Postprint: Research on the Calculation Method for Prefabrication Rate of Precast Concrete Buildings Based on Revit API Development

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Abstract

To address the issues of low efficiency and amplified errors in manual calculation of prefabrication rates for prefabricated buildings, this study utilizes Building Information Modeling (BIM) technology. Through secondary development of Revit software, it achieves automatic quantification of precast components and automatic calculation of prefabrication rates for Precast Concrete (PC) buildings based on BIM models, thereby verifying the feasibility of calculating PC building prefabrication rates on the Revit platform. By leveraging the secondary development outcomes presented in this paper, construction costs can be estimated through dynamic selection and combination of component-specific prefabrication rates, 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

Preamble

Research on 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 leverages Building Information Modeling (BIM) technology to achieve automatic quantity takeoff of prefabricated components and automatic calculation of prefabrication rates for Precast Concrete (PC) structures through secondary development of Revit software. The feasibility of calculating PC building prefabrication rates based on the Revit platform is verified. Utilizing the redevelopment outcomes presented herein, construction costs can be estimated through dynamic selection and combination of different component prefabrication rates, enabling the selection of prefabrication schemes within acceptable cost ranges to enhance economic benefits and provide decision-making support for scheme development.

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

1. Prefabrication Rate Calculation Problem Analysis

Prefabricated construction transforms traditional site-based building processes into factory-dominated manufacturing. Compared with conventional construction methods, prefabricated buildings can shorten construction periods, improve building quality, conserve resources, and protect the environment, thereby enabling sustainable development in the construction industry. 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, and vigorously developing prefabricated concrete and steel structures to continuously increase the proportion of prefabricated buildings in new construction.

Building Information Modeling (BIM) establishes building models based on data and information from various project phases, capable of authentically integrating and reflecting relevant project information. With characteristics such as visualization and coordination, BIM platforms can effectively improve efficiency in prefabricated building design, manufacturing, and installation, and can even optimize entire projects using BIM technology to promote prefabricated building development. Currently, the integrated application of prefabricated buildings and BIM technology remains in the exploratory research stage. Applying BIM technology to solve maintenance and management problems in prefabricated concrete construction can effectively reduce rework during construction. The proposed framework theory for BIM-based prefabricated building integrated construction systems, referencing computer integrated manufacturing systems, holds significant meaning for improving prefabricated building informatization and component productivity. Combining 3D laser scanning technology with BIM enables automatic inspection of dimensional quality for prefabricated components. Applying BIM software to establish connection joints for precast beams and columns allows design of code-compliant prefabricated seismic frame models, thereby establishing a PC component structural system library. BIM platforms for collaborative design in prefabricated buildings reduce designers' repetitive work and improve efficiency.

In summary, the problem of automatic quantity takeoff of prefabricated components and automatic calculation of prefabrication rates using BIM technology requires further research. As prefabrication rate is a crucial indicator for measuring prefabricated buildings, investigating automatic component quantity extraction and prefabrication rate calculation is essential.

Prefabrication rate is one of the key metrics for evaluating prefabricated buildings and serves as the primary basis for government policy support. Simultaneously, prefabrication rate directly affects project costs. Through quantitative analysis of costs for projects with different prefabrication rates, the economically viable prefabrication rate for prefabricated buildings falls between 46%-65%. Therefore, prefabrication rate is the first indicator that must be considered in prefabricated building implementation.

However, several problems exist in prefabrication rate calculation. Traditional calculation methods manually compute precast component concrete quantities based on drawing dimensions, featuring complex processes, low efficiency, and inaccurate results. The emergence of BIM technology provides powerful technical support for automatic calculation of prefabrication rates in prefabricated buildings. However, merely establishing BIM models for prefabricated buildings and utilizing the native functions of modeling software makes it difficult to achieve automatic quantity takeoff and automatic prefabrication rate calculation. As one of the mainstream BIM modeling software platforms, Revit contains a function-rich API (Application Programming Interface). Through secondary development of Revit, users can expand functionality according to needs to meet various design and construction requirements. Therefore, this research focuses on utilizing Revit' s secondary development capabilities to solve automatic quantity takeoff of prefabricated components and automatic calculation of prefabrication rates for PC buildings based on BIM models.

This paper establishes a prefabricated building BIM model using Revit modeling software. Based on Revit secondary development, it investigates the use of model information to quantify various prefabricated components, thereby establishing calculation rules to compute component-specific prefabrication rates. This solves the problems of complex manual calculation, low efficiency, and inaccurate results, achieving 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, increasing economic benefits.

2. Development Approach and Steps

2.1 Development Tools and Procedures

Revit software provides excellent functional support for modeling work, enabling rapid and efficient creation of 3D models containing rich data information, including geometric dimensions, elevations, materials, types, etc. Autodesk provides API interfaces for Revit software, allowing direct access to this information through API programming. Therefore, the development approach and objective of this paper is to investigate the use of BIM models to establish filtering rules for quantifying various prefabricated components in the model, obtaining quantities of cast-in-place concrete components, and thereby establishing 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 help documentation and source code examples, while Revit Lookup is used to visually inspect API elements within model components. 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 must be implemented in external commands for user extension of Revit. This interface contains only one abstract function, Execute(), which is overloaded to implement external commands. The IExternalApplication interface has two abstract functions, OnStartup and OnShutdown, which customize required functions when Revit starts and closes. Both modes must first reference two interface assembly files, RevitAPI.DLL and RevitAPIUI.DLL, before development. This paper adopts the external command approach, writing programs to generate DLL files that are loaded and run through the AddIn Manager.

3. Implementation Methods

3.1 Parameter Design

The calculation rules adopted in this paper follow national standard methods, achieving rapid and accurate acquisition of concrete volumes through Revit secondary development. Prefabrication rate is calculated as the volume of prefabricated components above outdoor ground level divided by total concrete volume.

According to prefabrication rate calculation rules, two primary 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 prefabricated composite floor slabs, the thickness is typically 60mm with a 70mm cast-in-place topping, making the cast-in-place volume equal to the prefabricated composite slab volume multiplied by a factor of 13/6.

Prefabricated components include prefabricated exterior walls, interior walls, floor slabs, balcony slabs, air conditioning slabs, etc., all created using the generic model family template. The process for obtaining volumes of these prefabricated components 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 is called to quickly filter family categories in the project. All prefabricated components are filtered by name attribute and stored in corresponding collections. Specific code is shown in [Figure 2: see original paper].

2) **Categorize components by name**: Prefabricated exterior wall names contain "WQ" , interior walls contain "NQ" , and floor slabs contain "DB" . Different component types are placed in separate collections through name-based judgment. As shown in [Figure 3: see original paper], the filtering method for prefabricated exterior walls first obtains wall family types in the project, then filters all instances under that type using LIMQ statements and stores them in the corresponding collection.

3) **Obtain prefabricated component volumes** by retrieving built-in parameters of instances. Note that Revit' s backend operations use feet as the unit, so volume parameter values must be multiplied by 304.83 to convert to cubic meters. Code is shown in [Figure 4: see original paper].

4) After obtaining component volumes, retrieve each component' s name, quantity, etc., by calling properties. Finally, this data information is set as the data source for the dataGridView control and displayed in a list.

(2) Cast-in-place concrete component volume acquisition

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 at joints. Walls, floor slabs, and joint cast-in-place volumes are obtained through processes similar to those described above. Cast-in-place volumes for prefabricated composite slabs and beams are obtained by multiplying prefabricated composite slab volume and prefabricated interior wall volume by corresponding coefficients.

(3) Calculate component-specific prefabrication rates

The prefabrication rate for each component type equals that type' s prefabricated volume divided by the sum of prefabricated and cast-in-place component volumes. The total prefabrication rate equals the sum of prefabrication rates for selected prefabricated components.

3.2 Parameter Acquisition

To view prefabricated volumes and prefabrication rates for various component types, prefabricated concrete volumes should be obtained 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 columns, beams, and other components without dedicated classes, they are all instances of FamilyInstance and 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 through new generic models, which also belong to FamilyInstance and are accessed by filtering their built-in parameters.

Creating prefabricated components must follow certain naming rules 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 rules is summarized in .

3.3 User Interface Interaction

A form is created to display component names, volumes, and other information. As mentioned earlier, the Execute() function has three overloaded parameters. 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 set. 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 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, shown in [Figure 6: see original paper]. Running Revit software, the plugin' s DLL file is loaded through the AddIn Manager in external tools to run the prefabrication rate calculation software. As shown in [Figure 6: see original paper], clicking different tabs can display quantity lists for various prefabricated component types separately. On the right side, prefabrication rates can be calculated dynamically. By checking different components, the software automatically calculates the prefabricated volume and prefabrication rate for that component type, with the prefabricated volume and rate for checked components displayed dynamically below.

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. To verify the plugin' s reliability, a standard floor BIM model was established. The standard floor prefabrication rate calculated by this plugin 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%, shown in [Figure 7: see original paper]. The standard atlas gives a standard floor prefabrication rate of 60.81% for this project, a difference of 1%, which is within acceptable error range. In the export tab, prefabricated component information from the project can be exported to Excel.

5. Conclusion and Outlook

Revit is one of the primary BIM application software platforms, but current application levels mostly remain at modeling. Developing required functions through Revit' s API helps explore deeper applications of BIM technology. This paper uses Example 4 from the National Building Standard Design Atlas 15J939-1 to establish component BIM models, then assembles 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 statistical analysis 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 basis for determining prefabrication schemes.

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