Application of "Lean Construction" Management in Large Group Housing Project

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Abstract. In order to meet the increasing demand for cost reduction and efficiency increase of engineering projects, lean construction management has gradually come into the attention of enterprise managers. This paper expounds the basic concept and connotation of lean construction theory. Modern intelligent construction technologies are introduced in the project implementation process. So that the concept of lean construction and the concept of project management are well integrated. From the technology optimization, process optimization, intelligent support, BIM construction simulation and other scenarios, this paper introduces several application examples of lean construction in construction in detail. Some experiences since the implementation of lean construction are summarized. Examples of benefit optimization achieved by lean construction are given. Experience references for the implementation of lean construction management in large group housing projects can be provided.

Keywords: lean construction · Large group housing · Science and technology construction · Rapid construction · Intelligent construction

1 Introduction

In recent years, with the rapid development of China's urban agglomeration construction, shantytown renovation has become the major measure of urbanization. To improve project management, the theory of "lean construction" has increasingly attracted the attention of project management personnel. They hope, through fine management of projects, to realize the purpose of improving engineering efficiency and quality and reducing engineering waste and management costs [1].

This paper, taking the shantytown renovation project in a centralized settlement area in Shijiazhuang Hi-tech Industrial Development Zone as an example, introduces the management theory of "lean construction", supplemented by other guiding theories such as technology-driven construction, rapid construction, intelligent construction and low-cost construction. By combining the actual situation on site, this project innovated the process optimization measures and achieved the project goals.

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2 “LEAn Construction” Management

“Lean construction” is a comprehensive production management theory and construction management theory. It is also a systemic method that considers the distinctive features of construction engineering and can continuously reduce and eliminate waste in the full lifecycle of engineering products, so that clients’ requirements can be met to the fullest extent possible. Lean construction of the shantytown renovation project in this research is guided by and based on the technology-driven construction system, pays attention to the rapid construction system, lean cost construction system and high-quality construction system that the clients are concerned about, and takes the intrinsically safe construction system, intelligent construction system and environment-friendly construction system as the guarantee. Guided by the targets of zero waste, zero stock, zero defect, zero accident, zero rework and zero idleness, the project company did its best to reduce surplus procedures, idle working faces, resource waste and one-time investments and improve the first pass yield and reduced during the construction. The company also created a high-quality resource-saving and ecological construction project with fine management, which helped improve enterprises’ operational efficiency and perfectly meet homeowners’ demands [2].

3 Application of Lean Construction in This Project

The popularization and application of lean construction need to be customized and adjusted according to the practical conditions of homeowners, enterprises and engineering projects. This paper emphasizes presenting practice achievements of this shantytown renovation project in the technology-driven construction system, rapid construction system and intelligent construction system after introducing the lean construction theory and approach, and hopes to provide a reference for lean construction management in similar projects.

4 Technology-Driven Construction System

Technology-driven construction emphasized optimizing design and techniques, with the key lying in construction drawing identification and procedure prediction. At the beginning of the project, benefited from system coordination and technical support from the construction company, conflicts between various specialties in the drawings were sorted out and then the drawing was analyzed and optimized consequently. Besides, construction difficulties and conflicts hidden in the drawings which would appear during construction were listed in detail, and the construction procedures at different phases were simplified. All the above measures provided a technical guarantee for improving the construction quality and efficiency [3].

4.1 Construction Phase of Underground Structure

In the original drawing of this project, the basement floor was divided into 64 blocks by post-cast strips, and there were 1404.19m temperature post-cast strips and 2943.85m settlement post-cast strips. These post-cast strips caused unnecessary personnel and material investments since additional form-work supports needed to be erected, and they also negatively affected the waterproof performance, backfill and maintenance. Based on the successful experiences over the years and reference to the construction standard DB13 (J)-T292–2019 Technical Specification for Application of Hopping Method in Mass Concrete Structures, the Project Department made a comprehensive comparison and actively organized technical discussions. After several rounds of technical verification, this project abandoned temperature post-cast strips and settlement post-cast strips, becoming the first project in Shijiazhuang that removed all post-cast strips.

4.2 Construction Phase of Aboveground Structure

In traditional construction of the standard floor in the aboveground structure, wood form-works are combined with I-beam cantilever scaffolds. However, wood form-work splicing construction and disassembly cause certain losses, and pre-burying of cantilever holes reduces form-work turnover. After construction is finished, blocking of the pre-buried holes increases the risk of leakage of the main structure, and splicing construction on each floor needs die assembly construction under the leadership of foremen familiar with the drawing. This paper introduced another construction technology of combining aluminum form-works with tie rod cantilever scaffolds. After sufficiently comparing the advantages and defects of these two construction patterns and comprehensively analyzing the construction duration, cost and application value, this project finally adopted the new pattern of combining aluminum form-works with tie-rod cantilever scaffolds (Fig. 1). This can prevent excessive holes and follow-up blocking because it is only necessary to reserve corresponding bolt holes through walls and no holes were needed to be reserved in the form-works. Therefore, the construction process was further simplified, the step pitch of construction on each floor was reduced, and the project duration was shortened. The in-depth design of aluminum form-works applied the building information modeling (BIM) simulation technology to comprehensively analyze the relations between structural walls and filler walls (Fig. 2). Besides, door piers, wall piers, door and window openings, lintels, structural columns and encased columns that need secondary structure construction were designed profoundly, and this not only fastened the construction of the main structure but also accelerated the construction progress of secondary structural masonry.

4.3 Comprehensive Analysis of Project Construction Difficulties

In the drawing identification phase, the BIM technology was used to simulate project construction and further identify critical and challenging technological points of the project. Under the leadership of the project manager and planning of the chief engineer, the identified critical and challenging technological points were analyzed in depth for solutions, and finally, the optimizing scheme as below was adopted.

The overhead corridor (not for the fire escape) and the roof truss are critical and challenging technological points of this project. The overhead corridor had an ultrahigh initial height and a very long structure, both of which exceeded the construction criteria. After several seminars discussing and comparing the floor type support frame, I-beam

Fig. 1. Tie-rod cantilever scaffolds

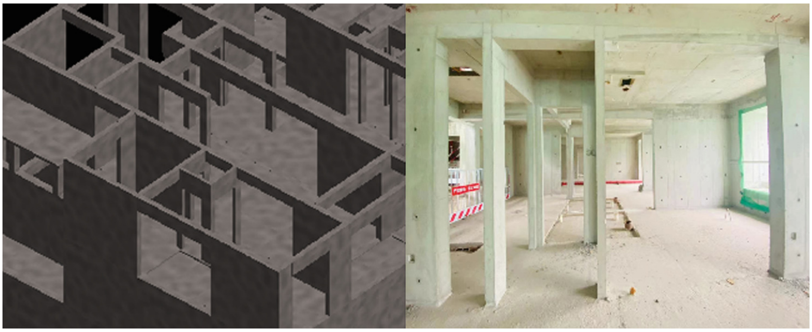

Fig. 2. Optimized encased columns and lintels

cantilever support frame, Bailey support frame, tie rod cantilever scaffolds and triangular support frame, the project team finally chose the triangular support frame for the construction of the overhead corridor.

The roof truss is difficult to construct in the later phase. Traditionally, the triangular support frame is used for form-work setup, but there is a hidden safety hazard during frame hanging and erection. Besides, the form-work and outside scaffolding cannot

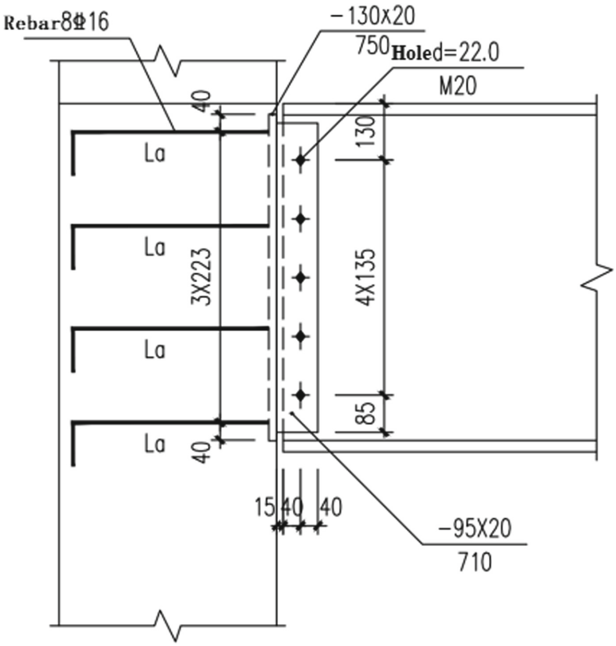

Fig. 3. Pre-buried nodes of roof truss structure

be dismounted until the concrete is cured to the specified date which generally needs 45 days. This seriously delayed secondary masonry construction, leaving it to fall behind in the construction of the main structure. To ensure safety in construction and reduce the negative influence on follow-up procedures as much as possible, the comprehensive construction duration and cost were split in detail. After obtaining approval from the construction company, the steel-structure prefabricated assembly technology was used to replace the roof truss (Fig. 3). During the construction of the main structure, the outside scaffolding can be dismounted after embedded anchor botls were fixed to the designated position and concrete pouring was finished. This operation shortened the construction duration by about one month and effectively relieved the pressure of reducing construction time.

5 Rapid Construction System

If the technology-driven construction system is the technical premise of the lean construction system, then the rapid construction system is a critical part of the lean construction system. Building a full-process interlacing construction model is an essential step for realizing lean construction and shortening the construction duration.

In the construction phase of the underground structure, different construction sections were divided at the construction joints which were originally reserved for post-cast strips. Then construction was conducted in sequence based on the same step pitch according to the overall construction plan of the main building construction followed by underground parking garage construction. This reduces the time interval of the material cycle and fastens construction.

In the construction phase of the aboveground structure, masonry construction and plastering were arranged in sequence by referring to the time when the main structure was inspected. Guided by the reasonable process interlacing model, masonry construction and plastering were respectively carried out when the 8th layer and the 10th layer of main structure construction started.

In the electromechanical engineering phase, this project was guided by the principle of combining permanent and temporary measures. For example, formal circuit lines were paved in advance to replace temporary lighting devices, laying fire pipes in advance to provide water for construction, and building a fire-pump room in advance to replace the temporary one. Besides, the construction company actively employed electromechanical construction and civil construction technologies, and optimized construction procedures by conducting support pre-burying, water pipe laying and plastering in sequence, thereby fastening construction.

6 Intelligent Construction System

As the guarantee for management of lean construction, the intelligent construction system aimed to build an intelligent construction site based on the BIM technology, thereby laying a foundation for comprehensive control and intelligent decision making of this project [4].

Before the project kickoff, the Project Department paid great attention to the application of the BIM technology, and drafted the BIM application plan for this project in advance, for the purpose of applying BIM in different phases with different levels of emphasis [5].

In the early planning phase, the construction company developed site layout models for temporary buildings of all phases and independently developed a sort of software for calculating the costs of the temporary buildings (Fig. 4). This realized fast calculation of temporary building costs, and the business accounting result showed a cost calculation deviation of smaller than 2% [6].

In the in-depth design phase, architectural, structural and electromechanical models were integrated, and the following simulation activities were conducted [7]. Lighting effect simulation was performed to optimize the layout of the temporary lighting system; material transport path simulation was carried out to optimize construction roads on site; the in-depth structural design was adopted for the casting of structural columns, flashing, lintels and encased columns in advance along with the construction of the primary structure; in-depth design for pipeline layout was done to realize pre-burying of the pipeline box along with the construction of the main structure. All these in-depth designs provided data support for the work combining permanent and temporary measures, laid the foundation for rapid process interlacing and saved project resources.

In the construction phase, this project promoted intelligent site construction from various aspects by combining technologies of the Internet of Things, intelligentization, mobile Internet, cloud computing and big data. In labor management, facial recognition technology was used for real-name inspection and appraisal. In material management,

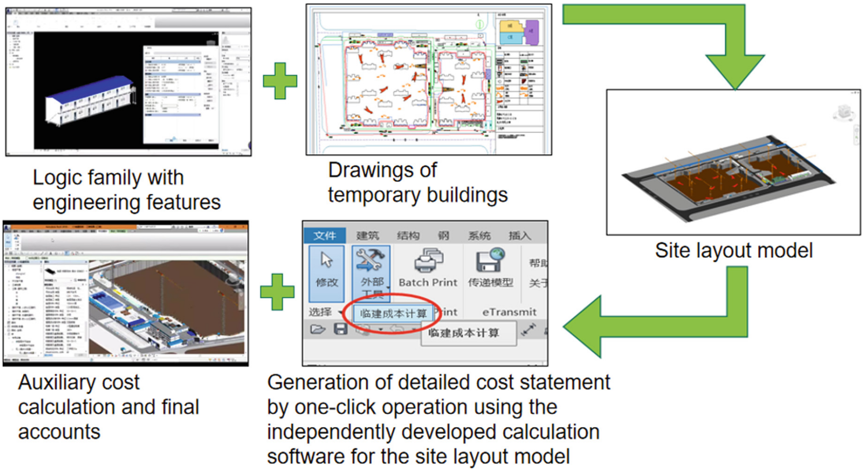

Fig. 4. Independently developed software for calculating costs of temporary buildings

the unattended material acceptance inspection system was used for material in and out of warehouse registration management. In safety management, AI cameras were used to intelligently capture and record illegal behaviors on site and monitor the operating states of cranes, elevators and other special equipment. In quality management, automatic measurement robots (Fig. 5) were used for fast actual measurement, which helped reduce the measurement time and cost by 90% and 25% respectively. In green construction management, the noise and flying dust monitoring system was interlinked with the site spraying system, realizing automatic control of flying dust. In addition, other technologies such as photography using unmanned aerial vehicles, 3D model printing and presentation, VR experience and AR routine inspection were used and interlinked to the data application center of this project, realizing whole-process intelligent management and control of the project [8].

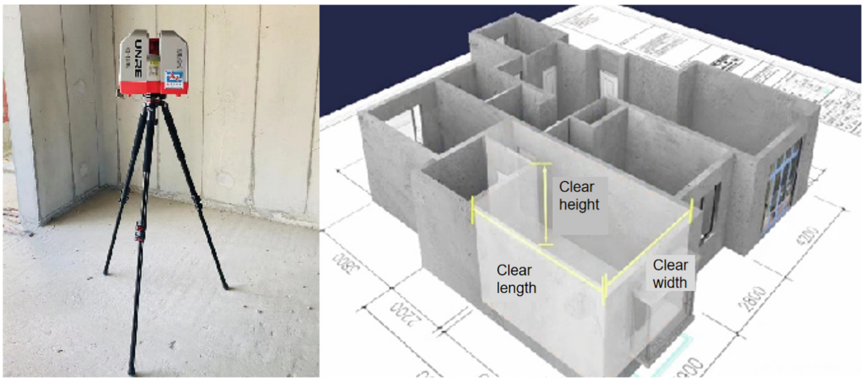

Fig. 5. Fast actual measurement on site by measurement robot

7 Analysis on Benefits of Lean Construction

7.1 Economic Benefit

Theories of technology-driven construction and rapid construction, which were included in the theory of lean construction, pointed out the direction for early planning of this project [9]. Process optimization emphasized key procedures that had a large impact on the project duration and cost, and the perfect interlacing of key lines also attracted great attention. Through active planning, major procedures were changed and optimized [10]. For example, removing the post-cast strips significantly reduced the construction duration and costs of the underground parking garage by 80% and around 8% respectively compared with the traditional ways; changing the roof truss to the steel structure reduced the construction duration and costs of the main roof structure by 50% and 3% respectively compared with the traditional ways; the combination of permanent and temporary measures used for building the garage lighting system, although did not shorten the construction duration, reduced the lighting cost by 60% compared with the temporary lighting measures.

7.2 Social Benefit

The application of lean construction management brings good social benefits to the centralized settlement area where this project is located [11]. In the planning phase, the construction company shared its experience of lean construction in a centralized settlement area of the South New Town of Shijiazhuang, which aroused a strong response from units in the construction industry and raised its reputation in this area. These units paid special attention to technology-driven construction, especially the abandonment of post-cast strips because it filled in the blank of this area in hopping technology. The success in later planning such as replacing traditional plastering with limestone, combining permanent and temporary measures in fire protection and lighting, and removing counterweights from the suspended platform contributed to the project becoming an industrial benchmark and attracting other participating units for visits and communications.

8 Conclusion and Expectation

This paper combined the theory of lean construction and the management experience of construction engineering and introduced the innovative application of lean construction in project management. Besides, the practical management of this project strengthened management and control of project safety, quality and cost. Finally, the in-depth analysis and thinking on various aspects of project management ensured the achievement of the overall project goals.

Today, with rapid development in technology and management, the traditional construction industry is in urgent need of an innovative management pattern [12]. In this context, the combination of lean construction theory and project management is the optimal choice for overcoming many defects in traditional project management. The in-depth study on lean construction will improve the fine management level of engineering projects and ensure construction quality, further realize clients' and owners' maximum benefits and effectively promote China's construction industry to develop towards environmental friendliness, industrial intensification and high efficiency.

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