Frontiers of Engineering Management
DOI 10.15302/J-FEM-2015039

ENGINEERING MANAGEMENT TREATISES

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Construction Technology of Off-Site Precast Concrete Buildings

Abstract The industrialization of building construction is gradually becoming a new choice of construction technology driven by some great advantages such as high efficiency in construction, low energy consumption and environmental friendliness. Construction management plays an important part to ensure the quality of projects. A comparison between traditional on-site and modern off-site construction methods has been conducted. The streamlining of the process including the fabrication, transportation, stacking and assembling of precast components has also been analyzed with a discussion on the BIM application in the process.

Keywords: off-site construction, precast concrete, modular construction, construction management, building information model (BIM)

1 Introduction

Originally developed in Europe, off-site building construction played an important role in solving the housing shortage problem after World War II in the 1950s. The US, France as well as the former Soviet Union accumulated a wealth of experience in off-site building construction. And in Japan, where the government made huge effort in both economic and legislative parts, off-site building has already taken up 50% of the concrete buildings (Li, 2014; Li, Geng, Qi, Lei, & Luan, 2013). In China, however, off-site construction is not as popular as in the aforementioned countries and there is still a lot to improve with regards to the technical details such as joints treatment and modular precast components.

Compared to the traditional on-site construction, off-site method possesses great advantages as shown in Table 1.

Manuscript received December 20, 2014; accepted March 12, 2015

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It can be concluded from the Table 1 that off-site construction stands out in its high construction proficiency, low energy consumption, environmental friendliness, etc. In this field, BIM technology plays an important role in monitoring and optimizing the whole life time management.

2 Design for prefabricated components

Off-site construction consists of design, material procurement, components fabrication, logistics, on-site construction and maintenance. The following processes and the capital of the project largely depend on the first step of design, which can be rarely modified afterward due to its prefixed position and independence. Therefore preparation is quite important at this stage.

2.1 Design of modular construction components (beam-slab system and shear wall)

The module is designed for fixed size components and each part of the building can be fabricated in mass production. Beam, slab, stair case, shear wall and in-filled wall should be designed in a set of standard guidelines. The construction functions and joints connection should also be considered in the design stage.

2.2 Design of joint

The joint design is a crucial part for the whole construction because the components are generally installed at site. Thus any unreasonable design of joints will lead to installation failure and extend the time for the project.

2.3 Integration of design

BIM provides a platform for coordination of various participants in the projects such as heating and ventilation, pipelines, indoor decoration and curtain wall through visualization and collision analysis to ensure the order of procedure and the joints design.

Table 1

Comparison between On-site and Off-site Construction

	On-site construction	Off-site construction
Labor/time	Labor intensive Longer time for construction	Technology intensive Shorter time for construction
Environmental independence	Remarkably influenced by the ambient temperature and other factors	Prefabricated components can be directly assembled on site
Quality control	Hard to find an agreed standard for various situations	Quality can be easily controlled through joint connection with fixed size components
Shape flexibility	On-site construction is often applied for buildings with complicated designs	Buildings are relatively alike due to fixed scale
Construction management	Complex management of material stacking, human resources and safety	Lean logistics can reduce the material stacking dramatically and help simplify the management on site
Resource consumption	Low efficiency of resource usage Huge energy consumption	Industrialization of components increases the efficiency of resource usage A specified factory is usually needed
Environmental friendliness	Noise and pollution influence the ambient environment greatly	Rare noise and pollution hence more environmentally friendly
Construction function	Special processes need to be applied for water and fire protection Lower construction efficiency	Components of specified functions are precast in factory Lower construction difficulty
Structure performance	Better performance in integrality and stability	Relatively weaker in stability and earthquake-resistance

A bearing wall combining a shear wall, a thermal insulating wall, a curtain wall, pipelines and a wallboard, is generally known as 'sandwich wall', as shown in *Figure 1*.

Pre-assembling is also applied during prefabrication to idealize synchronization of installation and decoration. For example, structure components and materials of both inside and outside walls can be assembled in factory to facilitate work at site.

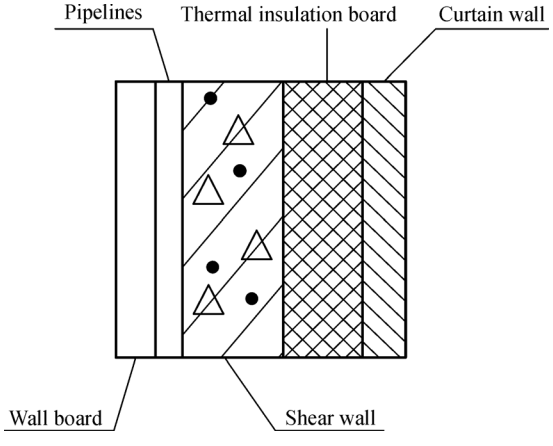

Figure 1. Integrating design for "sandwich" bearing wall.

A recently developed theme park in China has adopted off-site construction during the construction of its hotel. After deciding the fixed size of certain rooms, pipelines are prefabricated and assembled at site. It's the idea rather than the specific method that counts for green construction.

3 Concrete casting and lean logistic of components

Both traditional and modern materials can be used in factory. In particular, all procedures from design to installation satisfy the automatic production requirements while production and maintenance of components should refer to the given standard.

A reasonable division of construction site will greatly increase the efficiency. And a smart logistic management system is applied to ensure a smooth supply for "Just in Time" installation. Vehicles should obey the rules for PC transportation to ensure its quality.

4 Installation at site

Installation can be divided into two ways according to the hoisting methods: 1) Temporary factory for assembling, where components can be assembled in box and installed integrally. 2) Install the components at site. Precast wall board and cast on-site walls are constructed at the same time with cast-in-place joints with regards to the building integrity (Wang, 2012).

In the Tangshan earthquake in 1976, lots of prefabricated concrete buildings collapsed due to their weak connections between components. However in modern constructions, concrete is cast at joints to ensure the safety of the whole structure and increase its earthquake-resistance.

After the construction, waste materials can be recycled and used in other project.

5 Management of supply chain

The integrated supply chain management system of off-site precast concrete construction is an innovation of traditional building idea. Through the use of BIM technology, different participants in design, procurement, fabrication, logistics, installation and maintenance can all share the information timely and submit their needs and questions on the integrated forum.

Figure 2 shows the process for integrated management. And the apparent advantage of BIM management system is its coordination of designers, producers, contractors, clients and customers. Through analysis of key points, collisions can be avoided from the very beginning, and the management can be optimized based on lean principles to increase the construction efficiency, to ensure the construction safety, to control the carbon emission and to reduce cost and waste.

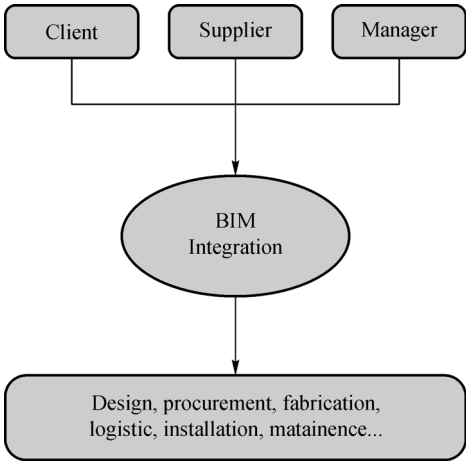

Figure 2. BIM integrated management system for off-site precast concrete building.

6 Indicators for off-site construction

A competitive advantage for off-site building is the environmental friendliness. During the whole procedure, electricity, water, material, field and time consumption can be cut down by 70%, 80%, 20%, 20% and 70% respectively. According to the statistics, only 1/3 of the labor force as in traditional construction method is needed, while time needed for construction is also about 1/3. The waste produced by construction is only 20% of traditional method.

Off-site construction is a typical method for environment protection with higher safety standard and lower management difficulty. Building industrialization is a comprehensive practice for technical internationalization and construction standardization.

7 Conclusions

Building industrialization meets the requirement for cost reduction and environment protection. Moreover, green material development and combination of information technology and project management have provided positive supports. However, experience is not adequate and there is still a lot to be improved.

Product protection is an important part of the construction, while in China, even if the warning signs are set up at site, workers often step on products directly causing unnecessary damages. Product protection calls for specific rules, proper management, adequate promotion as well as individual awareness improvement.

Off-site construction is a newly applied method in China with both technology and standard being immature. The cost of construction is higher than the traditional one in short terms. Thus a proper direction from government is urgently needed for advance in legislation and economy.

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