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Cost Optimization Analysis of Prefabricated Steel Structure Building Based on BIM Technology—Taking Project A as an Example

Yi Yang, Ming Zhang

Jiangmen Polytechnic, Jiangmen, 529000, China

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Abstract: This paper takes the prefabricated steel structure project (A project for short) in a city as an example to study the cost optimization idea of prefabricated steel structure building based on BIM technology, and further study the cost control points compared with the traditional mode.

1. Introduction

This paper takes the prefabricated steel structure project in a city (referred to as project A) as an example, mainly analyzes the construction and operation costs of the project, and through the comparison of project case costs in the same period, studies the key points and paths of cost control and optimization of prefabricated steel structure building based on BIM technology, which will be of great significance to promote the application of BIM technology in the cost management of prefabricated steel structure building.

2. Basic information of the project

The total building area of project A is 83091.33m^2, including 56066.51m^2 above ground (including 40461.72m^2 of residential building area and 15604.79m^2 of public service facilities) and 27024.83m^2 underground. Building floors: 24 floors above the ground and 2 floors underground of Building 1; Building 2 # has 24 floors above the ground and 4 floors underground; Building 3 # has 21 floors above the ground and 2 floors underground; Building 4 # has 22 floors above the ground and 2 floors underground; Building 5 # has 3 floors above the ground and 4 floors underground; The kindergarten has three floors above the ground; The primary school has three floors above the ground; 2 floors of garbage station; The garage has three floors underground. Construction standard: (1) The structural assembly rate is more than 92%; (2) Sand aerated batten partition and decorative integrated exterior wall; (3) Geothermal heating; (4) Steel entrance door; (5) Hollow LOW-E glass, bridge-cut aluminum alloy window; (6.85% exterior wall coating+15% stone exterior wall. (7) Rough delivery, public hardbound.

3. Cost comparison of similar projects in the same period

The cost analysis of the construction and installation of individual high-rise residential products is shown in Table 1.

Table 1: Construction and installation cost analysis of high-rise residential single product

Classification	Structural style	Fabricated steel structure		Traditional steel structure engineering		Prefabricated reinforced concrete structure		Cast-in-situ reinforced concrete shear wall structure	
	Built-up area（m2）	Above-ground	12602.62	Above-groun	8603.00	Above-groun	10619.52	Above-groun	12888.34
	Product function design	The building is 53.4m high and 2.9m high, with 18 floors and 2 units, totaling 145 households. Five house types, two rooms, two halls and one bathroom, 70-90m2 small house type		The building is 75m high, 2.9m high, 24 floors, 1 unit, 95 households in total. Four house types, two rooms, two halls and one bathroom, 70-90m2 small house type		The building is 42m high, 2.8m high, with 15 floors and 2 units, totaling 90 households. Three house types, three rooms and one hall, two rooms and one hall, 70-90m2 small house type		The building is 52.5M high and 2.85M high, with 18 floors and 2 units, totaling 72 households. Four house types, two rooms, two halls and one bathroom, 70-90m2 small house type	
	Product feature description	1. The structural assembly rate is more than 92%; 2. Sand aerated batten partition and decorative integrated exterior wall; 3. Geothermal heating; 4. Steel entrance door; 5. Hollow LOW-E glass, bridge-cut aluminum alloy window; 6.85% exterior wall coating+15% stone exterior wall. 7. Rough delivery, public hardbound		1. The structural assembly rate is more than 80%; 2. Sand aerated batten partition and decorative integrated exterior wall; 3. Geothermal heating; 4. Steel entrance door; 5. Hollow LOW-E glass, bridge-cut aluminum alloy window; 6. Litchi surface stone paint exterior wall. 7. Rough delivery, public hardbound		1. The structural assembly rate is more than 40%; 2. Traditional secondary structure; 3. Geothermal heating; 4. Steel entrance door; 5. Hollow LOW-E glass, bridge-cut aluminum alloy window; 6. Exterior wall coating 7. Rough delivery, public hardbound		1. Cast-in-situ reinforced concrete structure; 2. Traditional secondary structure; 3. Geothermal heating; 4. Steel entrance door; 5. Hollow LOW-E glass, bridge-cut aluminum alloy window; 6. Exterior wall coating 7. Rough delivery, public hardbound	
Description of cost conditions	Cost range	This cost scope is for the cost of single main building and installation engineering, including earthwork engineering, foundation engineering, ground main structure engineering, secondary structure engineering, public part decoration, door and window engineering, mechanical and electrical installation engineering, indoor equipment supply and installation engineering, and the standard of blank delivery. It does not include land costs, preparation and acceptance evaluation fees before and after construction, community pipe network engineering fees, garden environmental engineering fees, supporting facilities fees and other project construction costs.							
	Project construction period	2017-2019		2017-2019		End of 2019		2017-June 2020	
	Cost statistics basis	Contract settlement price		Contract settlement price		Contract settlement price		Contract settlement price	
No.	Unit works	Price index per square meter（yuan/m2）	Total price (yuan)	Price index per square meter（yuan/m2）	Total price (yuan)	Price index per square meter（yuan/m2）	Total price (yuan)	Price index per square meter（yuan/m2）	Total price (yuan)
1	Basic engineering	120.00	1,512,314.40	146.00	1,256,038.00	170.00	1,805,318.40	170.00	2,191,017.80
2	Main structure	1,050.09	13,233,849.24	1,291.21	11,108,289.22	1,259.43	13,374,580.26	646.63	8,333,990.97
3	Main structure	311.58	3,926,720.67	316.02	2,718,705.53	251.40	2,669,740.22	253.63	3,268,846.75
4	Main structure	410.00	5,167,074.20	459.33	3,097,080.00	471.00	5,608,157.54	458.00	6,647,159.59
5	Main structure	49.20	620,000.00	49.20	423,267.60	49.20	522,480.38	49.20	634,106.33
6	Main structure	110.37	1,390,912.50	170.20	1,464,230.60	159.56	1,694,400.81	172.78	2,226,836.63
7	External doors and windows, unit doors, entrance doors, fire doors, railings and other works	283.62	3,574,348.75	291.30	2,506,045.00	271.01	2,878,006.84	278.06	3,583,704.75
8	Measures	159.49	2,010,006.96	173.30	1,490,899.90	263.56	2,798,912.83	443.51	5,716,152.18
Total construction and installation cost		2,494.35	31,435,345.20	2,896.56	24,919,091.84	2,891.26	30,703,806.56	2,489.56	32,086,281.40

4. Construction and operation cost analysis

According to the actual cost settlement of the project, the construction and installation cost of the above-ground engineering of the prefabricated steel structure residential project of Building 1 # of the project is 2494.35 yuan/m2, and the main cost optimization items are as follows:

4.1. BIM virtual construction, real-time dynamic vertical control, effectively reducing management costs, measure costs and ineffective costs.

(1) The project construction management cost is directly reduced by 9% compared with the traditional management mode. The traditional supply chain management cost and profit are about 15%. The BIM technology and fabricated steel structure industrialization components realize the direct supply of the factory. The total management cost and profit are 6%.

Change negotiation and invalid cost: according to the actual cost of the project, this cost has been reduced from 8% - 10% to 2%.

Measure cost: the cost of temporary facilities for site construction, vertical transportation period, formwork and scaffold turnover materials have been significantly reduced, as shown in Table 1.

(2) Standardized design and selection of components, customized mass production in the factory, and reduction of raw materials and manufacturing and processing costs.

Reduce the steel content index by optimizing the steel structure system. Taking the high-rise building where the project is located as an example, the steel content of the traditional steel structure residential project is 105kg/m^2, and the steel content of the fabricated steel structure is 95kg/m^2, reducing about 10 kg per square meter; Through design optimization and repeated verification, the standardized type selection of components has been realized, and the types of components have been reduced to the minimum. There are 10 section types of load-bearing components in one building, which reduces the manufacturing and processing costs by 40% compared with traditional steel structure engineering as a whole[1].

(3) High assembly rate, high turnover rate of machinery, greatly reducing labor consumption

The traditional steel structure engineering mostly uses concrete column core inclined beam support for vertical members, resulting in relatively large workload of on-site assembly, while the overall engineering assembly degree of fabricated steel structure engineering reaches more than 70%, which greatly reduces the labor consumption.

(4) Mechanical and electrical installation works. The use of BIM model has improved the effective utilization rate of the reserved and embedded works, optimized the layout of the system route reasonably, and reduced the technical contradictions between different disciplines. The cost of the same type and standard system setup has been reduced by about 10% in the same period, as shown in Table 1.

(5) Integrated system of secondary structure and SI interior decoration. The external wall thermal insulation and decoration integrated panel, AlC panel wall and electromechanical wall process products matched with the fabricated steel structure products can reduce the cost of the later fine decoration. According to the statistical analysis, the cost of its secondary structure and SI interior decoration integrated system is about 15% lower than the traditional masonry plastering, grooving and pipe embedding process. As for the underground engineering, the earthwork, foundation and foundation engineering are basically the same as the traditional reinforced concrete structure engineering, and the cost is basically the same, so no analysis is made[2].

4.2. Capital cost analysis

The construction period advantage of prefabricated steel structure residential products has correspondingly improved the capital turnover efficiency in the development process of the project and effectively reduced the financial cost. Taking the residential project with a building area of 12602.62m2 as an example, roughly calculated, the development cost is considered as 60% of 22000 yuan/m2 GFA, and 10% of the financial cost is calculated according to the difference between the fixed construction period of prefabricated buildings and traditional steel concrete buildings, It can save about 1.35 million yuan in financial costs for 35 days (22000 * 0.6 * 10%/12 * 12602.62), equivalent to 110 yuan per square meter.

According to the above analysis, compared with the traditional cast-in-place reinforced concrete structure, the total construction investment cost of prefabricated steel structure will be reduced by 110 yuan/m2 GFA according to the quota construction period, and more according to the actual construction period.

4.3. Analysis of construction period and labor consumption

4.3.1. Construction period

(1) Quota duration comparison: According to the construction period quota standard of the city, take the above-ground project with a building area of 9390.6 ㎡ (an above-ground building area of 8603.76 ㎡) with two floors underground and 24 floors above the ground of Building 1 as an example, and calculate the quota duration:

The above-ground quota duration of the traditional reinforced concrete structure project is 410 days, including 330 days for the structure;

The above-ground quota duration of steel structure works is 380 days, including 300 days for structure.

In comparison with the above, the construction period of steel structure is shortened by 30 days. In addition, the traditional reinforced concrete structure is greatly affected by weather such as winter, wind, rain and high temperature season, while the fabricated steel structure project is relatively less affected by it.

(2) Comparison of actual construction period: According to the statistics of actual completed projects, the construction of steel structure earthwork, foundation and basement is basically consistent with that of traditional concrete. The construction period of main structure is 30% of that of traditional concrete and 50% of that of traditional reinforced concrete structure.

4.3.2. Labor consumption at construction site

According to the actual completed project cases, the actual labor consumption of reinforced concrete structure residential buildings is 4.88~5.5 fixed man-days/square meters (blank delivery, excluding outdoor works). However, the actual labor consumption of the residential project of Building 1 # of Project A is 3.29 quota workdays/square meters, and the average reduction of labor consumption is about 2.0 quota workdays/square meters.

4.4. Operation cost analysis

According to relevant statistics, the life cycle cost distribution of residential buildings is: one-time construction cost 15%, repair and maintenance cost 15%, equipment renewal cost 23%, energy consumption cost 27%, and cleaning cost 20%.

The prefabricated steel structure residential products adopt integrated design, and the standardized components have better durability, which can reduce the number of maintenance in the later stage; The separated equipment system is convenient for maintenance and replacement and reduces the property maintenance cost.

5. Research on key points of cost optimization and control

The project integrates the BIM model into the whole life cycle of cost management for optimal control. The main conclusions are as follows:

5.1. Basic ideas

5.1.1. Cross-border collaboration and total cost management

According to the statistics of many actually completed projects, more than 50% of the settlement price of construction and installation projects exceeds the contract price. Most of the reasons are due to the poor management of each functional end. The cost control is deeply affected by the "cask effect". The overall management level of the project must be improved, with the help of the application of BIM technology of construction products.

5.1.2. Cost front management

Product planning determines the cost gene of the project, and the impact of the design stage on the construction and installation costs of the project can reach 75%~95%. Therefore, the owner and its planning, design and cost management professional teams should attach great importance to the cost and benefit comparison of multiple schemes in the early stage of the project, and should put the focus of cost management forward to the competitive product research and planning and design stage.

5.1.3. Dynamic monitoring management

During the development and construction of the project, its input cost will be gradually refined and clarified with the deepening of design and the implementation of bidding procurement. At the same time, the target cost will also be disturbed and affected by design changes, new regulations issued by the government, changes in material prices, loan interest rates, tariffs, RMB exchange rate adjustments, and unforeseen factors in the market and construction site. Therefore, the cost management work must constantly collect and update the actual value, Implement dynamic control.

5.1.4. Reasonably and effectively grasp the development rhythm

Speeding up the development and construction process of the project can reduce the financial and management costs, improve the capital turnover and investment income, which requires comprehensive analysis and comparison, and reasonably grasp the pace of project development.

5.2. Studying Cost Control from a Management Perspective

When project managers apply BIM technology to prefabricated steel structure projects, they need to study cost control from a management perspective, improve cost management performance from a project management perspective, and realize the professional value of cost management.

(1) Project managers should use the BIM model to conduct digital cost management of the entire process and all elements.

(2) The management focus of project managers has shifted from post cost accounting to target control, including:

1) Project managers use cost model data to identify cost risks from similar completed project cost management model data, and work with relevant functional departments to develop targeted control

plans to minimize ineffective costs caused by human factors;

2) Project managers actively participate in the selection of multiple options, improve project genes, and control costs from the source;

3) Involve designers, BIM engineers, third-party design optimization companies, manufacturers, and other organizations to reduce changes and potential cost risks.

6. Conclusion

Combined with the actual cost optimization analysis, project A has certain cost advantages compared with the traditional steel structure and prefabricated concrete structure residential products; Even compared with the fully cast-in-place reinforced concrete residential products, although the current costs are comparable, from the perspective of medium and long-term development, as the fabricated steel structure residential products account for the smallest proportion of labor costs, they will gradually show cost advantages as the labor price continues to rise. Therefore, it is hoped that the idea of cost optimization and control of fabricated steel structures based on BIM technology provided in this paper can provide reference for the promotion and application of BIM technology and fabricated steel structures.

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