Journal of Southeast University (English Edition) Vol.19 No.4 Dec. 2003 ISSN 1003—7985

# A working model of the Internet-based steel construction consulting system for architects

Zhou Qi

(College of Architecture, Southeast University, Nanjing 210096, China)

**Abstract**: As Internet becomes largely used in the AEC (architecture, engineering and construction) industry, the main focus is in the area of information and project management. In the dynamic engineering consulting, less has been done so far. This research tries to find the possibility and potential of the Internet application in design and consulting for the AEC industry by proposing a working model in specific area, steel construction. Several issues have been discussed: defining and formatting the typical procedure and character of the steel construction consulting, behavior approach based on activities among partners, and the model organization.

**Key words**: steel construction consulting; behavior approach; object-oriented methods

In this research, we will propose a practical working model of steel construction consulting for architects based on previous theoretical research and the conceptual model of engineering consulting in architecture. It is assumed that all the basic concepts and methods in configuring the conceptual model of Internet-based engineering consulting can be applied in this steel construction consulting because this is one of the more nature engineering disciplines in the AEC industry.

## 1 Significance of Selecting Steel Construction as the Application

There are several reasons to select steel construction technology for architecture as the main research topic:

1) Steel structures are one of the most important building technologies because they meet several critical needs of the modern building industry: mass production, industrialization, standardization, and efficiency. These are also the characteristics necessary to achieve the full potential applications of Internet technology. If this comparatively simple application would prove successful, then it should be possible to apply this model to other sophisticated areas in AEC industry. There are also the practical demands of the industry. That will encourage even more future development. From an architectural point of view, steel can represent new era esthetics similar to Gothic Architecture in terms of a harmony in structure, materials, and construction.

2) Steel not only has its own technology but, more important, has the ability and potentiality of becoming a formative expression, just like organic machine design. It is necessary to make a thorough investigation of the international experience in this field of integrating steel construction into information technology.

3) There will be an unlimited development in the future concerning that "an integrated, whole life design approach considering all of these issues will be necessary, with an energy and environment audit taking account of materials, manufacture, construction, building usage, servicing, maintenance and finally demolition and recycling."[1]

## 2 Defining the Steel Construction Consulting in Conceptual Design

Similar to the previous section of defining engineering consulting in architecture, it is now necessary to establish a clear definition and understanding of what is steel construction consulting during the conceptual design process. Tab.1 and Tab. 2 show all the major components and factors in the definition of steel construction consulting in conceptual design and the related potential Internet applications.

### 2.1 Architects and architectural students: the major users of ISCA

This system is designed primarily for the architectural profession. It is focused on helping designers to have a better understanding of steel structural systems

**Received** 2003-09-28.
**Foundation item**: The National Natural Science Foundation of China (50238010).
**Biography**: Zhou Qi (1957—), male, Ph.D., associate professor, zhouqi@seu.edu.cn.

**Tab.1** Defining steel construction consulting for architects

| Components | Detailed attributes | | Potential Internet application |
|---|---|---|---|
| Participants | Primary participants | Architects, structure engineers | Internet collaboration tools for easy communication and activity interaction: on-line conferencing, instant message, wireless connection. |
| | Secondary participants | Clients, contractors, vendors, building managers | |

**Tab.2** Defining the functionality of steel construction consulting for architects

| Process | Activities | Functionality |
|---|---|---|
| Planning | Studies on site, function, and urban settings | General information services |
| Conceptual design | Space configuration, form-giving and preliminary selection of steel structure systems | Structural system generation and evaluation from web-based applications, specified information services |
| Contents | Pre-analysis consulting: for early decision on structure system based on brief analysis | Provide full services from web-based consulting tools on either standard or customized building types |
| | Building codes, material selection, products specification, CAD libraries, references | Interactive information system easy access and exact match on project-centered applications |
| Media | Personal meeting and discussion | Via virtual reality environment |
| | Electronic media | Integrated into a comprehensive system |
| Formats | Text documents, numeric information, calculations | Digital seamless work flow via Internet |
| | Physical models, drawings and specifications | 2-D and 3-D digital formats |
| Place | Offices, construction sites, cyberspace | Combination of physical and cyber-space |

and construction technology during the early design phases. Unlike other steel structural software and applications, which are mainly designed for structural engineers, this system will provide basic conceptual analysis not detailed calculations. Except for basic specification and searching, 2-D and 3-D graphics (including rendered and animated) which are familiar to architecture professionals, are the primary pattern languages appearing in this system.

Structural and construction engineers would be minor users for the system. However, they would benefit from the educational transfer with architects and finding worldwide information on existing projects and new technologies. Other minor users are the vendors and sub-contractors who have an early collaboration with architects and provide their services and material information.

## 2.2 Content & technology

The content or core in this research requires a series of questions with a hierarchy relationship that must be asked and answered. As stated before, the main purpose of this research is to provide an experimental model of Internet aided design and steel construction for architects has been selected as a vehicle to convey these objectives. If this model is successful, it can be extended to other design professions. Narrowing the task scope without losing the potential true meaning becomes the main concern in selecting the research content.

## 2.3 Scope and flexibility

Generally, the entire architectural design process can be divided into three or four phases: planning and conceptual design, schematic design, analysis and construction documentation, and finally, shop drawings.

The intent of this Internet-based consulting system of steel construction for architects (ISCA) is that it is primarily applied to conceptual design. There are basically two reasons for this premise. First, because of the diversity of building codes and physical conditions in different jurisdictions, flexibility and feasibility become important considerations for the ISCA system if it is to be used world wide. Conceptual design consulting is defined as at making preliminary decision in structure and materials from a database of intelligent information. Architects can also use the ISCA system for reference rather than for a final decision. In following the subsequent design phases, consulting engineers can make suitable appropriate adjustments that produce the final design.

As was previously discussed, liability is a serious concern of this research. Conceptual design normally does not apply to final construction and this design phase is not a legal construction document so there would be no legal engineering responsibility for this information.

However, the conceptual design does play a key role in shaping the final design result and the interface with other different design phases. Depending on the

special project, architects and engineers can also use this system in their other different design stages to get help in making preliminary decisions on structures and materials. But, the ultimate potential in the future would be to develop this system to be integrated with entire architectural process including construction that would involve the management of the complete steel construction life cycle.

Scope of content is another important issue in this research. As a typical working model of steel construction, it should cover all major structure types. However, at this research stage, it is inevitable that the scope must be narrowed without losing general significance.

## 3 Working Model Organization: Behavioral Approach and Object-Oriented

Behavioral approach and object-oriented methodologies are adopted in creating this working model. As was previously established, to be successful, any new technology and new tools must not totally change the way of working and the way of thinking. But rather, they must follow the conventional working habits and gradually improve or evolve these habits while using new technologies. Object-oriented concepts have been intensively used in the software industry because they involve simple and easy methods in programming. Wrapping and reusing are the key concepts of the object-oriented software programming. This concept is used in creating this working model but with a little different meaning. The following section discusses in more detail the behavioral approach and object-oriented methods and how they work.

### 3.1 Behavioral approach

The relationship between new technology and designer's behavior has been an interesting phenomenon in design fields throughout the industry revolution. Technology changes the way of people's working and after they get used to a certain kind of new technology and tools, the relationship between human behavior and technology become more stabilized and harmonious. As new technology develops and becomes introduced to the existing working environment, the conflict occurs. People struggle and are unwilling to use the unfamiliar and uncomfortable tools unless these new tools will show great advantages and profitability in their practice.

This is exactly what happened in the transition of hand drawing and computer aided design. Even today, a lot of people still refuse or feel uncomfortable using the computer tools. However, since the majority of design professionals have used this new CAD, the way of working and the process of design product delivery have been greatly changed and the relationship between the CAD technology and design activity has become more harmonious. Today, Internet technology has become a prevailing influence throughout the industry and now new tools of information technology are emerging. On one hand, all these new tools should be carefully designed to gradually change the way of working rather than force a radical change. However, design professionals should realize the advantages and disadvantages of this new Internet technology in practice and not try to hold back this revolution or evolution in the information age.

In this proposed working model of steel construction consulting for architects, there are two issues related to this behavioral approach. One is the procedure or process in the consulting activities. These new consulting tools should be introduced to follow the conventional working habits in the design process. The second issue is that the interface of this Internet-based steel construction consulting be designer friendly and incorporate a familiar media dialogue with the computer.

#### 3.1.1 Procedure or process

This model will concentrate on only the initial process for conceptual design and the preliminary decision making of steel structural systems. Normally, there are four steps leading to the preliminary decision of determining a structure system. First, architects have to understand the function and requirements of the client's desired building. Secondly, based on a thorough investigation of the building's function, architects have to develop their initial space studies and review the form-giving considerations. The third step is to define all the basic geometric parameters. The final phase review all of the input to make a preliminary decision on selecting the structure system. In this proposed working model, every consulting procedure is designed to follow the above steps to make the architects feel familiar and comfortable.

In this conceptual design consulting, what preconditions are needed to make the preliminary decision on the structure system a consulting success? There are a number of factors or conditions for the architects to consider: including the function requirements, brief engineering analysis by consulting

with the engineers, aesthetic considerations, cost and budget limitations, construction period of time, construction site limits and constraints, engineer's capability of some of then new systems, and finally vendor or manufacturing availability in that area or region. In this proposed model, designers are required to input some basic design data and the consulting system would provide step by step consulting to analyze all these conditions with information for the designers to make their own decision depending on the different priorities. In the late prototype simulation section, a more detailed consulting procedure will describe the process.

### 3.1.2 Interface

Providing a user-friendly interface is another important factor that is required for any online application system to succeed. In the previous chapter of proposing a conceptual model of engineering consulting in architecture, the interface issues of new technology and tools 3-D objects and voice input were outlined. Here, the model will also focus on a behavioral approach of a pen-pencil sketch method, which asks the designer to input geometric shapes and parameters to generate conceptual structural systems.

This consulting application provides multi-choices for considering basic geometric parameters (see Fig. 1). One function is to select and reorganize the basic shapes from the platform provided by the system.

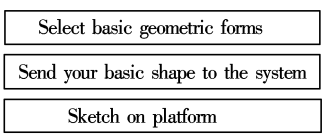


**Fig.1** Methods to input geometric shapes for structure generation

The other is to send a user's space study shape to the consulting system by uploading standard CAD drawing formats, such as DWG of DXF. This method has been successful and widely used in the design profession.

Another input method is to sketch on a sheet-like platform, which designers feel is more comfortable and flexible for handling the different shapes and forms. This also requires more human involvement compared with previous two input methods. There has also been some progress in creating pen-pencil sketch computer applications. One of them is SketchUp by @Last Software. This is a sketch-based 3-D modeling program that allows designers to focus more on design and less on the technology by simplifying the user interface. The designer can simply draw the edges of the desired model in 3-D space and SketchUp automatically completes the shapes to create 3-D geometry.

The most important characteristic is its simulation of the pen-paper working process. Fig.2 (downloaded from www.skecth3d.com/gallary/muilti-image.php?recordid = 4&page = 0) shows one of the examples that recently won the first place in 2002 Cadalyt Image Awards. From this work, it is possible to see the similarity with conventional hand sketches.

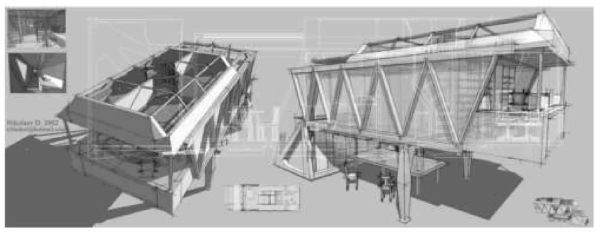

**Fig.2** Example of SketchUp works

Another distinguishing difference from most other CAD software is its special push/pull feature. This makes it much easier to create 3-D volumes and shapes. Fig.3[2] shows the process of how pull/push works in creating a composite box.

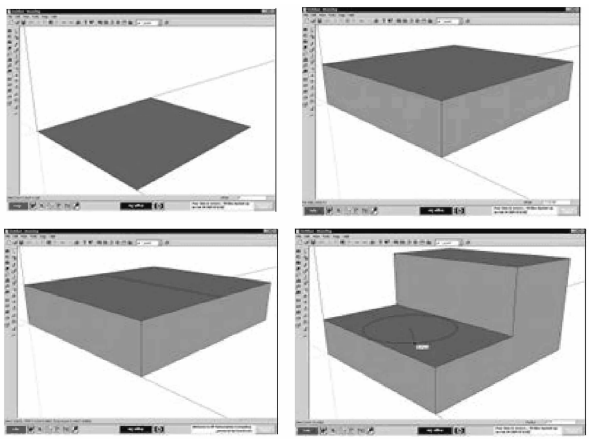

**Fig.3** An example of creating 3-D volume by SketchUp

The problem with this sketch software is that it is not natural pen-paper sketch method that still has a machine like operation with the process of moving a mouse and clicking many key points required to get a desired 2-D or 3-D object. Instead of the standard mouse-click tool, Greenberger has argued that a special designed more pen-sheet like tool might be necessary for real a human sketch interface[3].

## 3.2 The object-oriented method

One of the concepts included in this research is the object-oriented consulting system. There are three conditions of the object-oriented method. First, the object-oriented method in software programming

languages is adopted, such as C ++ and Java ++. All the basic applications and information database packages are wrapped and reused as independent objects. Secondly, all the applications and information systems are closely related to objects, here referring to physical objects layered as, designed project, its sub-system, and sub-components, as shown in Fig.4. Thirdly, these objects live with building and related component properties and are also hyper-linked to both the in-house database and external resources. A more detailed description of this object-oriented method will be presented in the prototype simulation section.

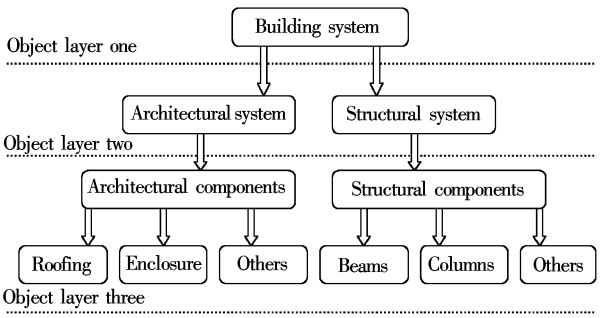


**Fig.4** Hierarchical relationship of objects in ISCA

From Fig.4, it is possible to see that there are three basic levels of objects in steel construction consulting. The first level is the designed project itself, appearing as an independent object in this consulting system. All applications and information will be focused on this specific project, or object. The secondary object level or layer consists of two parts: architectural components and structural components. The third object level is a set of sub-components of both secondary levels objects. All searched information and provided applications are based on the target objects. It can be assumed that the potential users are logging on this site to find solutions for their design projects or that some users will log on just for a general search to obtain some information in the area of steel construction.

### 3.3 Model organization

In the working model of ISCA, the above hierarchy objects are closely merged into the entire system, which consists of two parts. One is the information center and the other is consulting applications. These two parts are mutual interactive by connecting with objects as shown in Fig.5.

The information center provides both the internal basic database and the exterior search engine for users to get technical data they need. For example, in searching for a steel frame structure, the database has

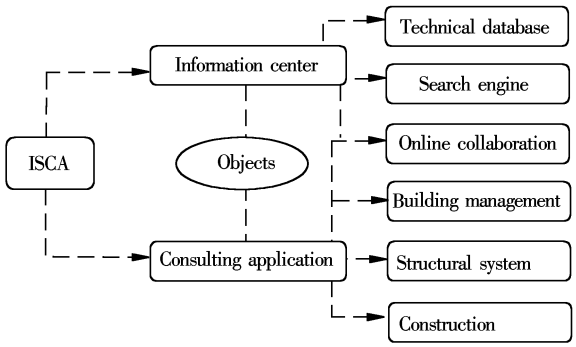


**Fig.5** Working model organization in ISCA

all basic information from the structural systems to details. In addition, if users want to know more updated examples or material vendors, the search engine will provide outside information through the Internet leading to related web sites. All of these internal and external connections are high lighted when the mouse is moved to and then clicked on the certain objects.

Consulting applications provides solutions for structural systems and construction technology. If the users select architectural space in their preliminary design, when the parameters are inserted into this consulting application, it will generate a structural system. To learn additional details, the users can click on a selected system (object), and then a series of information sources become available for selection. At this step, the information center and the consulting application are connected together by the clicked object.

## 4 Information Center

As stated before, the information center consists of two parts. One is the technical database, which provides abundant steel construction information categorized by structural types, and the other is the search engine, which provides world wide web information related to specific objects. These two parts are internally connected and interacted by means of the object orientation. The following describes the process:

### 4.1 Technical database

First step is for users to decide what kind of structure type is to be selected. This selection comes from two sources. One is simply by searching the database and to click on a series sub menus to produce the selection. The second comes from consulting applications. The user enters the geometric parameters following certain rules, and the system generates the

structure type.

As shown in Fig.6, after the structure type with certain parameters has been selected, the information center will give a number of finished building examples for this type of structure. Depending on the users' requests, the sub-system can also provide more detailed information including images, technical details and project partner information. All of those objects in the different layers are "live", which means they are connected to certain data points either through an internal database or through external Internet web sites by hyper linking.

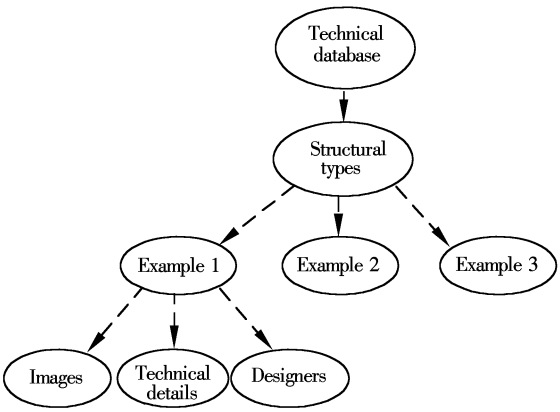


**Fig.6** Working model of the technical database

### 4.2 Search engine

This information system provides a content-sensitive search function rather than text-based search engines. All of the search functions are related to both different design requirements and different objects. There are three major categories for the search. One search is for vendor information that might be for certain structural types within a certain limited distance from the project location. The second is a search for built examples of certain structural types that would provide design references. This is very important and useful resource for designers and makes it possible to have a thorough investigation and understanding before making any decisions. The third is a search that can be for capable of engineers who have expertise in solving some specific type of structure. Other search functions can include material information CAD libraries or product specifications related to certain types of projects.

## 5 Consulting Applications of Structural System

As stated before, the consulting applications consist of three parts, again based on the design behavior or functions of steel construction in architecture. The first part is structural systems, which helps the designers to determine a basic structural solution after defining the architectural space. The second part is construction consulting including building materials, technology, and vendor information. The third part is the online collaboration system, which provides a web-based platform for design partners and other related professionals to collaborate.

Structural system consultation is the most significant segment of the process. It is designed neither as a set of structural analysis software nor a static information provider. The objective is to take advantage of information technology, specially the nature of Internet functions that makes it possible to provide the integrated networking and computing platform. In the case of steel structural consulting, this system generates a number of structural systems, which have incorporated computing properties. And, the system can also provide broader information consultation on specific structural types, both from an in-house database or external resources, which have networking (Internet working) properties. Another characteristic of this consulting (that is different from other analysis software and information systems) is that this is Web services based third party provider. Users do not have to download any software to their PCs and don't have to be concerned about updated software. Finally, this structural consulting application is not designed to replace other structural analysis software or replace practicing structural engineers because it only provides a conceptual design tool in bridging the gap between architects and structural engineers. The following summary explains how some of the major functions work.

### 5.1 Generating structural systems

As shown in Tab.3, for the consulting system to generate structural systems, the users have to input some of the related information.

**Tab.3** Users imported data and the system's response

| Imported data | System response |
|---|---|
| Project location | Codes and other physical conditions |
| Building types | Structural loads |
| Architectural requirements | Other loads |
| Geometric properties | Structural selection and generation |
| Roof profile | Roofing structural selection |

First, the project location tells the system how to determine the building codes and the physical conditions. Secondly, the user inputs the building type for the system to analyze the different kinds of loads. Thirdly, other special architectural requirements might

be entered into the system that could include insulation or temperature. The system would recognize the other loads that have been applied to the structure. The next input is the geometric shape which is very important data for the system to know. And finally, a roof profile is given for the system to know before selecting the enclosure solution or the structural system. After all of the data input, the system would be able to generate a number of structural systems, which fit the requirement of that architectural space. The working process supporting the structural generation is based on both an internal expert system and a database (both internal and external) comparison. The expert system includes the basic structural analysis and calculations, and the database produces the similar project types and structures.

### 5.2 Evaluation of generated structural systems

After a number of structural systems are generated, an automatic evaluation which provides a comparison of different factors, is presented for the users to make a further judgment of which system is the most suitable for the project (refer to prototype simulation for the details of the evaluation).

### 5.3 Highly customized space

For any kind of atypical or custom projects, the system can search for similar structural systems and provide a number of examples for the users to study. The consulting system can also search for experienced structural engineers that have produced similar structures and introduce both professional who can work together through the virtual reality environment.

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# 以互联网为基础的,为建筑师服务的钢结构咨询系统模型

周 琦

(东南大学建筑学院, 南京 210096)

**摘 要** 互联网技术在建筑及工程中的运用越来越普及,但其主要的研究及实际应用大多集中在信息服务和项目管理方面,而在设计及咨询领域则没有太大进展.本研究试图通过建立一个以互联网为基础的钢结构设计咨询模型来探讨这方面的可能性和潜力.重点讨论以下几方面的问题:定义并用计算机语言来格式化钢结构咨询系统,设计和咨询过程中的行为方法以及模型的组织.

**关键词** 钢结构咨询; 行为法则; 以物体为导向的方法

**中图分类号** TP393; TU2