Development and Application of Engineering Quantity Calculation Module for Foundation Pit Based on BIM

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Abstract

Based on the Revit of BIM software, this paper carries out secondary development. At first, it builds the family library of all components of foundation pit engineering in Revit, so as to ensure the effectively establishment of the foundation pit model. Secondly, the engineering quantity calculation module for foundation pit design is developed in Revit, which can automatically extract the effective information in the foundation pit model for engineering calculation, and then automatically generate the bill of quantities. In the end, this paper takes the deep foundation pit of ZHONGQING Square project in Changsha city of Hunan province as an example to verify the effectiveness of the function module. The function module developed by our team will be used as part of the BIM-based construction management platform, and lay the foundation for the integrated management of survey, design and construction of foundation pit based on BIM.

Keywords: BIM, foundation pit engineering, engineering quantity calculation, module development.

1. INTRODUCTION

With the acceleration of urban construction, and gradually develop to the underground space, the number and depth of deep foundation pit are increasing. As you Known, design, construction and safety monitoring are three main contents of foundation pit engineering. Traditional two-dimensional foundation pit design already can’t meet the safety and quality requirements of foundation pit engineering. Each traditional design drawings of the foundation pit are independent, and there is no central database which can integrate all drawing information (Solihin and Eastman, 2015). Regarding to these drawings only technical personnel can understand, thus it lacks of project information integration and coordination degree; The floor plans drawing, elevation drawing, sectional drawing according to the traditional design methods often appear inconsistent information, furthermore they can’t clearly express the spatial structure relationship between the support structure, the surrounding buildings, underground pipes between the of relations the surrounding buildings, underground (Song et al., 2012). Thus, under the premise of ensuring the construction period, safety, quality, building, to complete the construction with high efficiency, high quality and low cost is a serious problem.

The emergence of BIM (Building Information Modeling) technology provides a good opportunity to solving the foundation problems. In the whole life cycle of building engineering, BIM can achieve integrated management. In this way, BIM includes both the information model of the building, as well as construction management behavior model (Singh et al., 2015). By perfect combining the information model of the building with the management behavior model of the construction project, then the building information model can be used to simulate the actual building construction behavior. The emergence of BIM has changed the pattern of cooperation and payment in which all parties involved in the project (owners, architects, engineers, construction contractors, post-property management operations, etc.), at the same time, it is able to increase the productivity.

The BIM technology is introduced into the design, construction and monitoring process of the deep foundation pit, especially the deep foundation pit. By creating the BIM information model of the foundation pit, the traditional barrier between the design, construction and monitoring of the foundation pit is broken (Lee et al., 2011). So as to achieve multi-barrier-free information sharing, so that different teams can work together, through the three-dimensional visual communication to strengthen intuitive control of management team on the cost, schedule and quality, improve work efficiency, reduce error rate, reduce on-site rework, save the investment and bring users with add value (Heikkila, 2013).

2. THE ADVANTAGES OF BIM TECHNOLOGY
(1) The use of multi-dimensional information model instead of two-dimensional drawing

The design of the foundation pit based on BIM is to transform the 2D design to the 3D dynamic visualization design by creating a three-dimensional foundation pit model (BIM model) which including all kinds of information, and then automatically generates various graphics and documents according to the 3D model, meanwhile logically related with the model from the beginning to the end, when the model changes, the associated graphics and documents will be automatically updated (Huang, 2007); There is a built-in logical association among the objects created by BIM model, when an object changes, the associated objects will change as well. Thereby it will achieve information sharing between different professional designs. Each professional system can obtains the required design parameters and related information from the information model, and does not need to repeat input data, to avoid data redundancy, ambiguity and errors.

(2) To achieve collaborative design between the various professional and information sharing of relevant parties

The design process based on BIM is the process of building the central information database of the project, including the information of all entities and functional characteristics of the foundation pit and the surrounding environment. When a professional design object is modified, the other professional design of the object will be updated. All the entities and functions of the project are stored in this database, which facilitates the exchange of information among project team members, making it possible to improve project integration and collaboration (Park et al., 2014). BIM uses three-dimensional dynamic visual design, transform the past two-dimensional line-type components into three-dimensional physical graphics. The components and units among the professions can be expressed by three-dimensional effect picture. The design can be optimized so as to make better use of the building space and effectively avoid the conflict of pipe and line between the professions, as well as improve the professional cooperation and coordination, reduce the phenomenon of wrong, missing, imperfect in the various drawings (Lin et al., 2016).

(3) To achieve intelligent design

Revit software provides developers with a powerful API interface, which can realize secondary development on Revit platform through API interface (Choi et al., 2011). It can provide intelligent auxiliary function for survey, design, construction and safety monitoring of foundation pit, built an intelligent data management platform, at the same time, by cooperating with Revit powerful modeling, rendering, animation technology, can easily provide effect picture and animation of the various stages of the foundation pit project, which is convenient for inspection of the parties and accordingly modifying.

3. DEVELOPMENT OF ENGINEERING QUANTITY CALCULATION MODULE FOR FOUNDATION PIT

Revit provides an API interface for developers to access model data and model parameter data, create revision model elements and plug-ins, so as to achieve automatically processing of repetitive task, develop third-party software for data integration and analysis and other functions. At the same time, Revit provides developers with Revit SDK, which contains the common functions and libraries developed by Revit, as shown in Figure 1, in this way, it provides developers with convenient conditions.

![Figure 1. Revit API Interface](image-url)
3.1 Module design flow

The general steps to get a fully functional module by secondary development of Revit are roughly divided into seven steps: 1. Create a new project. 2. Add the necessary references. 3. Write the source code. 4. Debugging. 5. Plug-in registration. 6. Ribbon panel code written. 7. Ribbon panel registration. As shown in Figure 2.

![Diagram of module design flow]

Figure 2. General steps for Revit secondary development

3.2 Functional analysis of the module

(1) IFC file analysis and data extraction function

Firstly, the IFC files obtained in the BIM model are analyzed, so that important information related to the engineering can be transformed into recognizable language information. Secondly, the work of extracting the structure-related data from the files is finished, finally the results are used as the model input information.

(2) Friendly user interface

The software mainly communicates with the user through the human-computer interaction interface. The user inputs the information to the internal optimization model through the human-computer interaction interface, and answers the questions raised by the optimization model. The model outputs the optimization result for the user and presents it in a user-understandable way (Chen et al., 2015). The user-friendly interface can help users to obtain effective knowledge accurately and understand the information analysis mechanism more easily, so as to improve the accuracy of information submission and the accuracy of the final optimization results.

(3) Knowledge base which meet the optimization model

The knowledge base is used to store the knowledge needed for the template optimization design, such as the BIM model data extraction according to the requirement, the related standard of the engineering quantity calculation of foundation pit.

(4) The automatic generation of quantity bill

Picture processing is critical step in IFOD system. Support system optimization design results which according to the optimization model output and board layout optimization results all will be in the form of data, transform
into graphical form through the graphics automatically generated module, then intelligent display in the graphics window, so as to achieving lower construction costs, while reducing designer workload, improving the efficiency of the design work.

![Diagram of modular structure]

**Figure 3.** Hierarchical graph of modular structure

### 3.3 Data expression of module

In intelligent system, generally speaking intelligent module is set as a custom format file. The maintenance staff of the module can only maintain the system by design module editing system. Intelligent template editing system has the function of assisting the designer to complete the task of input information to the system, it is not only the bridge between engineers and system design, but also it can realize intelligent detection of language errors, to help the effective exchange of information, thereby it is necessary to write a special code read-in memory to call intelligent module.

Such as: Class Quantity Calculation

Knowledge representation 1

Knowledge representation 2

...

Knowledge representation n

}

This intelligent module has the characteristic of easy maintenance, which is convenient to expansion of the design module, but it also has the disadvantage that requires to writing a dedicated knowledge base editing system.

The foundation pit engineering quantity calculation module designed in this paper is applied to intelligent design for specific products, the knowledge of the module has already be determined in the function development. Therefore, it is not required to maintain the module after it has been developed. For this functional module, it can be regarded as an organic part of a system, that is to say knowledge is stored in a function, when the system is running, the function will write knowledge into a specialized knowledge database one by one.

### 4. APPLICATION CASE
4.1. Project overview

The proposed site is located at POZI Street in Changsha City Hunan Province, between People's West Road and LIANGDAO Street, there is a multi-storey commercial building on the east side, multi-storey residential building on the west side, ID•Mall commercial plaza and residential building on the north side, people's west road on the south side. The project covers an area of about 4600 square meters, a total construction area of about 10,000 square meters, the basement layer is 3 layers, the underground layer is with height of 4.80m, the second-floor underground is 3.50m high, the third floor underground is 5.00m high. The design floor elevation is 40.50~43.20m, the elevation of foundation pit is 28.00m, the depth of foundation pit is 12.5~15.2m, and the circumference of foundation pit is about 315.0m. The safety grade of the foundation pit is grade 1. The proposed building profile is shown in Figure 4 and Table 1.

![Figure 4. Site schematic](image)

### Table 1 Project Overview Table

<table>
<thead>
<tr>
<th>Building name</th>
<th>Structure type</th>
<th>Number of layers</th>
<th>Design floor elevation</th>
<th>Base depth</th>
<th>Foundation design grade</th>
<th>Foundation type</th>
<th>Building safety class</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZHONGQING square</td>
<td>Shear wall</td>
<td>Third floor underground</td>
<td>42.3</td>
<td>-15.2</td>
<td>Class A</td>
<td>Pile foundation</td>
<td>Class 2</td>
</tr>
</tbody>
</table>

4.2 The establishment of BIM model

The three-dimensional design of the foundation pit is carried out by using Autodesk's BIM modeling software Revit Architecture. At first, the parametric family members of the components of the foundation pit are completed in Revit (as shown in Figure 5), these parametric family members can refer to the size requirements of designers automatically generate the appropriate size of the components, without need of re-construction. After building the family library, the three-dimensional model of foundation pit support structure can be constructed, and the BIM model will be compared with the traditional two-dimensional construction drawing (as shown in Figure 6). By contrast, we can find that the traditional the two-dimensional drawings requires a lot of
drawings in order to express each foundation pit, while it can be clearly expressed in the BIM platform, only through rotate, hide, profile and other operations on the established model, the entire foundation pit design can be expressed clearly. The expression form is simple, clear, intuition.

![Foundation Pit](image1)

![Anchor design](image2)

Figure 6. Comparison of BIM model and traditional two-dimensional construction drawings

4.3 Engineering quantity intelligence computation

The Revit API interface is used to developing the engineering quantity calculation module of foundation pit. The module can automatically extract the valid data in the foundation pit model and automatically calculate the engineering quantity. At the same time, the calculation result is outputted and the whole process is realized intelligently.

6. CONCLUSION

(1) In this paper, the advantages of BIM technology in design, construction and management are expounded, and the development trend of BIM in future construction industry is pointed out. On this basis, the paper summarizes the existing problems of foundation pit, further to proposes the idea that by applying the BIM technology to solving the existing problems. Besides, the paper finds that it is feasible to develop the functional modules related to the foundation pit engineering on the BIM platform from the three aspects of theory, technology and operation method.

(2) The family library (such as: pile, bolt, beams, etc.) of the foundation pit engineering components is established in BIM software Revit, it guarantees the effective construction of foundation pit model. At the same time, combined with the relevant standards of foundation pit engineering, develops foundation pit design engineering quantity calculation module in Revit, the module can automatically extracts effective information data of the model for engineering quantity calculation, and automatically generates the bill of quantities. The
validity of the function module is verified by taking Changsha Zhongqing Square project as an example. The function of calculating the amount of foundation pit on BIM platform is realized.

(3) Based on C# language, the engineering quantity calculation module of foundation pit will be used as part of the information management of BIM-based foundation pit engineering. In the following work, we will continue to develop other function models related with foundation pit on the Revit platform. (Such as stability calculation, structural internal force calculation, deformation calculation, safety analysis and so on). Finally, the auxiliary design of foundation pit and construction of information management platform based on BIM is realized.

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