ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

Study on the Influence of New Early Dismantling Formwork on the Structural Performance of Reinforced Concrete Floor Slabs

Mingqi Lu [a] *, Saifei Zhang [b], and Shujun Li [c]

School of Civil Engineering, Beijing Jiaotong University. China.

[a] mqlu@bjtu.edu.cn, [b] 23126027@bjtu.edu.cn, [c] 23121037@bjtu.edu.cn

Abstract. The application of the new type of early-removal formwork system in engineering is relatively rare, lacking sufficient practical experience. To ensure the safety and reliability of this new type of quick-release formwork in actual engineering applications, this paper relies on the Beijing Wannian Huacheng Building 9 Project to conduct an in-depth theoretical study on the construction mechanical behavior of the new quick-release formwork system after the floor concrete reaches the specified strength for formwork removal and proposes suggestions. Through the research of this topic, it can be seen that under the action of the self weight of the floor slab and the construction load case, although the reinforced concrete floor slab only reaches 50% of the design strength after early removal of the formwork, its bending resistance, and local compressive bearing capacity can all meet the requirements.

Keywords: early dismantling formwork; reinforced concrete slab; structural performance; bending resistance; local compressive bearing capacity.

1. Introduction

The new early dismantling formwork system adopts square steel as the main keel, steel wood composite components as the secondary keel, and uses bowl fasteners and quick dismantling heads to form the support system of the formwork. The application of this early dismantling formwork system in building structure construction can effectively save wood, facilitate material recycling, and facilitate construction, accelerate construction progress, with good technical and economic benefits. Wang [1] analyzed the key points of early formwork removal construction technology. Wei [2] analyzed the application of early formwork removal technology in construction. Tian et al. [3]Zhao et al. [4] respectively conducted finite element analysis on the early formwork support system. Zhang et al. [5] proposed some application strategies for early formwork removal technology in construction enterprises. However, it is still an emerging technology and lacks sufficient engineering practice experience. In practical applications, when the formwork is removed early and the main and secondary keels are removed at the same time, only the support brackets are used to support the reinforced concrete floor slab that has not yet reached the design strength. This belongs to single point support in terms of structural stress condition, which may cause local stress concentration and have adverse effects on the overall structural performance of the reinforced concrete floor slab, and even threaten the safety of construction. To ensure the safety and reliability of this new type of quick release formwork in practical engineering applications, this study was based on the practical project, and the theoretical research was carried out on the construction mechanical behaviors of the new quick release formwork system after the concrete floor reaches the construction strength and the formwork is removed. The impact of the new early dismantling formwork support system on the bending, local compression was analyzed in detail. Through the research of this topic, safety evaluation and suggestions were proposed for the application of this new type of early dismantling formwork system in practical engineering.

2. Research Background

In this study, a theoretical calculation and analysis model was established to carry out, based on the background of the Beijing Wannian Huacheng Building 9 Project. The formwork support layout was shown in Fig.1.

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

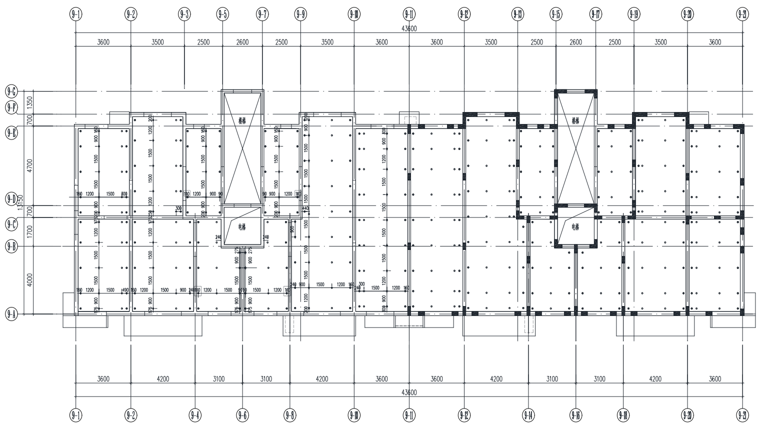

Fig.1 Formwork Support Layout

In reinforced concrete floor slabs, the design strength grade of concrete was C25. When the concrete strength reached 50% of the design strength, the bottom formworks of the floor slab were removed and the 100mm ×100mm square supports were used to provide single point support for the floor slab. The strength grade of the steel bars in the floor slab was HRB400, with diameters of 14mm and 16mm.

3. Finite Element Analysis Model

To accurately study the construction mechanical behavior of reinforced concrete floor systems after early formwork removal, this project used the general finite element analysis software ANSYS for calculation and analysis. In the calculation, representative room elements were selected based on the structural form to establish a finite element analysis model.

Here, the room unit between axis 9-18 and 9-20 was selected for analysis. The selected room unit was shown in Fig.2.

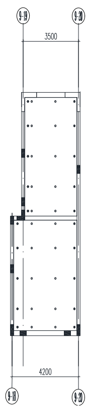

Fig.2 Calculate the Selected Room

Considering the follow-up construction process of the upper layer after the removal of the bottom formwork of the reinforced concrete floor slab on this floor, according to the suggestion of the construction party, the construction load of the upper three floors and the influence of the self weight of the floor slab would be considered in the calculation model.

In the general finite element analysis software ANSYS, SHELL63 elements can be used to simulate reinforced concrete floor slabs. The SHELL63 element is a four node spatial shell element with bending and thin film characteristics, capable of withstanding

loads in the plane of the element and in the direction of the plane normal. Each element node has six degrees of freedom in the translational direction along the x, y, and z axes and in the rotational direction around the x, y, and z axes, and can effectively consider the effect of large structural deformation. The finite element model could be seen in Fig.3.

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

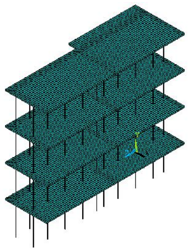

Fig.3 Finite element model of floor slab and support

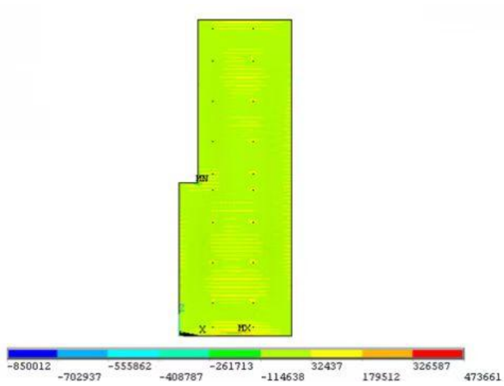

Fig.4 Cloud diagram of bending moment distribution around the x-axis
(Unit N · mm)

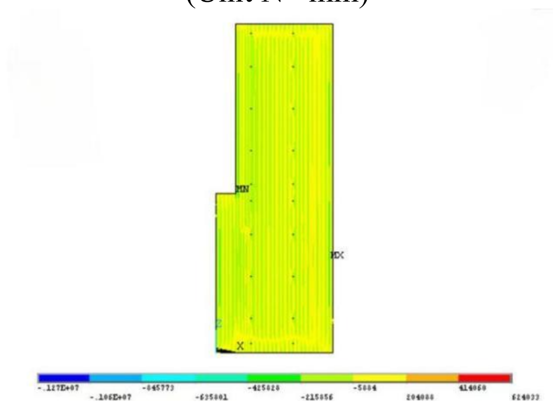

Fig.5 Cloud diagram of bending moment distribution around the z-axis
(Unit N · mm)

As shown in Fig.4~5, the maximum bending moment of the unit was 1.27kN·m. According to the results of finite element internal force analysis, the flexural bearing capacity of reinforced concrete floor structures was verified in accordance with the " Standards for the Design of Concrete Structures " (GB/T50010-2010) [6]. In the verification, according to the construction party's suggestion, the concrete strength was taken as 50% of the design strength.

According to Ref.[6], the calculation formula for the flexural bearing capacity of flexural members is as follows:

$$M = f_c bx(h_0 - \frac{x}{2}) \tag{1}$$

$$f_y A_s = f_c bx \tag{2}$$

In design, for floor slabs, b=1m is usually taken for calculation. However, considering that the mesh in finite element analysis was relatively fine and not divided into 1m squares, the above formula was deformed and the reinforcement ratio was set to $\rho = \frac{A_s}{bh_0}$. Substituting it into formula (2), there were:

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

$$f_y A_s = f_y \rho b h_0 = f_c b x \tag{3}$$

$$x = \frac{f_y \rho h_0}{f_c} \tag{4}$$

Substituting formula (4) into formula (1) yields:

$$M = f_y \rho b h_0 (h_0 - \frac{f_y \rho h_0}{2 f_c}) \tag{5}$$

The design strength grade of the concrete of the floor slab was C25, $f_c = 0.5 \times 11.9 = 5.95MPa$ and the steel reinforcement was HRB400 $f_y = 360MPa$, $h_0 = 110 - 25 = 85mm$, according to the construction party's suggestion, the reinforcement of the floor slab in this project was considered to be evenly arranged with a diameter of 14mm and a spacing of 200, so the reinforcement ratio $\rho = \frac{A_s}{bh_0} = \frac{769}{1000 \times 85} = 0.009$. Queried the maximum bending moment element length in the finite element model $b = 150mm$ and substituted it into formula (4) to calculate the ultimate bending capacity $M = 2.56kN \cdot m > 1.27kN \cdot m$. Therefore, after the early removal of the formwork, considering a construction live load of 2.5kN/m^2, the flexural bearing capacity of the floor slab met the requirements.

4. Analysis of Local Compressive Bearing Capacity of Reinforced Concrete Floor Slab

Reinforced concrete floor slabs would also bear the local pressure exerted by the steel pipe support of the upper floor slab, so it was necessary to calculate and analyze the local compressive bearing capacity of the floor slab. According to the above finite element analysis model, the axial force of the steel pipe support on the first floor slab was extracted as shown in Fig.6. As shown in Fig.6, the maximum axial pressure $P_{\max} = 8.465kN$.

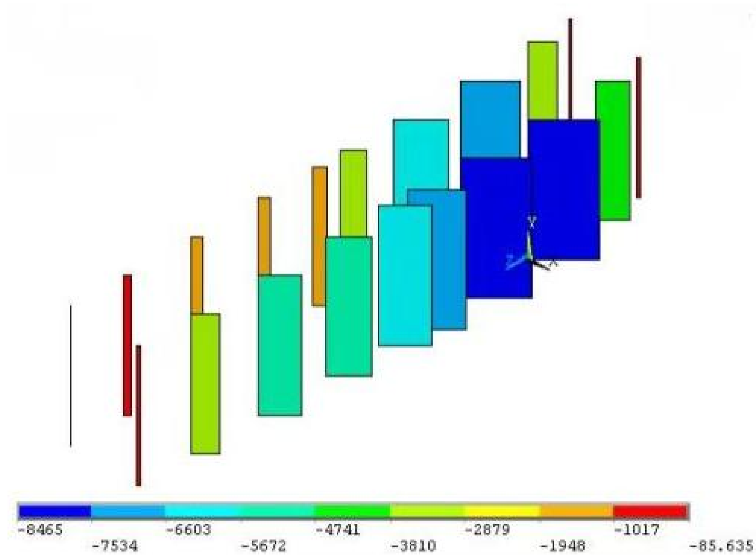

Fig.6 The Axial Force Diagram of the Second Layer Support (Unit: N)

According to the "Standards for the Design of Concrete Structures" (GB/T50010-2010) [6], the local compressive bearing capacity of the floor slab was verified. The simplified calculation diagram was shown in Fig.7.

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

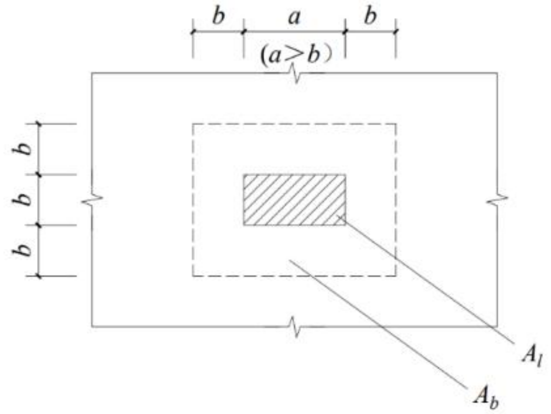

Fig.7 Simplified Diagram for Local Compression Calculation of Reinforced Concrete Floor Slabs

According to the "Standards for the Design of Concrete Structures" (GB/T50010-2010) [6], the local compressive bearing capacity of concrete can be expressed as:

$$F_l = 1.35\beta_c \beta_l f_c A_{ln} \tag{9}$$

$$\beta_l = \sqrt{\frac{A_b}{A_l}} \tag{10}$$

For C25 concrete, $\beta_c = 1$; as shown in Fig.15, $\beta_l = \sqrt{\frac{(3\times 100)^2}{100^2}} = 3$; According to the construction party's suggestion, $f_c = 0.5\times 11.9 = 5.95MPa$; $A_{ln} = 100^2 = 10000mm^2$. By substituting the above parameters into formula (9), we obtained

$F_l = 1.35\beta_c \beta_l f_c A_{ln} = 1.35\times 1\times 3\times 5.95\times 10000 = 240.975kN$

far greater than $P_{\max} = 8.465kN$ .Therefore, the local compressive bearing capacity of the floor slab could meet the requirements after early formwork removal when considering a construction live load of 2.5kN/m^2.

5. Conclusions

This work was based on the Beijing Wannian Huacheng Building 9 Project, and studied the construction mechanics behavior of a new early demolition formwork system after the concrete of the floor slab reached the required strength and the formwork was removed. The impact of the new early dismantling formwork support system on the bending, local compression of reinforced concrete floor slabs was analyzed in detail. Through the research of this topic, it can be seen that under the action of the self weight of the floor slab and the construction load case, although the reinforced concrete floor slab only reaches 50% of the design strength after early removal of the formwork, its bending resistance, and local compressive bearing capacity can all meet the requirements.

In practical engineering, it is recommended to align the steel pipe support positions of the upper and lower layers as much as possible, and ensure that the construction load after demoulding meets the verification requirements. The strength of concrete during demoulding can reach 50% of the design strength to ensure structural safety.

Acknowledgement

The authors would like to acknowledge the funding support from the National Natural Science Foundation of China (grant no. 51641802 and grant no. U1801254).

ISSN:3007-9640 DOI: https://doi.org/10.70114/acmsr.2025.2.1.P7

References

[1] Wang Yong. Application of Early Disassembly Formwork Construction Technology for Multiple Main Beams of Formwork Floor [J]. China Construction Metal Structure, 2023, 22(11): 80-82.

[2] Wei Jianjun. Application of Early Disassembly Formwork Technology in Building Construction [J]. Building Technology Development, 2021, 48(12): 41-42.

[3] Tian Yong, Wang Xiaoli, Zhao Fulong. Finite Element Analysis of an Early Disassembly Formwork Connection System [J]. Urban Architecture, 2022, 19(08): 144-146.

[4] Zhao, F. L., Wang, X. L., & Wang, W. (2016). Research on Early dismantling head of numerical simulation and experiment. MATEC Web of Conferences, 63.

[5] Zhang Lijian, Chen Aihua, Zhang Yeqiang. Research on the Design and Application of Early Disassembly Formwork in Construction [J]. Urban Construction, 2019, 16(32): 128-129.

[6] Ministry of Housing and Urban-Rural Development. (2024). GB/T 50010-2010, Standards for Design of Concrete Structures [S]. Beijing: China Architecture & Building Press.