Research and Application of a Revit-Based Parametric Rebar Modeling Method for Prefabricated Building Components

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Abstract

Three-dimensional rebar modeling in the Revit environment represents a significant challenge for designers undertaking detailed design of prefabricated building components. This paper analyzes the rebar arrangement patterns of prefabricated building components, investigates a parametric rebar modeling method, and develops an auxiliary design software based on this method and Revit secondary development technology. Engineering applications verify that this method can effectively reduce the workload of manual 3D rebar modeling, thereby saving time and cost. The method presented in this paper can serve as a reference for rapid 3D rebar modeling in prefabricated building design.

Full Text

Research and Application of a Revit-Based Parametric Rebar Modeling Method for Prefabricated Building Components

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Abstract Rebar modeling in a three-dimensional environment in Revit is a major difficulty that troubles designers in the detailed design of prefabricated building components. This paper analyzes the rules governing rebar layout in prefabricated building components, studies a parametric rebar modeling method for prefabricated building components, and, based on this method and Revit secondary-development technology, develops a set of auxiliary design software. Engineering application verifies that this method can effectively reduce the workload of manually drawing three-dimensional rebar models, thereby saving time and cost. The method presented in this paper can serve as a reference for rapid three-dimensional rebar modeling in prefabricated building design.

Keywords Revit; prefabricated construction; parametric rebar modeling; software development

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1 Introduction

Prefabricated construction refers to buildings assembled on the construction site from components and parts by means of reliable connections. It has such characteristics as standardized design, factory-based production, assembly-based construction, integrated decoration, and information-based management. Developing prefabricated construction is an important embodiment of firmly establishing and implementing the five development concepts of innovation, coordination, green development, openness, and sharing; promoting innovation in construction methods in accordance with the requirements of applicability, economy, safety, greenness, and aesthetics; and is an important means of stabilizing growth, promoting reform, and adjusting structure.

The *Guiding Opinions of the General Office of the State Council on Vigorously Developing Prefabricated Buildings* (State Council General Office [2016] No. 71) clearly requires vigorous development of prefabricated buildings, promotion of innovation in construction methods, and promotion of the transformation and upgrading of the construction industry. It also explicitly points out the need to innovate the design of prefabricated buildings, improve the collaborative design capabilities of all disciplines in the construction field, strengthen guidance and services throughout the entire process of prefabricated building construction, and encourage design organizations to cooperate with research institutes, universities, and other institutions in developing prefabricated building design technologies and general-purpose design software.

By studying the rules of rebar layout in prefabricated building components and combining them with Revit secondary-development technology, this paper develops general software applicable to the design of prefabricated building components. It assists designers in solving the problem of rebar modeling for precast components and provides a new technical approach for detailed rebar design of prefabricated precast components.

2 Detailed Rebar Design for Prefabricated Building Components

For prefabricated building components, if design omissions occur in a component—for example, rebar collisions—not only will on-site installation be impossible, but the production, transportation, and installation of the entire batch of precast components will also be affected, directly influencing construction progress and cost.

For rebar collisions, the traditional practice is to check them through a combination of two-dimensional plans and sections. This method is not only prone to omissions, but also inefficient. Through the three-dimensional visualization technology of BIM, it is possible not only to check from a three-dimensional perspective whether the design is reasonable, but also to quickly generate rebar drawings, formwork drawings, and other drawings for prefabricated building components, while ensuring consistency between the drawings and the model, thereby guaranteeing the production and installation of prefabricated building components.

However, in the detailed rebar design of prefabricated precast components, rebar modeling is a major difficulty that troubles designers in carrying out detailed design of prefabricated building components. The main reasons are as follows:

(1) **Software operation is difficult**

Rebar modeling in Revit is based on planes, which are divided into the "current work plane," "near cover reference," and "far cover reference" ; the placement direction is divided into "parallel to work plane," "parallel to cover," and "perpendicular to [[unclear: continuation beyond page]]"

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"upward to the protective layer" in three forms. Before drawing reinforcement, the protective layer for different parts must be set properly. During drawing it is necessary to switch among different planes and sections; this is not only difficult to master, but also results in low work efficiency.

(2) The forms of reinforcement are complex

Among the reinforcement forms commonly used in prefabricated building components, the relatively complex ones include stirrups, waist bars, hanger bars, etc. In the drawing process for this type of reinforcement, not only must the drawing plane be considered, but factors such as editing the outline of the sketch must also be considered, further increasing the difficulty of reinforcement drawing.

(3) Heavy workload

Prefabricated building components contain a large quantity of reinforcement. Manual drawing involves a heavy workload and low efficiency.

(4) Lack of software functions

In Revit, there are no common commands for reinforcement alignment, rebar cut-off, rebar connection, displaying reinforcement, or hiding reinforcement. When modifications are required, it is necessary to edit the rebar outline and manually adjust the "view visibility state" of each bar. The lack of software functions not only affects designers' working habits and work efficiency, but also hinders the application and promotion of BIM technology in prefabricated buildings.

3 Analysis of Parametric Reinforcement Modeling for Components

3.1 Reinforcement Rules for Prefabricated Building Components

According to standards and specifications such as *GB/T51231-2016 Technical Standard for Prefabricated Concrete Buildings*, *15G366-1 Truss-Reinforced Concrete Composite Slabs (60 mm Thick Bottom Slab)*, and *15G368-1 Precast Reinforced Concrete Balcony Slabs, Air-Conditioner Slabs, and Parapets*, prefabricated building components are mainly divided into components such as exterior wall panels, interior wall panels, truss-reinforced concrete composite slabs, precast reinforced-concrete stairs, precast reinforced-concrete balcony slabs, precast reinforced-concrete air-conditioner slabs, precast reinforced-concrete parapets, precast concrete composite beams, and precast concrete columns[^1-5].

Among these, the reinforcement arrangement of components such as precast concrete columns, precast concrete composite beams, truss-reinforced concrete composite slabs, precast reinforced-concrete balcony slabs, and precast reinforced-concrete air-conditioner slabs has uniformity, regularity, and repeatability, providing prerequisite conditions for parametric automatic modeling.

1) Uniformity: the reinforcement types contained in the same type of prefabricated building component are uniform. For example, a precast concrete column contains such types as longitudinal bars, corner bars, middle bars on one side of the b edge, middle bars on one side of the h edge, and stirrups.
2) Regularity: the reinforcement of the same type of prefabricated building component is arranged according to specifications. For example, the positions of bottom bars and waist bars in a precast concrete beam, the positions of stirrups, and the requirements for densified and non-densified zones are all arranged according to specifications.
3) Repeatability: the reinforcement arrangement in prefabricated building components of the same type but different specifications is similar. For example, truss-reinforced concrete composite slabs with different specifications have only different dimensions. For new components, the model must be manually and repeatedly adjusted, making the work cumbersome.

After analysis and summary, the reinforcement rules for prefabricated building components and the formulas of the algorithms are shown in Table 1. Due to the limited length of the article, only part of the content is presented. In the table, protect = protective layer thickness; i = loop variable (in algorithms for different types of reinforcement, i is less than the number of different types); dGu = stirrup diameter; dJiao = corner-bar diameter; rJiao = corner-bar radius; rGu = stirrup radius; rDi = bottom-bar (corner) radius; numB = number of middle bars on the b side; numH = number of middle bars on the h side; numD

= number of bottom bars (middle); lengthB = length of the b side; lengthH = length of the h side; width = beam width; hight = beam height; floor = slab thickness; firstShouli = edge distance of load-bearing reinforcement; firstFenbu = edge distance of distribution reinforcement; firstZhijia = edge distance of truss reinforcement; spaceShouli = spacing of load-bearing reinforcement; spaceFenbu = spacing of distribution reinforcement; spaceZhijia = spacing of load-bearing reinforcement; spaceLajin = spacing of load-bearing reinforcement; firstLajin = edge distance of tie bars.

Table 1 Statistical table of reinforcement distribution for prefabricated building components (partial content)

Main component type	Reinforcement arrangement rules and algorithm formulas
Various types of reinforcement usually have the same models, and the center-to-edge distance of reinforcement of the same type is regular	
Precast concrete column –corner bars	Algorithm formula: rebar center-to-edge distance = protect + dG + rJiao
Precast concrete column –b-side middle bars	Algorithm formula: rebar center-to-edge distance = (protect + dG + dJiao) + i * (lengthB − (protect + dG + dJiao) * 2 / (numB + 1))
Precast concrete column –h-side middle bars	Algorithm formula: rebar center-to-edge distance = (protect + dG + dJiao) + i * (lengthH − (protect + dG + dJiao) * 2 / (numH + 1))
Precast concrete column –stirrups	Algorithm formula: rebar center-to-edge distance = protect + rGu
Precast concrete composite beam – bottom bars (corner)	Algorithm formula: rebar center-to-edge distance = protect + dG + rDi
Precast concrete composite beam – bottom bars (middle)	Algorithm formula: rebar center-to-edge distance = (protect + dG + rDi) + i * (width − (protect + dG + rDi) * 2 / (numD + 1))
Precast concrete composite beam – stirrups	Algorithm formula: rebar center-to-edge distance = protect + rGu

Main component type	Reinforcement arrangement rules and algorithm formulas
Precast concrete composite beam – waist bars	Algorithm formula: rebar center-to-top distance = hight – floor – 150
Precast concrete composite beam – tie bars	Algorithm formula: rebar center-to-top distance = firstLajin + i * spaceLajin
Composite slabs, balcony slabs, and air-conditioner slabs –load-bearing reinforcement	Algorithm formula: rebar center-to-edge distance = firstShouli + i * spaceShouli
Composite slabs, balcony slabs, and air-conditioner slabs –distribution reinforcement	Algorithm formula: rebar center-to-edge distance = firstFenbu + i * spaceFenbu
Composite slabs, balcony slabs, and air-conditioner slabs –truss reinforcement	Truss reinforcement includes upper chord bars, lower chord bars, and web bars; algorithm formula: truss position = firstZhijia + i * spaceZhijia

3.2 Software Foundation

Revit is a software product of Autodesk. It can help architectural designers design, construct, and maintain buildings with better quality and higher efficiency, and is one of the most widely used software programs in China' s building-industry BIM system. Revit' s API provides a large number of development interfaces and is highly open; it supports languages such as VB.NET, C#, and C++, allowing developers to independently develop corresponding commands or plug-ins[^6-7].

It can be seen that parametric rebar modeling for prefabricated building components is feasible. Through secondary development technology in Revit, combined with the relevant standards for prefabricated buildings, a parametric rebar modeling plug-in for prefabricated building components can be developed to improve work efficiency.

4 Development of Auxiliary Software

4.1 Brief Introduction to the Functions of the Deepening Auxiliary Software for Prefabricated Building Components

The deepening auxiliary software for prefabricated building components is a collection of tool-set software based on the Autodesk Revit platform. It is applicable to Autodesk Revit 2016. At present, it is divided into three modules: the rebar modeling module, the rebar editing module, and the identification/annotation module. The software interface is simple and intuitive. All

Figure 1 Software interface

Figure 1: Figure 1 Software interface

Figure 2 Parameterized column rebar modeling settings interface and generated result

Figure 2: Figure 2 Parameterized column rebar modeling settings interface and generated result

commands can be assigned shortcut keys separately or added to the quick-access toolbar at the top by right-clicking, so that they can be invoked quickly, as shown in Figure 1.

Figure 1 Software interface

The rebar modeling module mainly implements functions such as beam rebar modeling, column rebar modeling, structural-wall rebar modeling, composite-slab rebar modeling, and balcony-slab rebar modeling. Different operations are performed by clicking the corresponding command icons. For example, clicking "Column Rebar Modeling" opens "Column Rebar Settings." After the parameter settings are completed, clicking "Start Selecting Columns" draws the column rebars, as shown in Figure 2.

The rebar editing module mainly implements functions such as displaying rebars, rebar breaking, rebar alignment, and rebar collision. "Display Rebars" can set the "view visibility status" of rebars with one click. "Rebar Breaking" and "Rebar Alignment" are functions that Revit does not have; they can assist designers in editing and modifying rebars. "Rebar Collision" is intended to facilitate designers in checking collisions in prefabricated components and promptly identifying locations where rebars collide. For example, by clicking "Rebar Breaking" and then clicking at the location where breaking is required (as shown in Figure 3), the rebar can be segmented.

Figure 2 Parameterized column rebar modeling settings interface and generated result

Figure 3 Example of rebar breaking

The identification/annotation module mainly implements functions such as embedded-part identification, contour boundary lines, dimension avoidance, and setting rebar outer diameter. This module is used to assist designers in producing reinforcement drawings and template drawings for prefabricated building components based on Revit, thereby realizing BIM three-dimensional

Figure 3 Example of rebar breaking

Figure 3: Figure 3 Example of rebar breaking

Figure 4

Figure 4: Figure 4

Figure 5

Figure 5: Figure 5

drawing output and ensuring that drawings are consistent with the model. For example, clicking "Contour Boundary Line" opens the "Contour Boundary Line" settings interface (as shown in Figure 4). After the parameter settings are completed, clicking "OK" draws the contour of the insulation material inside the component on the plan view (as shown in Figure 5).

Fig. 4 Interface for setting contour boundary lines

Fig. 5 Contours of the insulation material within the component

4.2 Advantages of Parametric Rebar Modeling for Prefabricated Building Components

The advantages of the parametric modeling method mainly include the following aspects:

(1) Easy operation

For different components, it is only necessary to input the corresponding rebar parameters in the settings window, and the required rebars can then be drawn automatically;

(2) High work efficiency

Taking a composite slab as an example, manually drawing a three-dimensional rebar model requires several hours, whereas using the plug-in can generate the basic model within one minute. Modifications can then be made on this basis, with the total time not exceeding 30 min, thus significantly improving work efficiency;

(3) Strong applicability

By simply adding the corresponding control parameters, the method can be adapted to prefabricated components of different sizes, and it is also applicable to similar components in different projects, with a high reuse rate;

(4) Remedying software defects

It solves the problem that rebar editing in Revit is cumbersome.

Figure 6

Figure 6: Figure 6

Figure 7

Figure 7: Figure 7

5 Engineering Application

A high-rise residential building with a prefabricated shear-wall structure has a building area of approximately 10,200 m^2, 27 above-ground floors, and a total building height of 78.3 m. This paper takes the standard floor as an example (see Fig. 6) and uses the auxiliary software to carry out rebar modeling. On the standard floor, there are 16 types of composite slabs in total, including 2 one-way composite slabs and 14 two-way composite slabs; there are 13 types of composite beams in total, including 10 frame beams, 1 secondary beam, and 1 coupling beam; there are 24 prefabricated exterior wall panel components in total; and the prefabricated shear-wall components are divided into 7 components according to differences in length.

Fig. 6 BIM model of the project standard floor

5.1 Application Effect of Modeling with the Auxiliary Software

Through the in-depth auxiliary software for prefabricated building components, rebar generation and editing are performed. Some BIM models of prefabricated components are shown in Fig. 7. Parametric modeling effectively reduces the modeling workload by more than 60%; among them, composite slabs, composite beams, and shear walls can reduce the modeling workload by 80%, greatly improving work efficiency.

5.2 Rebar Collision Check

For collisions between the rebars of prefabricated components and the cast-in-place portions around them, it is possible to

Fig. 7 BIM models of prefabricated building components

Using Navisworks to perform rebar clash detection can quickly locate clashes; however, importing the model from Revit into Navisworks is relatively cumbersome. This method is not difficult to implement, so it is not described in detail in this paper.

For rebar clashes inside prefabricated components and rebar clashes between adjacent prefabricated components, if the model is repeatedly converted between two software programs, work efficiency will be low. In response, by using the "rebar clash" function in the auxiliary software, rebar clashes can be checked directly in Revit, effectively improving work efficiency. The operation method

Figure 8 Rebar clash settings interface and result display

Figure 8: Figure 8 Rebar clash settings interface and result display

is to click "Rebar Clash," which opens the settings window. When checking rebar clashes between components, select "Ignore clashes within component," and then select the rebars; rebars with clashes will be automatically marked in red (as shown in Figure 8), assisting designers in inspection.

Figure 8 Rebar clash settings interface and result display

6 Conclusion

This paper analyzes the difficulties in modeling reinforcement for components required in the deepened design process of prefabricated building components, discusses the feasibility of parametric rebar modeling for prefabricated building components, and, in combination with secondary development technology, develops a set of deepened auxiliary software for prefabricated building components. The software is characterized by simple operation, high work efficiency, and strong applicability; at the same time, it remedies functional deficiencies in Revit software and improves the effectiveness of Revit in project applications.

Engineering applications show that parametric rebar modeling for prefabricated building components can effectively reduce the workload of manually drawing three-dimensional reinforcement, save time and cost, provide participation and reference for the application of BIM in prefabricated building component projects, and also offer new technical ideas for promoting the development of BIM technology.

References

[1] GB/T 51231-2016 Technical Standard for Precast Concrete Buildings [S].

[2] 15G366-1-2015 Truss Reinforced Concrete Composite Slabs (60 mm Thick Base Slab) [S].

[3] 15G368-1-2015 Precast Reinforced Concrete Balcony Slabs, Air-Conditioner Slabs and Bay Walls [S].

[4] 15G365-1-2015 Precast Concrete Shear-Wall Exterior Wall Panels [S].

[5] 15G365-2-2015 Precast Concrete Shear-Wall Interior Wall Panels [S].

[6] Xu Di. Development of a Revit-Based Auxiliary Modeling System for Building Structures [J]. Civil Engineering and Architecture Information Technology, 2012, 4(3): 71–77.

[7] Tan Jian, Li Feng. Research on Parametric Programming in BIM Automatic Modeling Technology [J]. Architectural Engineering Technology and Design, 2015(33).

Research and Application of Parameterized Rebar Modeling

for Prefabricated Building Component based on Revit

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Abstract: The 3D rebar modeling in Revit has been a difficult problem for the designers in the deepening design of prefabricated building component. This paper presents a parametric rebar modeling method for prefabricated building componentthrough the research on the arrangement ruleof rebar. Based on the rebar modeling method and Revit secondary development technology, a set of design-aided software is developed. It is proven through engineering applications that this method can effectively reduce the work load on rebar modeling, which saves a lot of time and money. This method can be used as a rapid modeling reference of 3D reinforced prefabricated construction design.

Key Words: Revit; Prefabricated Building; ParametricRebar Modeling; Software Development