STUDY ON BIM-BASED STRUCTURAL WORKING DRAWING DESIGN SYSTEM

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ABSTRACT

With the purpose of solving the bottleneck problems in the field of structural design, such as mapping and modification taking up most of the time for structural engineers in current paper-based design pattern. In this paper, BIM model and technology are introduced into the structural working drawing field. After the research of model requirements and description methods, a BIM model for structural design is established and verified by BIM-based structural drawing design prototype system in a test project. The research shows that BIM based structural design can improve the quality and productivity significantly. BIM based structural design needs a series of BIM software to work cooperatively. Now, BIM technology is not mature, there are so many technical and social problems to be solved for BIM based design and management.

Keywords: structural working drawing, BIM, intelligent design, collaborative design

1. INTRODUCTION

Building Information Modeling (BIM) has become a hotspot of research and applications in the field of construction in recent years. More and more enterprises and projects started the application of BIM. The technical advantages and application effect of BIM has been highlighting obviously(Eastman 2011). But because of the lack of the uniform standard for the application and the design software, the utilizations of BIM in the architectural design industry is in a lower and partial application stage and the bottleneck problems remain in the information communication between the relevant software(Howard 2008). Especially, the design process for the structural design is divorced from the BIM stages for being short of the mature BIM application software and the design pattern(Jeong et al. 2009, Eastman et al. 2009). It is an urgent issue to research the BIM-based structural working drawing design method, workflow, technology and to develop BIM application software in structural design.

Taking the reinforced concrete structural working drawing design as the research object, this paper has a comprehensive application of the latest research results of the BIM, standard of information sharing and the artificial intelligence technology. The methods, models and processes on structural design is studied, and an overall solution of BIM-based structural working drawing design is put forward. By introducing the Industry Foundation Classes (IFC) to the structural Working Drawing design domain. Moreover, we realized the dynamic creation of the BIM model by automatic conversion between the architectural design model, the structural

analysis model, the structural working drawing design model, and the construction quantity survey model, and at the same time have solved the a series of key technical problems such as associated mechanisms between design model and its view, rule based model checking, reinforcement optimization based on improved genetic algorithm, incremental model transmission and Conflict Resolution in collaborative design. On the basis of previous achievements, we have exploited the BIM-based Structural Drawing Design prototype System, BIM-SDDS for short. We have verified the feasibility and the validity of the prototype system by applying them to a practical engineering project.

2. RESEARCH BACKGROUND

2.1 Existing structural design processes

At present, structural working drawings are still the mainly deliveries for structural design. The existing structural design processes for reinforced concrete structure is shown in Figure1, the design work flow contains three stages: structural modeling, structural analysis and working drawing design.

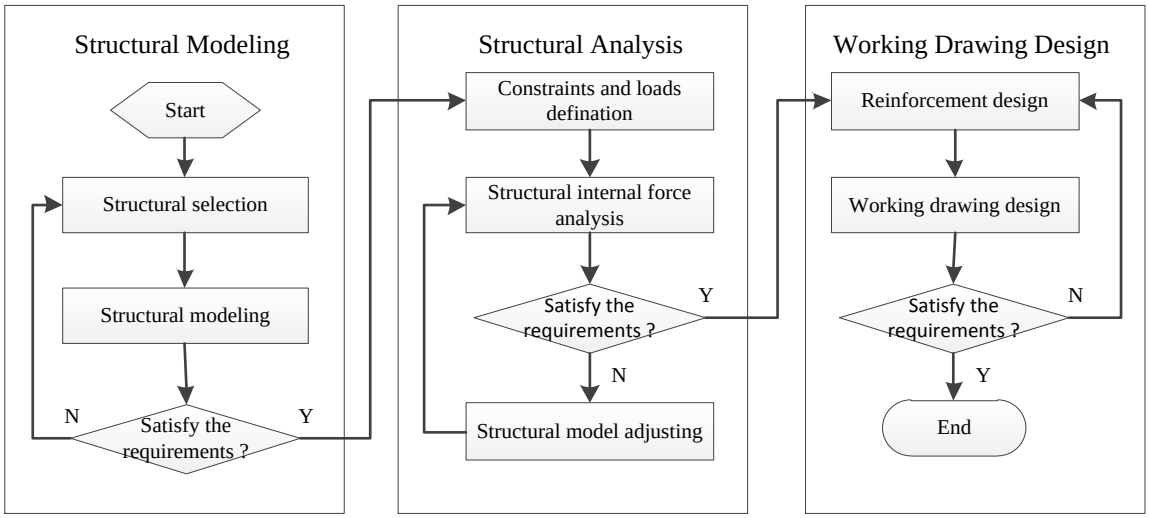

Figure 1: Existing structural working drawing design flow

(a) Structural modeling: firstly obtaining the architectural design working drawing, and then making structural form selection and structural modeling.

(b) Structural analysis: define the loads and constraints, make structural internal force analysis. If the analysis results satisfy the design requirements go to next stage. If not, make structural model adjustment until meets the requirements.

(c) Working drawing design: make reinforcement design and working drawing design, adjust design results until satisfies the structural design codes.

2.2 Overall situation of structural working drawing

In order to find out the problems of existing structural working drawing, we make investigation on senior structural engineers in several large structural design organizations by the form of questionnaire(Yong Wang 2013). By the statistical analysis of questionnaire, we find the main deficiency of the existing structural working drawing as follows:

(a) It is very difficult to reuse the architectural design information in the process of structural design. Structural engineers have to rebuild the structural model according to corresponding architectural working

drawing. This process not only takes up a lot of valuable time, but also makes more inconsistent risks between architectural design and structural design.

(b) The process of structural working drawing takes up more than 70% time in design. Although some software such as TSSD improve the drawing speed, it is impossible to liberate structural engineers thoroughly from mechanical type working drawing.

(c) Design alteration always induce updating of structural working drawing corresponding to the alteration. Because of the lack of appropriate mechanisms to ensure the consistency of drawings, modification process is very prone to leakage or wrong change phenomenon.

(d) Structural engineers usually do their design work stand-alone, it is lack of coordination mechanism among designers.

(e) It is difficult to articulate by two-dimensional drawings for complex structures, because of the lack of appropriate means to express the design.

(f) Structural design results in structural design is submitted by the form of two-dimensional drawings, it is difficult for information reuse in subsequent stages.

2.3 Opportunities and challenges brought by BIM

BIM to the structural design is not just design model change from two-dimension to three-dimension, it will bring a profound change to structural design, such as industry structure, occupational structure, construction model, working patterns etc.

As new methods and techniques, BIM will push forward the informatization process in construction. It will make extensive changes in production mode, the structural design becomes more sophisticated and intelligent. The opportunities BIM bring to structural design as follows:

(a) As design tools, BIM makes structural design easier by means of virtual design, engineering simulation, collision detection etc. Structural engineers will work in more intuitive and convenient.

(b) As information sharing approach, BIM will break the information island and information gap. Through international information exchange standards, the relevant BIM applications can exchange information seamlessly.

(c) The trends of modern buildings are higher, larger and more special-shaped. Traditional engineering methods have been incompetent for the increasingly complex engineering design. BIM-based design can overcome these challenges effectively.

(d) New technology usually lead to new changes in industry structure. BIM provides valuable opportunities for China's engineering design firms in international competition.

Just Like a coin, BIM also has the other face to engineering design firms, mainly includes four aspects:

(a) Enormous impact to traditional engineering design patterns. Practitioners have to learn new modeling technology on BIM accompany the arduous design tasks in simultaneous.

(b) BIM-based engineering application tools are not mature yet, the BIM-based design software such as Revit, ArchiCAD and other mainstream software are mainly covering the field of architectural design, the Domestic construction software vendors need to accelerate the development of related software.

(c) The lack of BIM application and delivery standards. government departments, industry associations , engineering design firms, research institutions and software vendors need to promote the relevant standards development work urgently.

(d) BIM-based engineering design requires a lot of expertise on BIM to support. In addition to engineering firms' existing staff training, colleges and universities need to take the latest leading-edge theory into BIM professional into training system.

2.4 BIM-based structural working drawing design

BIM is one of the most promising developments in the architecture, engineering, and construction (AEC) industries. With BIM technology, structural engineers can overcome the barriers in traditional structural design. In our study, a BIM-based structural working drawing design flow is put forward, as shown in Figure 2.

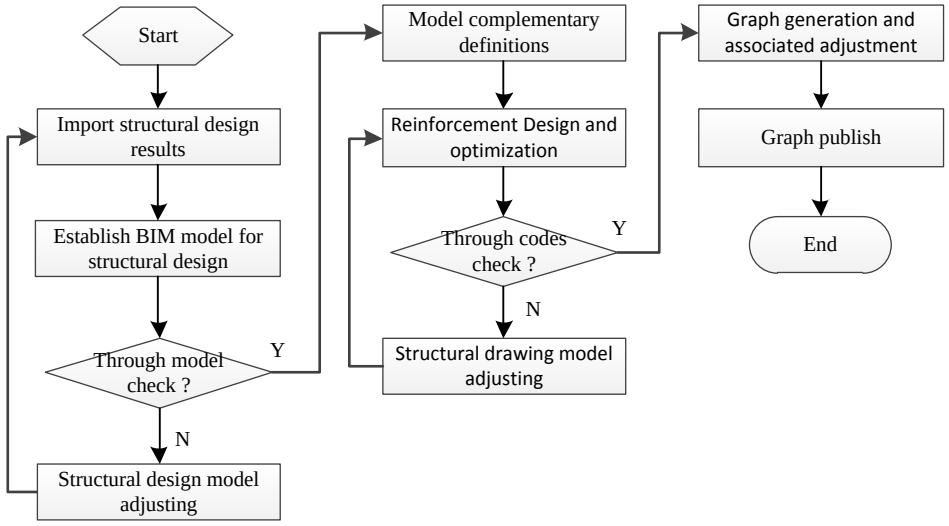

Figure 2: BIM-based structural working drawing design flow

Firstly, the structural design results are imported to drawing design system by the interface of model conversion. The structural design results are related automatically to the basic structural element model. Secondly, some model checking, adjusting and complementary definitions are done. And then, intelligent reinforcement design, optimization and codes check are operated on the structural design model to form a complete structural working drawing design information model. Finally, some intelligent algorithms are applied to make structural working drawing generation, associated adjustment, layout and publish. The whole design process is mainly done by the system automatically, and the design process into a large number of intelligent algorithms, which embody the intelligent BIM software applications, high degree of automation advantages.

3. BIM-BASED STRUCTURAL WORKING DRAWING DESIGN SYSTEM

Based on the structural working drawing design model, we have exploited an BIM-based Structural Drawing Design System, BIM-SDDS for short. It can create dynamically the BIM model; can achieve an extraction, transformation and integration of the BIM models which are based on the IFC and non-IFC standards, the automatic generation and associated modification of the structural working drawing design, BIM model management and collaborative design based on network.

3.1 Demand analysis

Demand analysis is a process for users to find the system requirements solving a problem or reaching a given goal(Ian 2004). The glossary of IEEE standard divides the software engineering requirements into three levels: business requirements, user requirements, functional requirements. Combined with the structural engineers questionnaire survey and interviews, the requirements of BIM-SDDS are summarized as follows :

(a) BIM-based structural drawing design: The traditional drawing design is based on two-dimensional drawings. For BIM-based structural drawing design, we propose a digital model based on a unified BIM database, which can generate the graphs and documents and make relative modifications automatically.

(b) Management of BIM model: BIM model provides a single data source for engineering design. But due to the complexity of the project information, it is extremely difficult for BIM model design. We will make use of IFC standard for BIM model definition and management.

(c) Model transformation among relative systems: The data source of structural design is the results of architectural design. The BIM-SDDS needs to combine the architectural design model and structural analysis

model, forming the structural drawing design model. In addition, this model can convert into quantities model for quantities statistics.

(d) Model checking and codes checking: Through automated model checks, it can ensure the consistency and integrity of model information. And the codes checks can ensure the results meet the relevant design specifications, code requirements. The application of these two techniques can significantly improve design automation, reduce construction design strength.

(e) Automatic graph generation and intelligent modification: By structural drawing templates, smart layout and other technologies, it ensures the graph generation automatically. Through the BIM model and view related technology, it ensures the model data modifications will automatically update drawings associated with the model, to achieve the goal "a modification, everywhere relative modifications", which ensure the consistency of two-dimensional drawings and the model.

(f) Web-based multi-user collaborative design and management: Collaborative design is the trend of construction with the growing size and complexity. Web-based multi-user collaborative design is a new system which has the function of user right management, version control, conflict management, to ensure the consistency of BIM models.

3.2 Logical structure design

According to the workflow and the demand analysis, we design a four-layer logical model for BIM-SDDS, as shown in Figure 3.

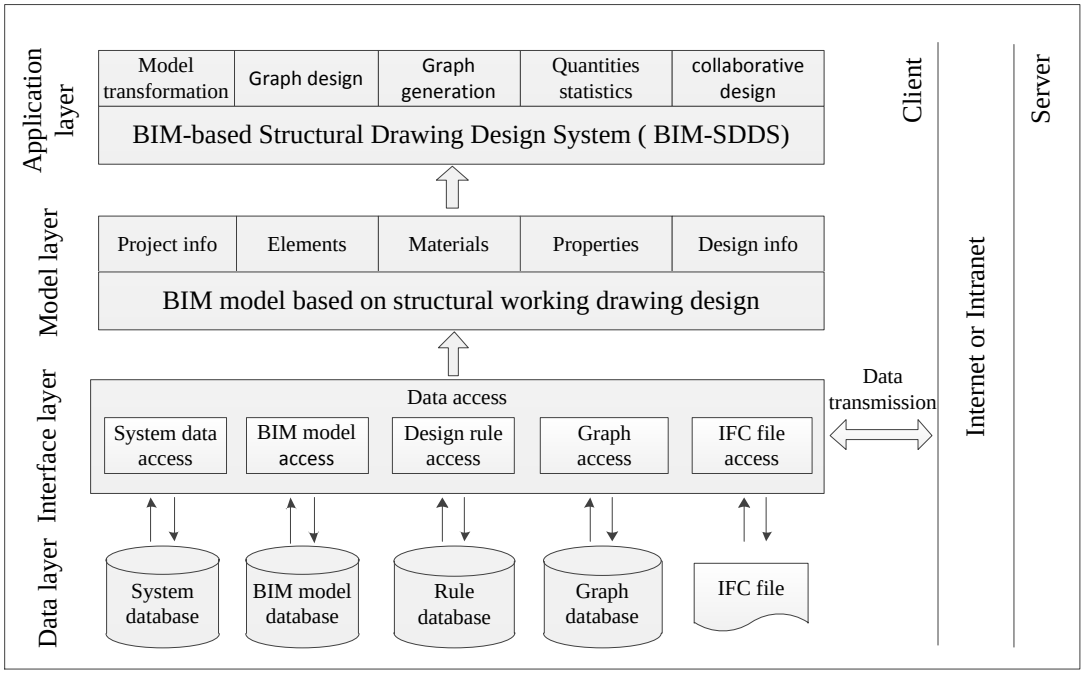

Figure 3: Logical structure of BIM-SDDS

(a) Data layer: It contains a data structure in which the system data are stored. The database storage forms and the documents are organized in this layer, including system database, BIM model database, rule database, Graph database and various documents such as IFC file.

(b) Interface layer: It provides and implements access control to the model layer. The layer serves as the data interactive intermediary between the model layer and the database or the disk file. The interface layer mainly solves the problem of data access by saving the data to the database, reading them, and then implementing the model modification or data statistics.

(c) Model layer: This layer is the kernel of the system. It contains project information, structural elements, materials, properties, and design information. The advantage of this model is the correlative information, which ensures the integrity and consistency of the whole project.

(d) Application layer: It contains a series of algorithms and function modules and the integrated environment. The application of the system includes model transformation, graph design, graph generation, quantities statistics and collaborative design. The will be accomplished by Microsoft C# programming, combining BIM and database technologies based on AutoCAD platform.

3.3 Physic structure design

We adopt smart client-server pattern in BIM-SDDS system, as shown in Figure 4. The system is composited of central BIM server, local BIM server and client. The central BIM server is in charge of project data version management, user rights management and model backup. The local BIM server is responsible for the ongoing project model management, including project data backup, restore, version management and log management. The physic structure of BIM-SDDS is double-server architecture which allows the system has a strong practicality and scalability. The local BIM server is primarily for individual projects management, which ensures operational efficiency in collaborative design. The central BIM server is primarily for multi-project and multi-regional collaborative design, which ensures the expansibility and security of the system.

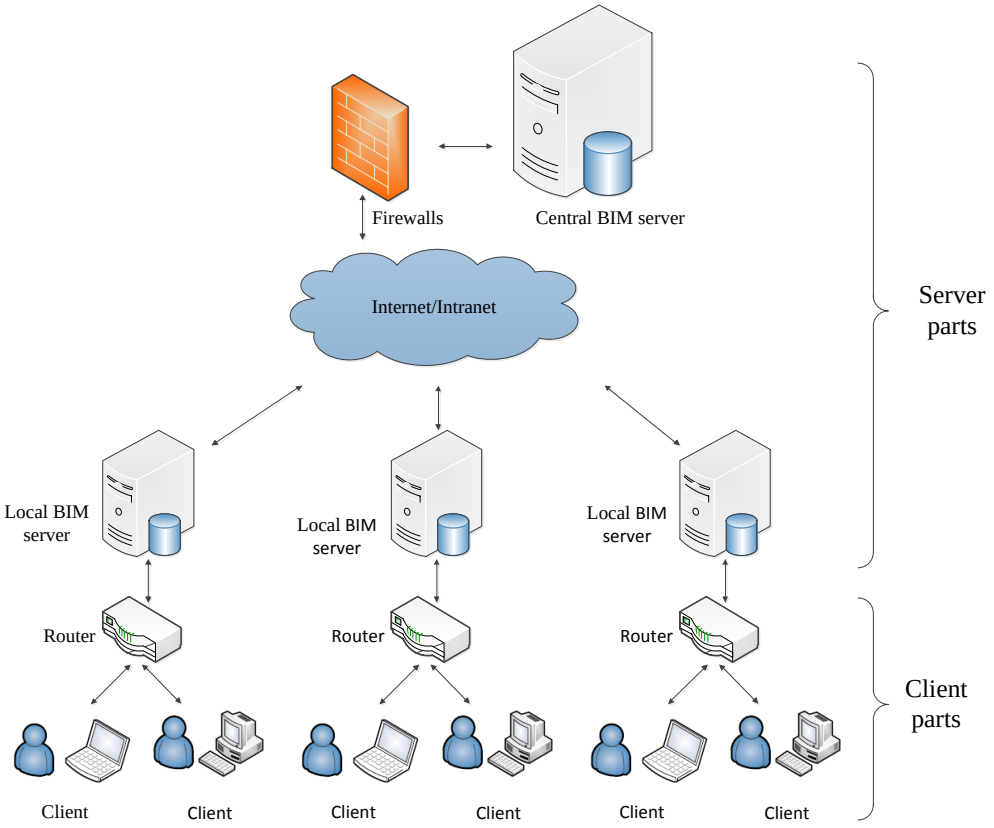

Figure 4: Physic structure of BIM-SDDS

The clients of BIM-SDDS can do their design collaboratively through the router connecting to the local BIM server. XML format documents are adopt for model interaction between server and client. In order to improve the efficiency of the system, it supports model backup from server to local for design work, through the "check in and check out" mechanisms to ensure the consistency of client-server model.

4. CASE STUDY

We have verified the feasibility and the validity of the prototype design system by applying it to a practical engineering project, shown as in Figure 5. Firstly, we create the architectural BIM models in the Revit Architecture 2009. Then through CSI's CSIxRevit plug-in, Etabs imports the Revit model to generate Etabs analysis model, make supplementary definition including loads and constraints, and internal force analysis and reinforcement design (①). Exporting the Revit model to a IFC model file, BIM-SDDS imports the Revit model, forming the structural elements model (②). Exporting the Etabs model an Access data file, BIM-SDDS imports this file, obtaining the information of materials and reinforcement results (③), associated with the elements information model to form a complete structural drawing design BIM models. Finally, the BIM-SDDS can realize three-dimensional model checking (④), intelligent structural drawing design and graph generation based on the "flat overall representation" rules (⑤), concrete and steel structural members quantities statistics (⑥) and other engineering applications.

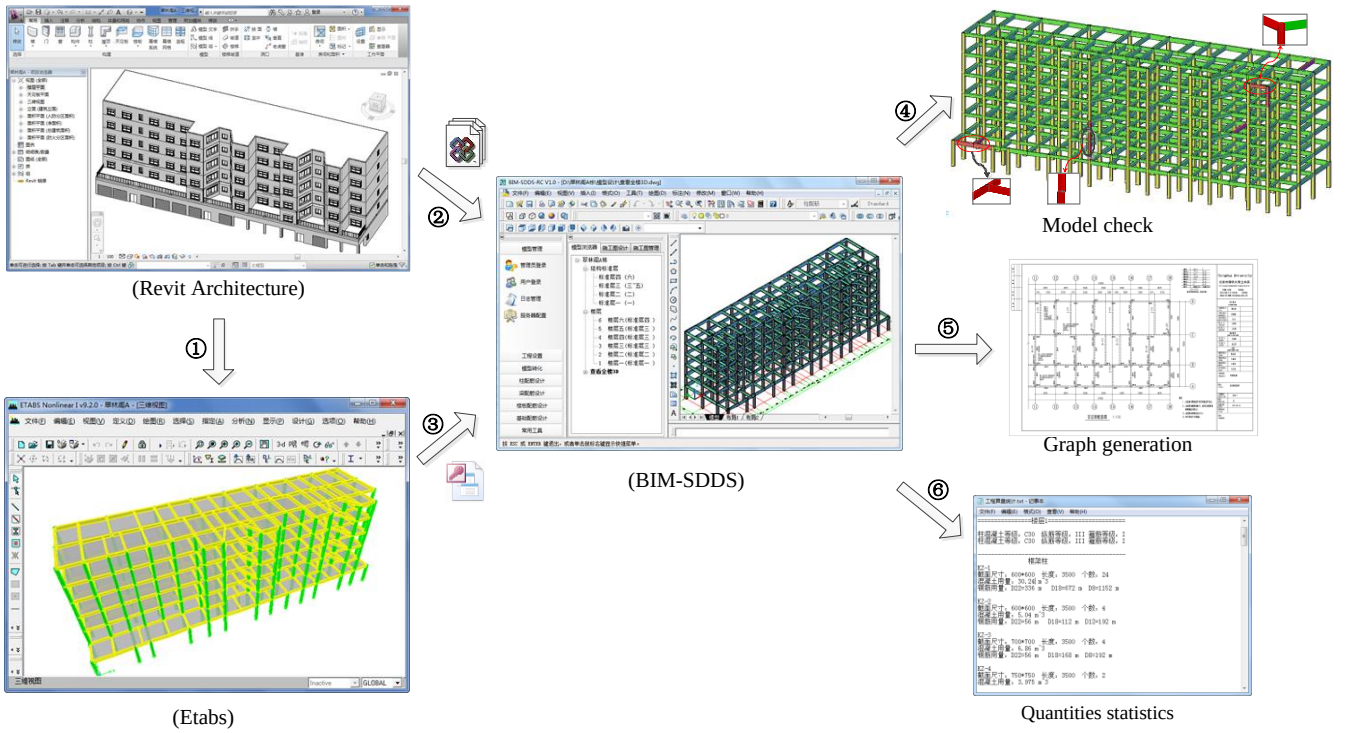

Figure 5: A test of BIM-SDDS platform

5. CONCLUSIONS AND FUTURE WORK

This paper has presented the study on methods, processes and model description of BIM-based structural drawing design system. On this basis, a structural drawing design BIM model is established, and an BIM-based structural design prototype system for reinforced concrete frame is developed. The main conclusions are as follows:

(a) The existing structural design processes and methods have been unable to meet the increasingly complex needs of engineering design, BIM-base structural design can break through the design bottlenecks of quality and efficiency.

(b) The BIM model architecture based on IFC standards can meet the structural BIM data description in demand, but we have to make some Simplification on the IFC model relationships in order to improve operation efficiency.

(c) BIM-based structural drawing design needs combining closely with domestic design specifications and drawing rules. The prototype design system only achieve reinforced concrete frame design, for more complex structures, it requires further study.

ACKNOWLEDGMENTS

We would like to express our gratitude to the National Natural Science Foundation of China (No.51278274) and the Tsinghua University Initiative Scientific Research Program (No. 2011THZ03) for funding this research project.

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