Research on the Calculation Method for Prefabrication Rate of Precast Concrete Buildings Based on Revit Secondary Development (Postprint)

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Abstract

To improve upon the problems of low efficiency and compounding errors in the current manual calculation of prefabrication rates for prefabricated buildings, this study leverages Building Information Modeling (BIM) technology. Through secondary development of Revit software, it implements automatic quantity takeoff for prefabricated components and automatic calculation of prefabrication rates for Precast Concrete (PC) structures based on BIM models, thereby validating the feasibility of PC building prefabrication rate calculation on the Revit platform. Utilizing the secondary development outcomes presented herein, construction costs can be estimated via dynamic selection and combination of component-level prefabrication rates, facilitating the selection of prefabrication schemes within acceptable cost parameters, enhancing economic benefits, and providing a decision-making foundation for stakeholders to formulate prefabrication strategies.

Full Text

The Calculation Method for PC Building Prefabrication Rate Based on Revit Redevelopment

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Abstract

To address the inefficiency and increasing errors associated with manual calculation of prefabrication rates in prefabricated buildings, this study utilizes Building Information Modeling (BIM) technology and conducts secondary development of Revit software to achieve automatic quantity surveying of prefabricated components and automatic calculation of prefabrication rates for Precast Concrete (PC) buildings based on BIM models. The feasibility of calculating PC building prefabrication rates using the Revit platform is verified. By leveraging the redevelopment tool developed in this study, construction costs can be estimated through dynamic selection and combination of different component prefabrication rates, thereby enabling the selection of prefabrication schemes within acceptable cost ranges to increase economic benefits and provide decision-making support for determining optimal prefabrication strategies.

Keywords: Prefabricated Construction, BIM, Prefabrication Rate, Revit Redevelopment

Introduction

Prefabricated construction transforms traditional site-based building processes to factory-based manufacturing. Compared with conventional construction methods, prefabricated buildings can shorten construction schedules, improve building quality, conserve resources, protect the environment, and promote sustainable development in the construction industry [1]. In September 2016, the "Guiding Opinions of the General Office of the State Council on Vigorously Developing Prefabricated Buildings" explicitly required promoting construction innovation, implementing green development concepts, vigorously developing prefabricated concrete and steel structures, and continuously increasing the proportion of prefabricated buildings in new construction projects.

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility, based on data information from various project phases. It can truly integrate and reflect relevant project information, featuring visualization and collaboration [2]. Prefabricated construction emphasizes coordination among various components, and BIM platforms can effectively improve efficiency in design, fabrication, and installation of prefabricated buildings [3], thereby promoting the development of prefabricated construction.

Currently, the integrated application of prefabricated construction and BIM technology remains in the exploratory research stage. Applying BIM technology to solve maintenance and management issues in prefabricated concrete building construction can effectively reduce rework during the construction process [4]. Drawing from Computer Integrated Manufacturing Systems, the proposed theoretical framework for BIM-based prefabricated building integrated construction systems holds significant importance for improving informatization and component productivity in prefabricated construction [1]. The combination of 3D laser scanning technology and BIM can enable automatic inspection of dimensional quality for prefabricated components [5]. Using BIM software to establish connection joints for precast beams and columns allows for the design of prefabricated seismic frame models that meet code requirements, thereby establishing a PC component structural system library [6]. BIM platforms for collaborative design of prefabricated buildings can reduce duplicate work for designers and improve work efficiency [7].

In summary, the automatic statistical analysis of prefabricated component quantities and automatic calculation of prefabrication rates using BIM technology remain subjects requiring further research. Since prefabrication rate is a crucial metric for evaluating prefabricated buildings, investigating methods for automatically extracting component quantities and calculating prefabrication rates is essential.

1. Analysis of Prefabrication Rate Calculation Issues

Prefabrication rate is one of the key indicators for measuring prefabricated buildings and serves as the primary basis for government policy support. Simultaneously, the level of prefabrication rate directly impacts project costs. Through quantitative analysis of engineering costs at different prefabrication rates, the economically optimal prefabrication rate for prefabricated buildings falls between 46%-65% [8]. Therefore, prefabrication rate is the first indicator that must be considered when implementing prefabricated building projects.

However, several problems exist in prefabrication rate calculation. Traditional calculation methods rely on manual computation of precast component concrete volumes based on drawing dimensions. This process is complex, inefficient, and yields inaccurate results. The emergence of BIM technology provides powerful technical support for solving automatic calculation of prefabrication rates in prefabricated buildings. Nevertheless, simply establishing a BIM model of a prefabricated building and utilizing the native functions of modeling software makes it difficult to achieve automatic quantity surveying and automatic prefabrication rate calculation. Revit, as one of the mainstream BIM modeling software platforms, contains a rich set of Application Programming Interfaces (APIs). Through secondary development of Revit, users can expand functionalities according to specific needs to satisfy different design and construction requirements. Therefore, leveraging Revit' s secondary development capabilities to solve automatic quantity surveying of prefabricated components and automatic calculation of prefabrication rates for PC buildings based on BIM models constitutes the focus of this research.

2. Development Approach and Steps

This study establishes prefabricated building BIM models using Revit BIM modeling software. Based on Revit secondary development, the research utilizes information within the models to statistically analyze quantities of various prefabricated component types, thereby establishing calculation rules to compute prefabrication rates for different component categories in projects. This approach addresses the problems of complex manual calculation, low efficiency, and inaccurate results, achieving the goal of accurate and rapid computation. Through dynamic selection and combination of different component prefabrication rates, construction costs can be estimated, enabling the selection of prefabrication schemes within acceptable cost ranges to increase economic benefits and provide decision-making support for determining prefabrication strategies.

2.1 Development Tools and Steps

This development is based on Revit 2016, with primary development tools including Visual Studio 2015, Revit SDK (Software Development Kit), and Revit Lookup. The Visual Studio 2015 development environment is used to write program code. The Revit SDK contains Revit API documentation and sample source code, while Revit Lookup enables intuitive visualization of component APIs within models. The specific development steps are shown in [Figure 1: see original paper].

2.2 Development Mode

Revit secondary development offers two modes: External Command (IExternal Command) and External Application (IExternal Application). IExternal Command is an interface that must be implemented when users extend Revit, containing only one abstract function, Execute(), which is overridden to implement external commands [9]. The IExternal Application interface has two abstract functions, OnStartup() and OnShutdown(), which customize required functionalities during Revit startup and shutdown. Both modes require referencing two interface assembly files, RevitAPI.DLL and RevitAPIUI.DLL, before development. This study adopts the external command approach, generating DLL files from written programs and loading them through AddIn Manager to run the application.

3. Parameter Design and Acquisition

3.1 Parameter Design

The calculation rules adopted in this study follow national standard calculation methods [10]. Based on Revit secondary development, concrete volumes are obtained quickly and accurately, and the prefabrication rate is calculated as the ratio of precast component concrete volume above outdoor ground level to total concrete volume.

According to the prefabrication rate calculation rules, two primary parameters must be obtained: precast concrete volume and cast-in-place concrete volume. Precast concrete volume is obtained by filtering rules to access the built-in volume parameters of component models. Cast-in-place concrete volume is obtained partly from component models in the project and partly through proportional calculations. For composite prefabricated slabs with a typical thickness of 60mm and a 70mm cast-in-place topping, the cast-in-place volume is obtained by multiplying the prefabricated composite slab volume by a coefficient of 7/6.

3.2 Parameter Acquisition

To view prefabrication volumes and rates for various component types, precast concrete volumes should be acquired separately by component type. In the Revit API, there are two methods to access objects. For system families such as Wall, Floor, and Opening, objects can be obtained by filtering their class names. For components like columns and beams, which lack dedicated classes and are instances of FamilyInstance, objects can be filtered through built-in parameters. In Revit, system families cannot be user-defined; therefore, prefabricated walls, floors, openings, and other components in this project are established through new generic models, which also belong to FamilyInstance and are accessed by filtering their built-in parameters.

Creating prefabricated components must follow specific naming conventions to enable filtering rules that access corresponding component parameters. Based on Example 4 in the National Building Standard Design Atlas 15J939-1, a set of prefabricated component naming rules has been summarized, as shown in .

Prefabricated component volumes are obtained by accessing built-in instance parameters. It should be noted that Revit' s backend operations use feet as the unit; therefore, volume parameter values must be multiplied by 304.83 to convert to cubic meters, as shown in [Figure 3: see original paper].

After obtaining component volumes, the name and quantity of each component are accessed through property calls. Finally, this data information is set as the data source for the dataGridView control and displayed in a list.

Cast-in-place components include walls, cast-in-place portions on prefabricated composite slabs, beams, cast-in-place portions on stair landing slabs, and cast-in-place nodes. Volumes for walls, beams, floors, and node cast-in-place portions are obtained through processes similar to those described above. The cast-in-place volume above prefabricated composite slabs is obtained by multiplying the prefabricated composite slab volume by the corresponding proportional coefficient.

The prefabrication rate for each component type is calculated as the ratio of that type' s precast volume to the sum of its precast and cast-in-place volumes. The total prefabrication rate is the sum of prefabrication rates for components selected for prefabrication.

3.3 Interface Interaction

A form is created to display information such as component names and volumes. As previously mentioned, the Execute() function has three parameter overloads, and creating a form to execute Revit commands requires passing these three parameters. First, the form is declared and instantiated in the Execute() function to set form display, and then a constructor is generated in Form1. The form design utilizes various controls including Button, Label, and CheckBox, requiring code to be written in each control' s event to implement software functionality. The software interface is shown in [Figure 4: see original paper].

4. Verification Example

This project adopts Example 4 from the National Building Standard Design Atlas 15J939-1. Based on the modeling rules described above and the component details in Example 4, BIM models for various component types are established separately. These component models are then assembled into the Example 4 standard floor BIM model, as shown in [Figure 5: see original paper]. Running Revit software and loading the plugin DLL file through AddIn Manager in external tools enables operation of this prefabrication rate calculation software.

As shown in [Figure 6: see original paper], clicking different tabs displays quantity lists for various prefabricated component types separately. The prefabrication rate is dynamically calculated on the right side. By checking different components, the software automatically calculates the prefabricated volume and prefabrication rate for that component type, dynamically displaying the prefabricated volume and rate for selected components below. Through combination of different component prefabrication rates, optimal prefabrication schemes can be selected to increase economic benefits.

The Example 4 project has 21 above-ground floors, with floors 5 and above using prefabricated concrete shear wall structure and floors below 5 using cast-in-place concrete shear wall structure. Plugin reliability is verified from two aspects: first, verification of prefabricated volume for individual components; second, establishment of a standard floor BIM model to calculate the Example 4 standard floor prefabrication rate using this plugin, with results compared against the standard atlas to verify calculation accuracy.

Taking composite slab YDBS_{01} with specifications of 3750*3130*60 (length*width*thickness, mm) as an example, its volume is 0.7 m^3, and its upper cast-in-place volume should be 0.82 m^3. Isolating this composite slab in Revit and calculating its volume separately using the plugin yields results consistent with manual calculation. When exterior walls, interior walls, floors, and stairs in the standard floor all adopt prefabrication, the plugin calculates a standard floor prefabrication rate of 60.84%, as shown in [Figure 6: see original paper]. The standard atlas indicates a standard floor prefabrication rate of 60.81% for this project, representing a 1% difference that falls within acceptable error margins, thus confirming the plugin' s calculation accuracy.

The Example 4 project case adopts a combination of prefabricated exterior walls, prefabricated interior walls, composite slabs, and prefabricated stairs, achieving a relatively high prefabrication rate. According to research in literature [8], without considering schedule benefits, this combination increases project cost by approximately 270 yuan/m^2, and high cost is a direct factor inhibiting prefabricated building development. Using this plugin to select a combination of prefabricated exterior walls, composite slabs, and prefabricated stairs directly calculates a prefabrication rate of 45.07%. Additionally, using lightweight partition panels for interior walls can effectively reduce construction costs.

5. Summary and Outlook

Revit is one of the primary BIM application software platforms, though current application levels mostly remain at modeling functions. Conducting function-specific development on Revit through its API helps explore deeper applications of BIM technology. This study uses Example 4 from the National Building Standard Design Atlas 15J939-1 to establish component BIM models and assemble project standard floor BIM models. Combined with Revit secondary development technology, a prefabricated building prefabrication rate analysis software has been developed to achieve rapid statistical analysis of various prefabricated component volumes and prefabrication rate calculation, improving work efficiency, dynamically displaying prefabrication rates corresponding to different prefabricated components, and providing decision-making support for determining prefabrication schemes.

References

[1] Yu Longfei, Zhang Jiachun. BIM-based integrated construction system for prefabricated buildings [J]. Journal of Civil Engineering and Management, 2015(04):73-78.
[2] Azhar S. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry [J]. Leadership and Management in Engineering, 2011, 11(3):241-252.
[3] Bai Shu. Analysis of BIM technology application value in prefabricated buildings [J]. Construction Economy, 2015:106-109.
[4] Ismail Z. Improving conventional method on precast concrete building maintenance: Towards BIM implementation [J]. Industrial Management & Data Systems, 2017:1485-1502.
[5] Kim M K, Wang Q, Park J W, et al. Automated dimensional quality assurance of full-scale precast concrete elements using laser scanning and BIM [J]. Automation in Construction, 2016:102-114.
[6] Guan D, Guo Z, Zhang C. Research on Precast Concrete Structures with BIM Involving Information on Structural Details and Behaviors [J]. Engineering Village, 2015:222-228.
[7] Li K. The application of BIM technology in prefabricated assembly concrete structure design [J]. Engineering Village, 2017:472-476.
[8] Li Lihong. Economic prefabrication rate accounting for assembled monolithic buildings [J]. Construction Economy, 2015:91-94.
[9] Qian Hai, Ma Xiaojun, Lai Kan. Construction of electrical equipment family platform based on Revit secondary development [J]. Journal of Information Technology in Civil Engineering and Architecture, 2015, 7(04):60-64.
[10] Tian Wei, Zhu Hai, Liu Zhilong. Research on new calculation method for evaluating industrialization degree of single buildings [J]. Chinese and Overseas

Architecture, 2016(07):130-132.

Note: Figure translations are in progress. See original paper for figures.