Cost comparison and difference analysis of prefabricated concrete shear wall structure housing

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Abstract—This paper makes a deep comparison and research on the cost of prefabricated concrete structure which is popularized vigorously by our country. By comparing the cost of three high-rise concrete residential projects with different prefabrication rates, this paper makes a detailed comparison of the total above-ground cost, civil construction and installation, and the cost of prefabricated components. On this basis analyzes the influence of adjusting prefabricated components on the prefabrication rate and the influence of prefabrication rate on the change of cost. Finally, it is discussed that the cost of prefabricated housing project is higher than that of traditional cast-in-place concrete housing mainly because of the increase of steel and concrete content of prefabricated components, transportation cost, main material consumption and comprehensive unit price. In this paper, the cost comparison and difference of prefabricated housing provides reference and reference for the future cost analysis of prefabricated housing.

1. INTRODUCTION

With the acceleration of the process of "building industrialization and housing industrialization" in China, the trend of housing industry industrialization is becoming more and more obvious[1]. Compared with the cast-in-place construction method, the prefabricated structure is conducive to green construction, can reduce the negative impact on the environment, and follows the principle of sustainable development[2]. At present, prefabricated construction enterprises in China are in the initial stage, and the relevant industries, processes and supporting policies are not yet mature, leading to higher costs compared with traditional cast-in-place buildings[3].

This paper analyzes the difference of prefabrication rate and other parameters on total cost and partial cost by comparing the cost of three similar actual engineering projects.
2. PROJECT OVERVIEW
The main research object of this paper will be three actual projects, which choose the building volume, comprehensive unit price, engineering quantities of similar single buildings to carry out the corresponding research. The detailed project description is as follows.

A Phase II Project in Nanjing (hereinafter referred to as Project A), located in Qixia District, is constructed with four scale operations and a total of 18 buildings, all of which are prefabricated and assembled with integral shear wall structure system, with single prefabrication rate ≥30%. Among them, the number of floors 1 to 8, 10, 11, 13, 15 and 16 is 24, and the building floor height is 67.65m. No. 12, No. 14 has 27 floors, with a building height of 77.35m; 17. The number of floors in No.18 is 27, and the building height is 76.45m. The safety level of the building structure is two, the seismic fortification category of the building is class C, and the seismic fortification intensity is 7 degrees. Architectural Completion Renderings is shown in Figure 1.

For a single building, the types of prefabricated components included in the building are: complex members (precast stairs), non-main stressed members (precast laminated floor slabs), main stressed members (precast shear walls), non-stressed members (autoclaved aerated concrete lightweight wall panels, autoclaved ceramic concrete lightweight wall panels).

Jurong Baohua Avenue (hereinafter referred to as Project B), the project is located in Jurong City, Zhenjiang City. There are 19 floors above ground and two underground floors, with a total height of 54.15m. Building No.1 of the project is used as the research object to study the cost. The building is mainly constructed with shear wall. The main shear walls are cast-in-place, the floor panels are prefabricated composite panels, and the stairs, balcony panels and air conditioning panels are prefabricated components. The main parts of the project include: concrete engineering, formwork engineering, reinforcement engineering, masonry engineering, indoor rough decoration, exterior wall rough installation, roof engineering.

Nanjing Golden Land (hereinafter referred to as Project C) is located in Qixia District, Nanjing, with 27 floors above ground and two floors below ground, and a total height of 78.3m. Building 19 of this project was adopted as the contrast object. The building uses the frame shear wall structure, shear wall and other major components are used in the field casting. Mainly includes the distribution of sub-projects are: concrete engineering, formwork engineering, reinforcement engineering, masonry engineering, indoor rough decoration, exterior wall rough installation, roof engineering, etc.

3. COMPARISON OF TOTAL ABOVEGROUND COSTS
Compare Building 1 (prefabricated shear wall structure) of Project B of Baolong Avenue, Jurong with Building 19 (cast-in-place shear wall structure) of Project C of Nanjing Gindi, and compare the cost of parts above ±0.00 of the building[4].

Building 1, Project B, Baohua Avenue, Jurong, covers a floor area of 6,605.19 square meters, with a total amount of 1849.45 cubic meters of concrete and 647.307 cubic meters of prefabricated...
components. The prefabricated rate of components is 647.307/1849.45=34.65%. The total cost is 9243866.29 yuan, and the unit square cost is 1399.48 yuan/m².

Building 19, Nanjing Gemdi C Project, has a construction area of 11390.52 square meters with a total of 4214.49 cubic meters of cast-in-place concrete. The total cost is RMB 9628686.11, and the single cost is RMB 845.33/m².

Compared with Building 19, the total cost of Building 1 is lower than 9628686.11-9243866.29=384,819.82 yuan. Considering the relevant building area, the cost per square meter of Building 1 is 1399.18-845.33=553.85 yuan higher than Building 19, accounting for 65.52% of the one-sided cast-in-place cost.

4. COMPARISON OF CIVIL CONSTRUCTION COSTS
The total construction cost of No. 1 Building is 8250,707.66 yuan, accounting for 8250,707.66/9243866.29=89.26%. The total construction cost of Building 19 is 8502527.88 yuan, accounting for the total cost of 8502527.88/9628686.11=88.30%. The difference between the two is about 1%, so it can be seen that the civil construction cost is the main part of the cost, accounting for more than 80%. When converted into unilateral cost, the unilateral cost of civil engineering of No.1 Building and No. 19 Building were 1248.90 yuan /m² and 746.12 yuan /m² respectively, with a difference of 1248.90-746.12=502.78 yuan.

5. INSTALLATION COST COMPARISON
The installation cost of No.1 building is 993,158.63 yuan, accounting for the total cost: 993,158.63/9243866.29=10.74%. The total construction cost of Building 19 is 1126158.23 yuan, accounting for the total construction cost of 1126158.23/9628686.11=11.70%. The difference between the two is about 1%, which accounts for a similar proportion of the cost. It is converted into unilateral cost, and the unilateral cost of civil engineering of No.1 Building and No.19 Building is 150.36 yuan /m² and 98.87 yuan/m², the difference is 150.36-98.87=51.49 yuan.

6. COST COMPARISON BY DIVISION AND ITEM
Analyze the sub-project of building 1 and building 19. The main projects include: concrete engineering, reinforcement engineering, masonry, process formwork engineering, indoor rough decoration, exterior wall rough installation, roof engineering. Building 1 also includes assembly work.

Relative to the cast-in-place building, the assembled building will separate the PC component separately in the sub-project, as an important project content, accounting for about 13% of the total cost. It is equivalent to cast-in-place structure masonry engineering.

7. COST COMPARISON OF PREFABRICATED COMPONENTS
The prefabricated components to be included in the main building of No.1 are: prefabricated laminated panels, prefabricated staircases, finished autoclaved lightweight concrete wall panels, prefabricated balcony panels and air conditioning panels. The main prefabricated component is the prefabricated laminated plate. In the process of valuation, taking into account the actual engineering practice, the composite board, balcony board, air conditioning board as the same subitem for list valuation. The comprehensive unit price is RMB 4382.26 /m³, reinforcement content is 216.31kg/m³(unit price 7.28 yuan /kg), the quantity is 204.44m³. However, the unilateral cost of C30 concrete in Building 19 is 334.44 yuan /m³, the cost of three steel is 3560.05 yuan /t. Therefore, for the prefabricated components of No.1 Building, the converted cost of the prefabricated slab is 334.44×204.11+3.5605×216.31×204.44= 225,462.30 yuan when converted into concrete and steel bars of the same volume, which reduces the cost by 670,336.56 yuan and the unilateral cost by 58 yuan.
8. COST DIFFERENCE BETWEEN PREFABRICATED STRUCTURE AND CAST-IN-PLACE STRUCTURE

Relying on No.17 architectural and structural drawings, the standard layer of prefabricated structure above 5 floors is compared with the standard layer of cast-in-place structure of 2 floors to restore the cast-in-place structure. The original design of prefabricated structure is converted into the corresponding cast-in-place design scheme. The engineering quantity of the prefabricated components is reduced to the amount of concrete, the steel bars in the prefabricated components are reduced to cast-in-place steel bars, the external wall parts are reduced to masonry, and the prefabricated composite plates are reduced to girder plates.

Through the analysis of the cost files, combined with the cast-in-place buildings of the same volume in the actual project, the civil construction and installation cost of the prefabricated structure is increased by about 15%, and 15% is taken as the standard value for verification.

9. CONTRIBUTION OF DIFFERENT COMPONENTS TO PREFABRICATION RATE AND COST

Building 1# of Project A is adopted as the research object, and the main structure area on the ground is 6,084m², a total of 18 floors. The building structure is prefabricated shear wall structure with a prefabricated rate of 30.56%[5]. The prefabricated components used are: prefabricated ALC panels (for internal wall partition), prefabricated laminated panels, prefabricated shear walls, and prefabricated stairs. The total cost of the related works is shown in Table 1.

| Project Name       | Total Cost  | Unilateral Cost (RMB/m²) |
|--------------------|-------------|--------------------------|
| Civil Engineering  | 4334789.16  | 712.49                   |
| Installation project | 1164355.92 | 191.38                   |
| PC component       | 2287340.64  | 375.96                   |
| Measures cost      | 1140628.32  | 187.48                   |
| Tax                | 892705.32   | 146.73                   |
| **Subtotal**       | 9819819.36  | 1614.04                  |

For the contribution of prefabricated components to the prefabrication rate of the project, it can be calculated by the actual amount of the component in the project. The specific data can be seen in Table 2.

| Name of prefabricated component | Quantity (m³) | Prefabricated rate contribution | Comprehensive unit price (RMB/m³) | Unilateral cost contribution |
|---------------------------------|---------------|---------------------------------|----------------------------------|------------------------------|
| Prefabricated ALC panel wall    | 392.7         | 13.7%                           | 1172.04                          | 4.69%                        |
| Prefabricated laminated panels  | 282.1         | 9.0%                            | 3543.85                          | 10.18%                       |
| Precast shear wall              | 174.9         | 6.1%                            | 4180.88                          | 7.45%                        |
| Precast stairs                  | 24.9          | 0.9%                            | 3773.72                          | 0.96%                        |

To sum up, in order to meet the stress requirements of the building structure, single building prefabricated components can be selected in the following order: composite plate > main stress member > non-secondary structural stress member > complex prefabricated components.
10. IMPACT OF PREFABRICATION RATE CHANGE ON COST

Combined with the above, considering the contribution degree of prefabrication rate and the comprehensive unit price of components, the prefabricated laminated plates are taken as the research object. The variation of prefabrication rate of laminated panels in different projects is studied to explore the trend of their contribution to the construction cost.

Building 1# of Project B is adopted, with a height of 54.15m and an above-ground area of 6605.19m². The structure is prefabricated shear wall structure with prefabricated rate of 35.02%. The main prefabricated component is the prefabricated laminated plate, and the comprehensive unit price is 4382.26 yuan /m³, the engineering volume is 204.44m³. The steel content of the prefabricated composite plate is 216.31kg/m³. The comprehensive unit price of C30 concrete is 334.44 yuan /m³, the cost of three steel is 3560.05 yuan /t. Therefore, for the prefabricated components of No.1 Building, the cost is 334.44×204.11+3.5605×216.31×204.44= 225,462.30 yuan when converted into concrete and steel bars of the same volume, which is 670,336.56 yuan less than the cast-in-place components of the same volume, and the unilateral cost is 58 yuan less.

Combined with the relevant data of the prefabricated laminated panels of Building 1# of Project A and some other projects, Excel was used to perform data fitting. The fitting curve is shown in Figure 2.

![Fig 2. Fitting curve of cost contribution rate](image)

\[ y = 1.7393x^3 - 2.1551x^2 + 0.7489x + 0.0244 \]

It can be seen from the curve that when the prefabrication rate is from 0 to 10%, the use of prefabricated laminated panels has no obvious impact on the total cost; while when the prefabricated laminated panels are from 20% to 35%, the use of prefabricated laminated panels has a more obvious impact on the total cost, accounting for a large proportion in the total cost of prefabricated shear wall structure: For buildings with a higher prefabricated rate of more than 40%, the impact of prefabricated laminates on the cost is gradually reduced, but it still remains at about 7%. According to the engineering practice, in this stage, the prefabricated shear wall component replaces the laminated slab as the main contributor of the total cost.

11. ANALYSIS OF THE REASONS FOR THE DIFFERENCE OF ASSEMBLY PROJECT COST

First carries on the analysis from the perspective of the cost of production, due to the increased amount of embedded component, at the same time, under the same intensity, under the same component, prefabricated components need to have overlap due to size problem, it needs the connector is longer than cast-in-situ type directly through reinforcement into the pouring way more directly, the increase of the volume of material, which can lead to cost increase. Therefore, the steel content of the building is studied and analyzed, and the correlation analysis of the material cost of the main structure of the prefabricated building is carried out in combination with the index of concrete content.
11.1 Steel content and concrete content (aboveground building)
Generally speaking, the steel content and concrete content of prefabricated buildings are higher than those of cast-in-place buildings. However, for G46 project, we calculated the steel content of No. 4 building and concluded that its steel content was 20% higher than that of conventional buildings of the same floor. Therefore, in the comparison between the two buildings at present, there is little difference between the steel content and concrete content of prefabricated buildings. Even the prefabricated buildings have slightly lower two indicators than the cast-in-place buildings.

11.2 Other factors

11.2.1 The increase of the comprehensive unit price of the main material
Taking the straight (circular) wall above the ground and the thickness ≤200mm(C30 pumped ready-mixed concrete)(conveying height >30m)(bulk dry mixed mortar) as an example, the comprehensive unit price of G53 project is 657.98 yuan/m³, and the comprehensive unit price of G46 project is 402.46 yuan/m³, with a difference of more than 250 yuan/m³. To multiply by the corresponding amount of engineering, the cost gap in 1,000,000 yuan.

11.2.2 Transportation problems
For cast-in-place buildings, concrete and steel bars and other relevant main materials are generally purchased nearby, while for prefabricated buildings, there are relatively few component factories, the transportation distance is long and the vehicle load is limited, and the number of transportation required is also more, leading to the increase of transportation costs. For the G53 project, the main materials such as concrete and precast components are mainly imported from Jurong and Zhenjiang, and the distance between the two is not big, so the impact on the cost is small.

11.2.3 the main material consumption problem
Under the same strength and the same component, the assembled component needs to be overlapped due to the size problem, so the connector required is more than the cast-in-place type which directly places the length of steel bar into the direct casting method, and the increase of the main material engineering quantity leads to the increase of the cost.

In general, the production cost and logistics cost is prefabricated construction and traditional cast-in-situ construction cost differences significant points, for prefabricated buildings, due to its technological characteristics and the limitations of the current process leads to the increasing of production cost and logistic cost, believe that with the development of technology to develop, the production cost will be down, eventually to promote the continuous development of prefabricated construction.

12. CONCLUSION
Containing the cast-in-place structure this paper compared the different of three high-rise concrete precast rate residential project cost comparison, the total cost, construction installation, detailed comparison on the prefabricated equal part of the project cost, on the basis of the analysis of the effect of the adjustment the prefabricated prefabricated rate and the impact of changes in the cost of prefabricated rate for, finally from the overall discusses the prefabricated housing project on the cost is higher than traditional cast-in-situ concrete reasons of the residence. This paper points out that the production cost and logistics cost is prefabricated buildings and traditional cast-in-situ construction cost differences significant points, for prefabricated buildings, due to its technological characteristics and the limitations of the current process leads to the increasing of production cost and logistic cost, believe that with the development of technology to develop, the production cost will be down, eventually to promote the continuous development of prefabricated construction. In this paper, the cost comparison and difference of prefabricated housing provides reference and reference for the future cost analysis of prefabricated housing.
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