Research and Accuracy Analysis on Engineering Quantity Calculation of a Projected Building by BIM Software

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Abstract Engineering quantity calculation is the premise and foundation of cost control in architectural engineering. However, the traditional calculation method of engineering quantity way by manual method is inefficient and with low precision. The calculation is faster and more accurate if Building Information Modeling (BIM) technology is applied. In this paper, the development and histories of BIM applications in engineering cost management are introduced. Based on the data of an actual building, a simulation model is established by BIM software. The engineering quantities are calculated, and then, the results of the traditional manual calculation method of engineering quantity and calculation method of BIM are compared and analyzed. The data with a relative error of more than 10% is listed, and the reason for the relative error is conducted. It is concluded that the rules of BIM calculation and manual calculation are different, causing BIM method not accurate enough for some nodes. The suggested method is that BIM method is firstly applied for the total engineering quantity calculation, and then, the manual method is proposed to check the accuracy in some key nodes.

Keywords BIM · Engineering cost · Manual engineering quantity calculation · BIM engineering quantity calculation · Relative error

1 Introduction

BIM technology was originated from the end of the twentieth century and was proposed by Dr. Chuck Eastman in the USA in the computer simulation system of architecture [1]. The General Services Administration launched the national 3D-4D-BIM program in 2003 and successively released a series of BIM guidelines. Early in the 1960s, computers have been used for building cost calculations [2]. The emergence of BIM cost calculation software simplifies the original manual calculation, reduces the repetitive and tedious workload caused by design changes as well as labor

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costs and improves the working efficiency of cost personnel [3]. Since 2002, BIM technology has been widely developed and applied in Europe, USA, Japan, South Korea, Singapore, Hong Kong and Taiwan [4]. In 2009, government of Wisconsin took the lead in applying BIM technology to new large-scale public building projects in the state. Currently, BIM standards have been established in the USA, and BIM technology is being applied in US government projects.

With the development of scientific information technology, BIM spread into China in 2008. In 2010 and 2011, the committee of China commercial real estate association, engineering construction quality management branch of China construction industry association, the engineering management research branch of architectural society of China and China civil engineering society computer application branch organized and issued 'Research Report on BIM Application of Commercial Real Estate in China in 2010' and 'Application Research Report of BIM in China Construction in 2011.' According to these two reports, the perceived degree of BIM has increased by 27% [5]. In 2014, the Ministry of Housing and Urban–Rural Development promoted the popularization of BIM and the practice of BIM technology in engineering in the 12th five-year plan [6]. BIM is developing rapidly in China, especially in the field of engineering cost. Zhang et al. [7] proposed that BIM technology can be used for four-dimensional (including 4D construction progress management, 4D resource dynamic management, 4D construction quality and safety management, 4D construction site management and 4D construction process simulation) to achieve dynamic management of project cost. Ye [8] studied the application of BIM technology in project cost management according to the analysis in definition, principle, development advantages and influence of BIM in each stage of the project. Fu et al. [9] studied BIM-based engineering quantity calculation and established an engineering cost method through practical cases. Tang [10] proposed the method to solve the problems in each stage by using BIM technology based on the existing problems in the current cost management project.

2 Methods

As shown in Fig. 1, the process of civil construction modeling is to draw the axis based on the engineering construction drawings in the modeling software of Revit firstly, and then, the definitions of some construction such as column, beam, board, wall, door and window are established. Furthermore, the model is imported into the civil construction calculation software of Glodon for the following work.

Figure 2 shows the three-dimensional diagram of a civil engineering model. The project is a single residential building with a frame structure and a service life of 50 years. The number of building layers is six floors, of which 0 is underground and 6 is the ceiling. Each layer consists of two units; the height of the first layer is 3.5 m, while the height of the second to the sixth layer is 3.0 m. There is no difference in indoor and outdoor height, and the total height of the building is 17.9 m. The building area is 2469.38 m^2. The independent foundation structure was adopted under the

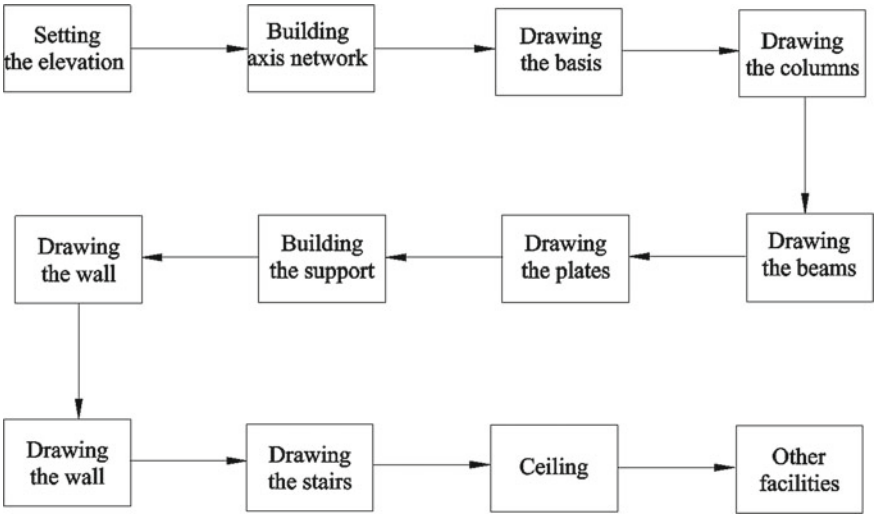

Fig. 1 Modeling process using the modeling software of Revit

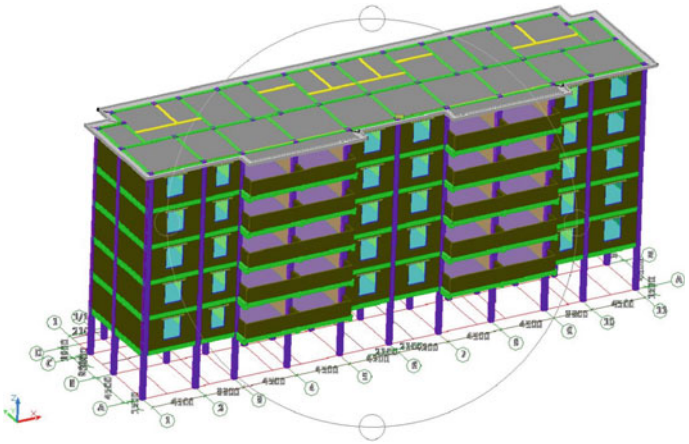

Fig. 2 Three-dimensional drawing of civil engineering model

column, and the wall body is made of clay bricks whose dimension is 240 mm × 115 mm × 53 mm. Similarly, the software of Revit was used for modeling, and then, the steel bar definition and drawings of columns, beams, boards and stairs were imported into the steel bar calculation software of Glodon. The amount of work was calculated according to the relevant list quota. Figure 3 is a three-dimensional diagram of the engineering model and the reinforcement model applied in the calculation.

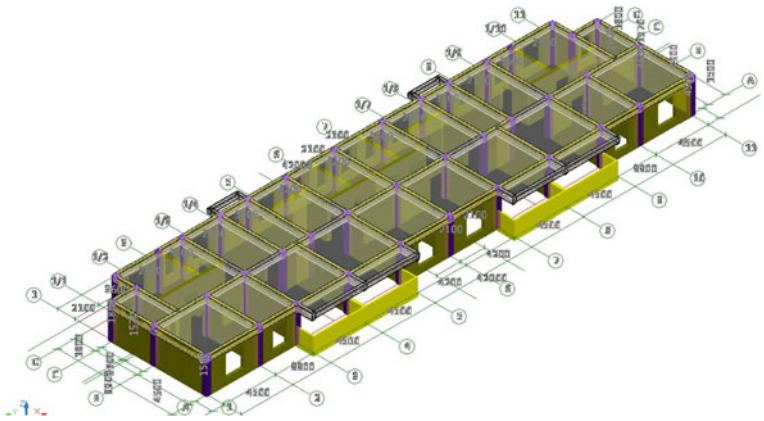

Fig. 3 Three-dimensional drawing of reinforcement in an engineering project

3 Results

3.1 Calculation Process and Results

The calculation of the engineering quantity is obtained by both the calculation software of Glodon and manual calculation (Table 1). As shown in Table 2, compared with manual calculation results, the relative errors are acquired, while the items with the deviation above 10% are listed.

3.2 Discussion

The reasons for the relative errors shown in Table 2 are:

(1) The engineering quantity of list code 010402001001, of which the project name is building block wall, manual calculation should be proposed according to the size of the design drawings in terms of volume, deducting the volume of doors, windows and the reinforced concrete column, beam, lintel and cast-in-place plate embedded in the wall. The outer wall should be calculated according to the central line and the inner wall according to the net length. But during the software calculation process, the length of the inner wall is calculated according to the centerline.

(2) The engineering quantity of list code 010503005001, of which the project name is lintel, manual calculation should be proposed according to the size of the figure, and the beam head and beam mat extending into the wall are merged into the beam volume. When the beam is connected to the column, the beam length is calculated to the side of the column. When the main beam is connected to the

Table 1 Part of engineering quantity list and pricing table

List coding	010515001001	10402001001	10503005001	11204003001	11301001001	11302001001
Project name	Cast-in-place component reinforcement	Building block wall	Lintel	Block wall	Ceiling plastering	Hanging ceiling
Project features and main project contents	1. Type and specification of steel bars: within Φ12/within Φ25	1. Brick variety, specification, strength, grade: clay brick 2. Wall type: exterior wall, interior wall 3. Mortar strength grade, mix ratio: cement lime mortar M5	1. Type of concrete: cast-in-place 2. Concrete strength grade: C30	1. Wall type: brick wall 2. Installation method: first hang and grout	1. Plaster thickness, material type: cement mortar 2. Surface material type, specification, color: colorful paint	1. Ceiling form, fishing rod specifications, height: 500 mm * 500 mm 2. Keel material type, specification, medium distance: T-shaped aluminum alloy keel
Units	T	m^3	m^3	m^2	m^2	m^2
Quantities	68.081	609.81	12.17	1007.4	1781.55	1687.7
Comprehensive unit price (RMB)	5281.76	345.72	568.02	288.59	42.16	88.83
Price (RMB)	359,587.5	212,652.9	6912.8	290,725.6	75,110.15	149,918.4

Table 2 List items with the deviation of 10% or more between calculated in software and calculated in manual

Serial number	Bill of material	Project name	Manual calculation of engineering quantity (m^3)	Software calculation engineering quantity (m^3)	Deviation (%)
1	010402001001	Building block wall	104.2	117.46	12.73
2	010503005001	Lintel	2.73	2.40	−12.09
3	011204003001	Block wall	248.64	201.28	−19.05
4	010301001001	Ceiling plastering	454.86	378.08	−16.88
5	011301001001	Hanging ceiling	308.78	359.38	16.38

secondary beam, the secondary beam is counted to the side of the main beam. But during the software calculation process, when the main beam is connected with the secondary beam, the length of the secondary beam is not counted to the side of the main beam, but the superposition of the main beam and the secondary beam is added.

(3) The engineering quantity of list code 011204003001, of which the project name is block wall, manual calculation should be proposed according to the surface area of the inlay. But during the software calculation process, the length of the inner wall is calculated according to the centerline, not the net length.

(4) The engineering quantity of list code 010301001001, of which the project name is ceiling plastering, manual calculation should be proposed according to the size of the figure to the horizontal projection area, without subtracting the area occupied by the column. The plastering area on both sides of the beam with beam canopy is merged into the ceiling within the area, while the plastering of the bottom of the slab staircase should be calculated according to the inclined area. But during the software calculation process, the length of the ceiling is calculated according to the centerline, not the net length.

(5) The engineering quantity of list code 011301001001, of which the project name is hanging ceiling, manual calculation should be proposed according to the size of the plane projected horizontally. The area, which is occupied by a single hole over 0.3 m^2, an independent column and a curtain box connected to the ceiling, is deducted. But during the software calculation process, only the area occupied by the beam is deducted, and the area occupied by the independent column is not deducted.

The BIM cost software calculation follows the principle of 'fine-grained rough calculation.' For instance, it is processed that the hole with a small area is not deducted, and the plastering beam on the side of the door and window opening is not added in the software. These factors cannot be simplified in manual calculation projects.

However, if BIM is adapted to the above-existing rules, the computational efficiency of BIM will be influenced, which is the major advantage of BIM. The solution to the problem is to try to improve the existing rules so that the rules can be flexibly adapted to different requirements.

4 Conclusions

In this paper, the development trend of BIM is reviewed. And then based on the specific engineering case, the calculation of engineering cost is carried out using the steel bar calculation software of Glodon, the civil construction calculation software of Glodon. The results are compared with the manual calculation results. The reasons are analyzed and the following conclusions are obtained:

- The process of calculating the cost using BIM software is as follows: (1) establishing BIM model; (2) applying relevant list quota; (3) combining calculation to obtain engineering quantity; and (4) obtaining reference cost.
- Compared with the traditional manual calculation, the use of BIM greatly improves the calculation speed of engineering quantity, effectively shortens the construction period and the burden of the cost personnel is reduced.
- It can be seen from the calculation and comparison results that although the software calculation has become a trend of engineering cost, there are still some errors in the processing of certain detailed parts. The method of reducing these errors is to use the software to calculate the engineering quantity first, and the results of key nodes are modified by some manual calculation, respectively.

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