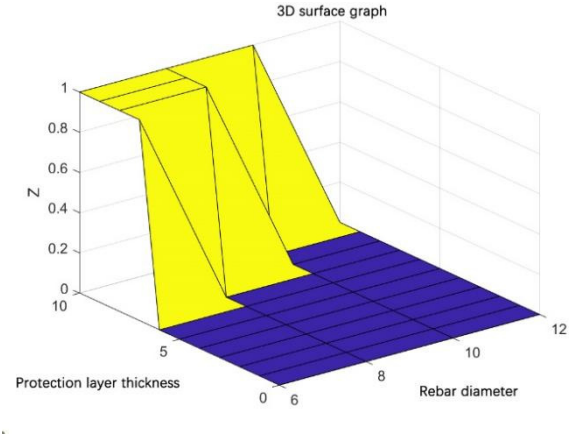

Fig. 7. Simulation of Connection Reinforcement Model

Through the grouping treatment of concrete cushion blocks, the drawbacks of the small size of existing concrete cushion blocks can be effectively overcome in terms of volume, making it easier for workers to access and use them during construction, and avoiding omissions during construction; secondly, it can also avoid displacement caused by workers and management personnel stepping on or accidentally touching during construction; what's more, it can avoid the fragmentation caused by the brittleness of the concrete cushion block and the excessive bearing of gravity during the steel bar binding process, thereby avoiding the problem of exposed steel bars in the cast-in-place concrete structure of construction projects, and effectively improving the quality of construction projects (Figure 8 and Figure 9).

Fig. 8. Modularized Concrete Spacer Blocks (1)

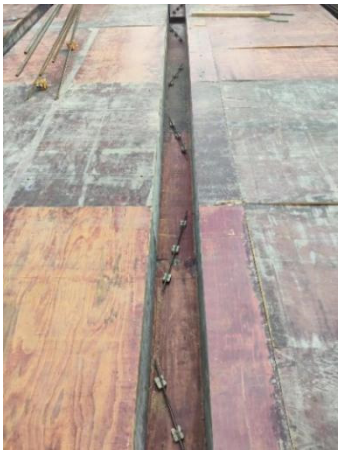

Fig. 9. Modularized Concrete Spacer Blocks (2)

In typical cast-in-place concrete structures, various factors can lead to insufficient or thin protective layers for the steel reinforcement, resulting in a reduction in bond strength and a corresponding decrease in effectiveness. Organizing concrete spacer blocks into groups can effectively address the issue of insufficient or thin protective layers in cast-in-place concrete structures, and it can significantly enhance fire resistance and thermal insulation properties.

(1) Regarding thermal insulation, organized concrete spacer blocks allow for the effective placement of fire-resistant protective layers. This prevents problems such as softening of internal reinforcement and subsequent cracking or strength degradation in high-temperature environments. As a result, it ensures improved performance and an extended service life [6].

(2) In terms of corrosion protection, organized concrete spacer blocks can prevent premature corrosion of the reinforcement, thereby extending its service life to a certain extent [7].

5 Conclusion

In the current scenario, building construction projects have grown in scale, and the construction process involves numerous phases. Neglecting proper management can lead to serious execution issues during construction. Both construction quality and safety are put at risk, significantly impacting the reputation of construction enterprises. Outdated management practices, for instance, hinder the supervision of construction technology applications and lead to disorderly on-site management. This, in turn, exposes construction companies to substantial construction risks. Therefore, it is imperative, in today's construction landscape, to fully acknowledge the significance of applying construction technology in building construction and the importance of effective on-site construction management. This recognition enables the tailored management necessary to align with the unique characteristics of building construction projects, ultimately ensuring construction quality and safety. Such an approach holds immense practical significance in promoting the high-level development of construction enterprises.

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