A Study on the Method for Calculating the Prefabrication Rate of Precast Concrete Buildings Based on Revit Secondary Development (Postprint)

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Abstract

To address the current issues of low efficiency and increasing errors in manual calculation of prefabrication rates for prefabricated buildings, this study employs Building Information Modeling (BIM) technology. Through secondary development of Revit software, automatic quantity takeoff of prefabricated components and automatic calculation of prefabrication rates for Precast Concrete (PC) buildings based on BIM models are achieved, thereby validating the feasibility of PC building prefabrication rate calculation on the Revit platform. Leveraging the secondary development achievements presented herein, construction costs can be estimated through dynamic selection and combination of prefabrication rates for different components, enabling the selection of prefabrication schemes within acceptable cost ranges, enhancing economic benefits, and providing decision-makers with a basis for formulating prefabrication schemes.

Full Text

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

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Abstract

To address the inefficiency and increasing error rates associated with manual calculation of prefabrication rates in prefabricated buildings, this study leverages Building Information Modeling (BIM) technology to conduct secondary development of Revit software. The research achieves 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. Through the secondary development outcomes presented in this paper, construction costs can be estimated via dynamic selection and combination of different component prefabrication rates, enabling the identification of optimal prefabrication schemes within acceptable cost ranges. This approach increases economic benefits and provides decision-making support for determining prefabrication strategies.

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

1. Analysis of Prefabrication Rate Calculation Challenges

Prefabricated construction transforms traditional site-based building processes into factory-dominated manufacturing operations. Compared with conventional construction methods, prefabricated buildings can significantly shorten construction periods, 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 mandated construction innovation, implementation of green development concepts, vigorous development of prefabricated concrete and steel structures, and continuous increase in the proportion of prefabricated buildings in new construction.

Prefabrication rate serves as one of the key indicators for measuring prefabricated buildings and constitutes the primary basis for government policy support. Additionally, prefabrication rate directly affects project costs; quantitative analysis of different prefabrication rates reveals that the economically optimal prefabrication rate for prefabricated buildings ranges between 46%-65% [8]. Therefore, prefabrication rate represents the first indicator that must be considered when implementing prefabricated construction.

However, several significant problems exist in current prefabrication rate calculation practices. Traditional methods rely on manual calculation of prefabricated component concrete volumes based on drawing dimensions, resulting in complex calculation processes, low efficiency, and inaccurate results. While Building Information Modeling (BIM) technology provides powerful support for automatic calculation of prefabrication rates, merely establishing BIM models for prefabricated buildings using 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 API (Application Programming Interface) that enables users to expand functionality according to their needs through secondary development, thereby satisfying diverse design and construction requirements. Consequently, this research focuses on utilizing Revit' s secondary development capabilities to solve the challenges of automatic quantity surveying of prefabricated components and automatic calculation of prefabrication rates for PC buildings based on BIM models.

This study establishes a prefabricated building BIM model using Revit software, investigates the use of model information to quantify various prefabricated components, establishes calculation rules for determining component-specific prefabrication rates, addresses the problems of complex manual calculation, low efficiency, and inaccurate results, and achieves accurate and rapid calculation. Through dynamic selection and combination of different component prefabrication rates, construction costs can be estimated to select prefabrication schemes within acceptable cost ranges, thereby increasing economic benefits.

2. Development Approach and Implementation

2.1 Development Tools and Procedures

Revit software provides excellent functional support for modeling work, enabling rapid and efficient creation of three-dimensional models containing rich data information, including geometric dimensions, elevations, materials, types, and other attributes. Autodesk provides API interfaces for Revit software, allowing direct access to this information through API programming. Therefore, the development approach and objective of this research is to investigate how to use BIM models to establish filtering rules for quantifying various prefabricated components in the model, obtain quantities for cast-in-place concrete components, and thereby establish calculation rules to achieve automatic calculation of prefabrication rates for prefabricated buildings.

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 source code examples, and Revit Lookup is used to visually inspect API elements in the model. The specific development steps are shown in [Figure 1: see original paper].

2.2 Development Mode

Revit secondary development offers two modes: external command (IExternalCommand) and external application (IExternalApplication). IExternalCommand is an interface that users must implement when extending Revit, containing only one abstract function, Execute(), which is overloaded to implement external commands [9]. The IExternalApplication interface has two abstract functions, OnStartup and OnShutdown, which customize required functionality when Revit starts and closes. Both modes must first reference two interface assembly files: RevitAPI.DLL and RevitAPIUI.DLL. This research adopts the external command approach, writing programs to generate DLL files that are loaded and run through AddInManager.

3. Parameter Design and Implementation

3.1 Prefabricated Concrete Volume Acquisition

The calculation rule adopted in this study follows national standards [10]. Based on Revit secondary development, concrete volumes can be quickly and accurately obtained, with the prefabrication rate calculated as the volume of prefabricated components above ground level divided by the total concrete volume.

According to the prefabrication rate calculation rules, two main parameters must be obtained: prefabricated concrete volume and cast-in-place concrete volume. Prefabricated concrete volume is obtained by filtering 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 precast composite slabs, the typical thickness is 60mm with a 70mm cast-in-place topping, making the cast-in-place volume equal to the precast composite slab volume multiplied by a factor of 13/6.

Prefabricated components include prefabricated exterior walls, interior walls, floor slabs, balcony slabs, and air conditioning slabs, all created using the generic model family template. The process for obtaining these prefabricated component volumes is as follows:

1) Create a collector to access all objects in the project. The collector is instantiated by declaring the FilteredElementCollector class. The OfClass() shortcut function quickly filters family categories in the project. Prefabricated components are filtered by name attributes. All prefabricated components are prefabricated elements and FamilyInstance objects that can be filtered through built-in parameters. In Revit, system families cannot be created as custom families; therefore, prefabricated walls, floor slabs, openings, etc., in this project are created using new generic models, which also belong to FamilyInstance and can be accessed by filtering their built-in parameters. Creating prefabricated components must follow certain naming conventions to enable filtering rules to access corresponding component parameters. Based on Example 4 in the National Building Standard Design Atlas 15J939-1, a set of prefabricated component naming conventions has been summarized, as shown in .

3.2 Parameter Acquisition

To view the prefabricated volume and prefabrication rate of various component types, prefabricated concrete volumes should be obtained separately by component type. In the Revit API, there are two ways 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, they are all instances of FamilyInstance and can be filtered through built-in parameters.

After obtaining component volumes, names and quantities are accessed by calling properties. Finally, this data information is set as the data source for the dataGridView control and displayed in a list.

3.3 Interface Interaction

A form is created to display component names, volumes, and other information. As previously mentioned, the Execute() function has three parameter overloads. To create a form and execute Revit commands, these three parameters must first be passed. In the Execute() function, the form is declared and instantiated, and form display is configured. Then, a constructor is generated in Form1. The form design utilizes various controls including Button, Label, and CheckBox, with code written in each control' s event to implement software functionality. The software interface is shown in [Figure 5: 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 from 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 6: see original paper]. Running the Revit software and loading the plugin DLL file through AddInManager 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 prefabricated volume and prefabrication rate for that component type are automatically calculated, with the prefabricated volume and prefabrication rate of checked components dynamically displayed below.

The Example 4 project has 21 above-ground floors, with floors five and above using prefabricated concrete shear wall structure and floors below five using cast-in-place concrete shear wall structure. To verify the plugin' s reliability, a standard floor BIM model was established. The prefabrication rate calculated by this plugin for the Example 4 standard floor was compared with the result from the standard atlas to verify calculation accuracy. When exterior walls, interior walls, floor slabs, and stairs in the standard floor all adopt prefabrication, the plugin calculates a standard floor prefabrication rate of 60.84%, as shown in [Figure 7: see original paper]. The standard atlas gives a standard floor prefabrication rate of 60.81% for this project, representing a difference of 1%, which is within an acceptable error range. In the export tab, prefabricated component information from the project can be exported to Excel.

5. Summary and Outlook

Revit is one of the primary BIM application software platforms, but current application levels mostly remain at the modeling stage. Developing required functions through Revit' s API helps explore deeper applications of BIM technology. This research uses Example 4 from the National Building Standard Design Atlas 15J939-1 to establish component BIM models, which are then assembled into the project standard floor BIM model. Combined with secondary development technology for the BIM software Revit, a prefabricated building prefabrication rate analysis software is developed to achieve rapid quantification of various prefabricated component volumes in projects, calculate prefabrication rates, improve work efficiency, dynamically display prefabrication rates corresponding to different components, and thereby provide decision-making support for determining prefabrication schemes.

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