Study on Mechanical Behavior of Fabricated PC Floor Structure in Construction Engineering

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Abstract. In order to obtain the best fabricated floor structure for construction projects, based on the non-linear finite element software ABAQUS, the PC floor and cast-in-place floor slabs of the C30 floor slab scheme of the Jiangyin Jinyi Project were fully simulated. Through the comparison of the two simulation results, it is found that the stress concentration at the center of the cast-in-place floor structure under the full static load is significantly greater than that of the PC floor structure; unlike the uniform force of the PC board, the most vulnerable position of the cast-in-place floor structure is The longer side is not the uniform force of the overall floor structure; after checking the ultimate bearing capacity, strength and deflection of the PC floor structure, it is found that the ultimate bearing capacity of the PC floor structure is 9.187 kN/m and the deflection is 0.049 mm, which are far less than The theoretical value of the design of the floor structure shows that it is feasible to select the PC floor structure in the assembly type of construction engineering, and it is recommended to popularize and apply it in engineering practice.

Keyword. Prefabricated architectural engineering; nonlinear finite element; PC floor structure; cast-in-place floor structure; stress concentration.

1. Introduction
Prefabricated PC board is a prefabricated structure with prefabricated concrete structure, steel structure and wood structure as the main components. It is a new form of construction engineering material that is processed, transported, and assembled on site. It has the characteristics of diversified functions, construction and assembly, and diversified designs; compared with traditional cast-in-place concrete structures, prefabricated structures have fast construction progress, energy-saving and environmental protection during the construction process, saving templates, lowering project costs. The appearance of the molded structure is beautiful and the advantage of reducing maintenance costs. As a green construction technology, prefabricated buildings have the advantages of avoiding repeated decoration in the future, accurate design, good seismic performance and anti-corrosion performance, and become the focus of the development of future buildings in my country. Zhou and others [1-5] performed a three-dimensional nonlinear finite element analysis of reinforced concrete slabs. Chen [6] and others analyzed the key points of the construction technology of prefabricated concrete structures and concluded that prefabricated concrete structures can reduce the energy consumption rate of other resources and reduce construction costs. Ma [7] found that prefabricated concrete can not only improve the quality of the building but also extend its service life. Wu [8] analyzed the flexural capacity and ductility of reinforced UHPC panels. Xiang and others [9-12] conducted research on the construction period and economic benefits of prefabricated concrete structures for housing
construction. Existing research has not made an analysis of the mechanical properties and failure mechanism of cast-in-place concrete floors under the same conditions. This paper uses nonlinear finite element method to study the performance of PC floor slab of new type floor structure and analyze the failure mechanism based on the housing construction project of Jiangyin Jinyi Project.

2. PC Floor Installation

2.1. Construction Process
Measure and set-up → support erection → component lifting → laminated board hoisting in place → correction of elevation and axis position → temporary fixation, loose hook → steel bar binding, hydropower pre-embedding → concrete pouring.

(1) PC laminated floor installation
Introduce control axis → floor elastic line → horizontal elevation measurement → support row erection → beam formwork and cast-in-place slab formwork installation → PC laminated floor slab installation → beam reinforcement binding → laminated floor level adjustment → post-cast laminate Bottom steel bar binding → horizontal electromechanical pipeline and box pre-embedding → plate surface steel bar binding → acceptance → concrete pouring.

(2) Hoisting of laminated floor
Hoisting process: check the upper level of the support and the slab joint rigid frame support mold → draw the superimposed floor position line → hoist the PC superimposed floor → adjust the length of the superimposed floor slab at the support → bind the reinforcement of the superimposed floor joint.

(3) Concrete pouring
Before concrete pouring, clean up the sundries on the PC laminated floor, and spray water on the upper part of the slab to ensure that the surface of the slab is fully moist, but there should not be too much water to ensure that the precast layer of the laminated slab and the cast-in-place layer are firmly bonded to form a whole Forced structure.

2.2. Detailed Structure
The key point of the installation of prefabricated PC floor slabs in architectural engineering is that the slab end structure is divided into one-way laminated slabs and two-way laminated slabs. This article mainly studies two-way laminated slabs. The detailed structure is shown in figure 1.

![Test loading device diagram.](image-url)
2.3. Material Preparation
The construction of the laminated slab adopts the fastener-type steel pipe scaffold support system, the vertical pole adopts ø48×2.7mm Q235 ordinary steel pipe, the vertical distance is 1.0m, the horizontal distance is 1.0m, the step distance is 1.5m, and the bottom sweeping pole is 200mm from the ground; The top adopts adjustable brackets, the main beam adopts 2 ø48×2.7mm ordinary steel pipes, the small beam adopts 40×80mm wooden square, the center spacing is 200mm, and the upper part is a laminated board. Before PC components are constructed, special temporary supports need to be customized to connect the floor and prefabricated components. Bolt sleeves need to be embedded in the floor and prefabricated components in advance according to the drawings. Professional and technical personnel should count the number of temporary supports needed before construction and contact Production support system.

3. Material Properties of PC Board in Construction Engineering Fabricated Structure
The prefabricated structural pc board for construction projects is made of cement, sand, stone and other aggregates and steel bars, which not only retains the advantages of traditional reinforced concrete structures, but also has the advantages of environmental protection and convenience compared to traditional cast-in-place reinforced concrete. The specific configuration is as shown in table 1.

| PC floor material. |  |
|-------------------|-------------------|
| Cement Ordinary Portland Cement |  |
| Sand Medium coarse sand with a fineness modulus of 2.3-3.0 |  |
| Stone 5-25mm gravel |  |
| Admixture Comply with GB8076 regulations |  |
| Low calcium fly ash Comply with GB13013 |  |
| Rebar Meet the requirements of GB1499 |  |
| Water for mixing Comply with JGJ 63 standard of “Water Standard for Concrete Mixing” |  |

4. Construction Period Performance of Fabricated Structure PC Board
The construction period of the standard floor of the prefabricated structure is mainly affected by factors such as the number of components and the design of construction organization. The construction period is slightly reduced compared with the traditional cast-in-place structure, and the general construction period is about 6-7 days. Specific influencing factors include the number of components, prefabrication rate, structural system, building layout, reasonable configuration of tower cranes, surrounding traffic and transportation routes, component storage yard settings, reasonable arrangements for component approach plans, lifting efficiency, and overlap of professional construction and other factors.

Compared with the traditional cast-in-situ concrete structure, the prefabricated PC board reduces the installation of formwork, and the production and installation process of the steel bar under the board surface has been optimized in the construction period, as shown in figure 2.

5. Finite Element Analysis of the Mechanical Properties of the Prefabricated PC Board in Construction Engineering

5.1. ABAQUS Nonlinear Analysis Simulation
The nonlinear sources of PC board structure are mainly divided into three categories: material nonlinearity, geometric nonlinearity, and boundary condition nonlinearity [7]. In the ABAQUS finite element analysis, the nonlinearity of the two materials of steel and concrete is mainly used to achieve structural nonlinearity [8]. In the model in the analysis, different definitions of the two materials at different stress stages are required. In the elastic phase, both materials only need to define the elastic modulus and Poisson’s ratio of the material. In the plastic phase, the two material definitions are essentially different. The plasticity definition of the steel bar only needs to input the stress-strain...
relationship of the material in the plasticity stage to realize the plasticity definition of the material. Compared with the other two models, the concrete damage plasticity model is used to simulate structures subjected to unidirectional loading, cyclic loading or dynamic loading conditions. The model has better convergence effects and more accurate analysis results. Therefore, the plastic characteristics of concrete materials are generally defined by concrete damage models.

![standard floor (PC board)](image)

![Standard layer (cast-in-situ board)](image)

**Figure 2.** PC standard layer construction period.

5.2. Research Object and Unit Grid Division

In this paper, PC board floors and cast-in-place floors of the same size of Jinyi project are selected for simulation. The floor size is 3950×1990×130. Adopt two-way plate to bear the force. This article combines network experiments to determine the mesh density when the model is generated. The meshing of the concrete element model adopts sweeping meshing technology, and the mesh size is 20mm tetrahedral elements. The specific meshing results are shown in figure 3.

5.3. Model Calculation Results

Comparing the failure modes of the specimens in figures 3 and 4, it can be seen that the center of the PC board under uniform load is relatively large but the stress concentration is relatively small. It is suitable for practical engineering. The cast-in-place concrete structure has long sides under the same uniform load. Larger stress is prone to damage, and the simulation values of the two sets of test pieces are combined. Compared with the traditional cast-in-situ slab, the PC board has a more uniform bearing capacity under a uniform load.
6. Calculation Formula of PC Board for Construction Engineering Fabricated Structure
The prefabricated part of the floor slab is for the cast-in-place construction. The prefabricated floor needs to bear the weight and construction load of the cast-in-place slab. There is a support frame under the prefabricated floor, so the prefabricated floor can be considered as a bending component. In this example, a simply supported beam is calculated with a unit width of 1m. The specific parameters of the PC board are shown in table 2.

| Table 2. PC board parameters. |
|-------------------------------|
| Precast slab concrete strength grade | C30 | Thickness of cast-in-place floor h1 (mm) | 80 |
| Prefabricated floor thickness h2 (mm) | 60 | Design value of concrete compressive strength f_c (N/mm²) | 14.3 |
| Prefabricated floor calculation method | Simply supported beam | Concrete protective layer thickness (mm) | 15 |
| Precast floor reinforcement (mm) | HRB400 Rebar 8@100 | Design value of steel bar tensile strength f_y (N/mm²) | 360 |
Load capacity limit state

\[ q_1 = \gamma_0 \times [1.3 \times (G_{1k} + (G_{2k} + G_{3k}) \times h_1) + 1.5 \times \gamma_l \times (Q_{1k} + Q_{2k})] \times b \]
\[ = 1 \times [1.3 \times (1.5 + (25 + 1.1) \times 0.08) + 1.5 \times 0.9 \times (2 + 1.35)] \times 1 = 9.187 \text{kN/m} \] (1)

Service limit state

\[ q = (\gamma_d (G_{1k} + (G_{2k} + G_{3k}) \times h_1)) \times b = (1 \times (1.5 + (25 + 1.1) \times 0.08)) \times 1 = 3.588 \text{kN/m} \]

The calculation diagram is shown in figure 5. The bending moment diagram and deformation diagram of the strength and deflection calculation are shown in figures 6 and 7.

(1) Strength Check

\[ M_{\text{max}} = 0.735 \text{kN} \cdot \text{m} \]

The unit width is 1m, and the reinforcement is calculated according to the bending moment:

\[ h_0 = h_2 - 15 = 60 - 15 = 45 \text{mm} \]

\[ \alpha_s = \frac{M_{\text{max}}}{(\sigma_{f} b h_0^2)} = 0.735 \times 10^6 / (1 \times 14.3 \times 1000 \times 45^2) = 0.025 \]

\[ \gamma = 0.5 \times [1 + (1 - 2 \alpha_s)^{0.5}] = 0.5 \times [1 + (1 - 2 \times 0.025)^{0.5}] = 0.987 \]

\[ A_s = \frac{M_{\text{max}}}{(\gamma f_{y} h_0)} = 0.735 \times 10^6 / (0.987 \times 360 \times 45) = 45.959 \text{mm}^2 \] (2)

According to the reinforcement 8@100: Reinforcement area \( A_{s2} \) in a width of 1 meter

\[ A_{s2} = 502.655 \text{mm}^2 \geq A_s = 45.959 \text{mm}^2 \]

which meets the design requirements.

(2) Deflection Check

\[ \nu_{\text{max}} = 0.049 \text{mm} \]
\[ \nu = 0.049 \text{mm} \leq \nu = \frac{L}{200} = \frac{1000}{200} = 5 \text{mm} \]  \hspace{1cm} (3)

which meets the design requirements.

7. Conclusions

(1) Compared with traditional cast-in-situ floor slabs in construction engineering, PC floor slabs have the advantages of energy saving and environmental protection during the construction process, saving templates, reducing engineering costs, forming structure appearances, reducing maintenance and plastering, and each standard floor can save an average of 1 day construction period;

(2) The stress concentration of the new material PC floor slab mainly occurs in the center of the floor under the action of uniformly distributed load. Compared with the traditional cast-in-situ concrete floor slab, the mechanical properties are more optimized, and it is suitable for actual engineering;

(3) The ultimate bearing capacity of the new material PC board is 9.187 kN/m and the deflection is 0.049 mm to meet the reliability of the building.

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