Research and Development of Concrete Pillar Working Drawing CAD System

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Abstract: This paper compiles computer-aided design procedure of concrete pillar component in PKPM to complete the development of concrete pillar working drawing CAD system. Concrete pillar working drawing CAD system is a subsystem of China Academy of Building Research's PKPM series software which realizes the reinforcement calculation design and completes various drawings. This paper studies the PKPM concrete pillar working drawing of 2004 edition and before, which fully accumulates the practical experience in the course of developing the PKPM software. What's more, it completes the following requirement analyses: based on the result of requirement analysis, it completes systematic functional design, module design and data structure design to accomplish the design and development of reinforcement calculation module as well as the optimization of working drawing and user interface module.

Introduction

It carries out structural analysis and functional analysis of the existing PKPM concrete structure bar system and working drawing system. In addition, it also studies demerits and merits of the original system. Based on this, it puts forward improvement project so as to complete the design and implementation for new concrete pillar structure system. The focus and innovation points show as follows:

Firstly, it adopts modern software engineering methodology to improve the current software structure, which puts forward systematic implementation schemes to improve the scattered reinforcement design module and change the demerits of its poor integrity and consistency. This paper adopts modern software engineering design approach so as to analyze the software structure and makes an overall reinforcement calculation and drawing system based on SATWE for component objects. The new system combines the scattered reinforcement calculation module for both the plane design and elevation drawing design to complete an overall reinforcement calculation module design for component objects. In addition, this new system takes the SATWE as the basis to organize the working drawing system as well as the user interface system. Users can directly modify the steel bar and operate, which is convenient for users.

Secondly, it completes the design and development for the overall reinforcement calculation module. Based on the computational requirement and construction requirement of concrete structure, this paper accomplishes new design and development for the reinforcement calculation module which can help to solve the reinforcement design problems under complicated stress condition for the concrete pillar. It takes the unsymmetrical combined pressure, crack width controlling which may occur in the course of reinforcement design into consideration. The reinforcement selects a glittering

array of reinforcement data in the bar library, so as to help users to adjust and control the dynamic reinforcement process. The reinforcement system keeps the result in a data document and various working drawings can share the data which helps to ensure the result consistency.

Thirdly, it accomplishes the optimization design for various working drawing modules. Concrete pillar working drawing CAD system is able to accomplish various drawings. In addition, the drawings which can be accomplished by the system include overall graphic demonstration, elevation drawing demonstration and pillar list demonstration. The drawing system is developed based on the national rules regulated in the Standard for Architectural Drawings. By the way, it also adopts automatic layout and unifies the character alignment setting so as to make the working drawing better fits the drawing habits of designers.

Fourthly, it adopts event-driven interactive platform technologies based on the MFC structure to complete the interactive system design. The 2005 edition PKPM structural software adopts new interactive platform based on event-driven to organize module. What's more, the pillar working drawing CAD software also completes the porting. The most outstanding characteristics include: the interface is friendly, which supports the customization of common interface elements such as the tool bar. Moreover, it also supports to execute an order freely which is easy to operate.

Fifthly, apply COM components programming concepts to software design: This paper applies COM components technological application to the design and development of system to improve the module degree as well as the reusability of code to finally lay a good foundation to the advancement and development of the system in the future.

Sixthly, realize the association technique linking configuration data and CFG system elements. The reflective information in CFG system can help to link configuration data and working drawing so as to further realize the quick partial modification as well as existing drawing editing.

Contents

The requirement analysis of pillar drawing CAD system: The concrete pillar working drawing CAD system adopts hybrid programming, combining C++ language and Forrtna language. C++ language is adopted to carry out the interactive interface design while Forrtna is to conduct the engineering calculation of reinforcement design. The advancement of pillar working drawing software is carried out within the framework. In order to develop the module degree and reusability of code, COM components are also adopted to modify the charts, layer and setting etc.

The essential task for the working drawing design software is to combine the overall module and structure of modeling software to obtain the internal force analysis based on calculation so as to have the construction design plan of for various components and sectors to finally complete the graphic layout, reinforcement and node detain plan. Working drawing software belongs to postprocessor of CAD system with relevant functions. At the same time, because the working drawing design is closely related to the detailed construction design, we have to study the characteristics of detailed construction in order to have a good knowledge of the working drawing software.

Design is a process step by step and the structure design should go through structure scheme choice, preliminary sketch, structural inner force analysis, and detailed structure design etc. The basic flow chart of structure design shows in Fig. 1:

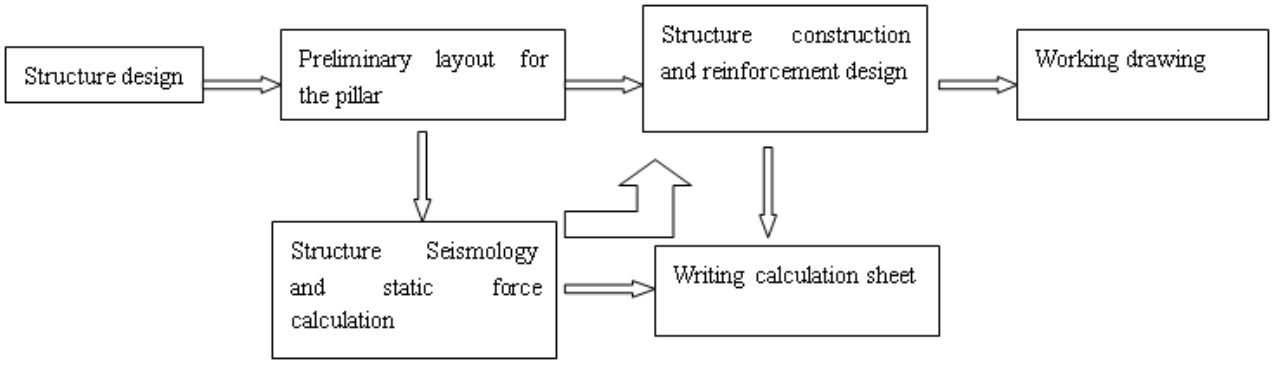


Fig. 1 Artificial design flowchart

One of the aims to compile CAD software is to release the working pressure of designers and improve working efficiency. In order to achieve this aim, steps to operate CAD software shall be decreased to improve degree of automation. Using components to design CAD system mainly reflects in two aspects: The input of structure module and the working drawing. To improve the degree automation, we have to start from two aspects. The pillar working drawing software should be designed and drawn based on a dazzling array of professional data, which cannot be input by labor yet we should play the integration advantage of PKPMCAD so as to design the results from various subjects (drawings, tables and notes) to obtain relevant data related with pillar design.

CAD system design for pillar working drawing

Based on the requirement analysis result, we can carry out the pillar working drawing CAD software system design. The software system design work mainly includes: functional design, module design and division, data interface design, data structure design etc.

Concerning the integrated structure design CAD system, the following requirements shall be achieved: the human-computer interface is friendly; the degree of automation is higher; the input result is simple and direct which is easy to understand. In the design, designers only have to input a small amount of data such as the componentized, marital nature and then the CAD system can automatically complete the calculation to accomplish all the design work. Taking the organic bond of automatic design and manual intervention into consideration, the pillar working design CAD system main completes the following designs:

Firstly, in terms of the overall design of three-dimensional structure, it completes the PMCAD interaction and data transmission module. It takes advantages of OMCAD to adopt the human-computer interactive approach and graphical environment to lead users to layout the settings of various layers and establish the basic component module for the whole building including wall, pillar, cave and floor so as to generate the data which can describe the overall structure of building.

Secondly, it completes the interaction and data transmission module between SATWE and PMSAP. By taking advantages of these modules, this paper completes the finite-element analysis and calculation for the overall three-dimensional structure which also obtains the internal force and reinforcement information of the structure.

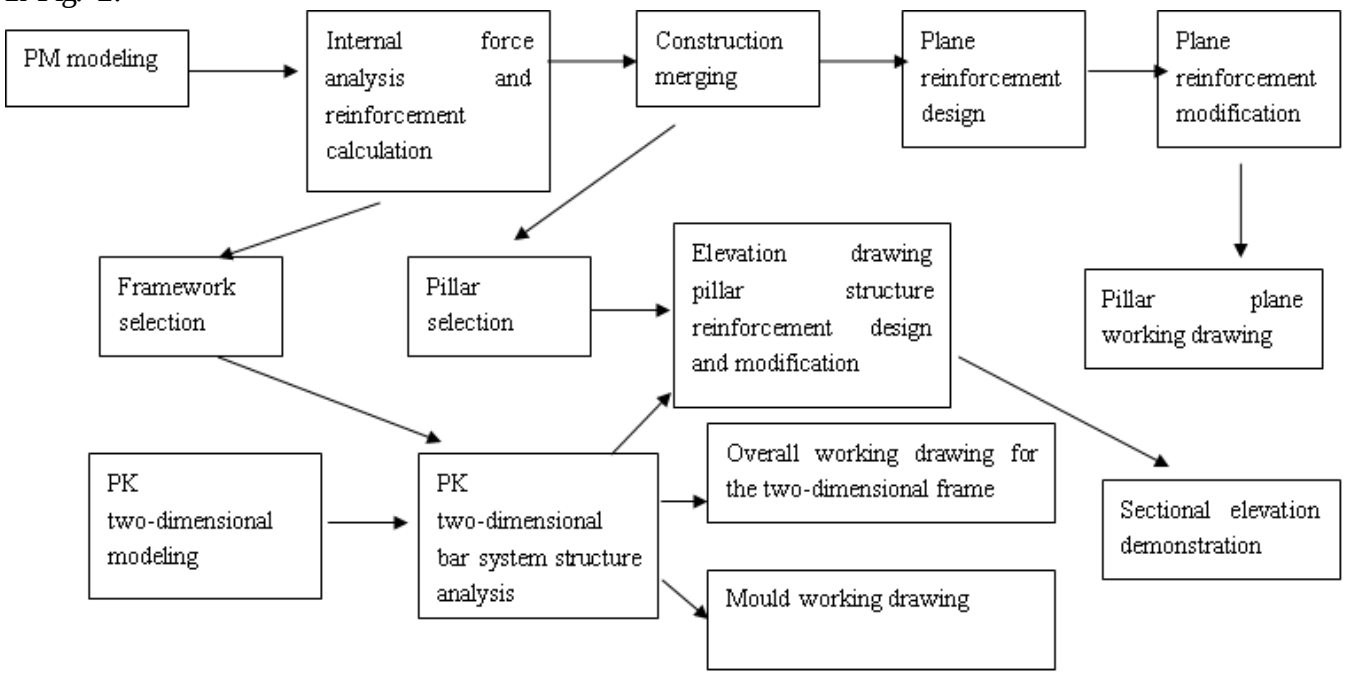
After completing the module input and finite-element analysis, it accomplishes the design and calculation for the real reinforcement of pillar components as well as the detailed design.

It automatically generates various working drawings, including overall graphic demonstration, elevation drawing demonstration and pillar list demonstration. What's more, it allows users to

interactively modify and edit the working drawing and automatically modify the data base for the reinforcement design.

Concerning the completed structure design, users can carry out normal serviceability limit state calculation and which can be demonstrated to users through figures and can be regarded as further references.

The original PKPM component software design divides the modules based on the construction forms. There are two types for the construction forms: the first is the one based on the overall demonstration such as the SATWE. The second is the elevation drawing and sectional drawing for single component such as the elevation drawing demonstration. So the reinforcement and drawing are carried out based on two modules. The PKPM modules for concrete structure CAD system shows in Fig. 2:



The realization of pillar working drawing CAD system

Component reinforcement design is an important and complicated work in concrete structure design. Reinforcement design and component setting are closely related to the force condition which also has a great effect on the construction. The reinforcement work is heavy, occupying a large amount of manpower and material resources in the later period. In order to improve the design quality and work efficiency, we have to realize the automation for component reinforcement design.

The basic principle for reinforcement design is to firstly calculate the internal force as well as the quantity of reinforcement and then select the diameter and piece based on the category and construction requirement. Finally, according to relevant construction requirements, the shale and configuration location will be determined.

If there should be over-reinforced phenomenon for main bar, the system will give us a hint. In the working drawing, the system presents ***** to show the over-reinforced parts. At this time, users should change the design and enlarge the size of the beam section or improve the strength degree of concrete. The following can be adopted to judge the main bar over-reinforced phenomenon:

Firstly, the flexural load-carrying capacity of beam section should meet the ultimate bearing bending moment when $\mathrm{M} \le \mathrm{M}_{\mathrm{u}}$: $M_u = 0.5 f_c b h_o^2 + f_c h_f \left(b_f - b\right)\left(h_o - 0.5 h_f\right)$

When $\mathrm{M} > M_u$, the system shall give a hint of over-reinforced phenomenon.

While considering seismic action combination, the height of concrete compression zone should meet the following requirements:

Anti-seismic grade 1 $x \le 0.25 h_0$

Anti-seismic grade 2 and 3 $x \le 0.35 h_0$

When calculating the height of concrete compression x, the procedure take the compressed concrete area into consideration, the Grade 1 is 50%, Grade 2 and 3 are 30%. If the calculation result cannot meet the above requirement, there should be a hint of over-reinforced phenomenon.

Thirdly, if there should be seismic action combination with the ratio of reinforcement $\le 25\%$ there will be a hint of over-reinforced phenomenon. In the real realization process, the over-reinforced phenomenon judgment is carried out by the finite-element analysis of SATWE and AT software. If one piece bar has the over-reinforced phenomenon, the finite-element analysis software will output an unreasonable maximum number (such as 99999). The maximum number is to determine the over-reinforced phenomenon and to output the character.

The design of pillar component should not only take limit state of bearing capacity requirement into consideration but also the general bearing capacity. The procedure can help to calculate the maximum crack width as well as the deflection amount to give a graph result for references. The strained condition can be valued by bending member. What's more, the standard combination of loading effect and the quasi-permanent combination are calculated according to the loading code for design of building structures GB500O9—2001.

For standard combination GB50009—20013..28, the design value S of load effect combination can be calculated according to the following formula:

$$S = S_{GK} + \sum_{i=2}^{n} \varphi_{ci} S_{Qik}$$

For quasi-permanent combination GB50009—20013..28, the design value S of load effect combination can be calculated according to the following formula:

$$S = S_{GK} + S_{QIK} + \sum_{i=2}^{n} \varphi_{ci} S_{Qik}$$

Various loading effects can be calculated by the analysis software TAT and SATWE and the live load combination value is regulated as 0.7 while its permanent value is input based on the real condition and other values determined by relevant regulations. The procedure takes various combinations of dead load, live load, and wind load in consideration so as to calculate the maximum number of cracking deflection. Concerning cracking deflections for different control sections, there may be different calculations.

The function and application for Pillar working drawing CAD system

After the updating of pillar working drawing CAD system, the 2005 edition PKPMCAD system is promoted to the market. A dazzling array of project inspection tests show that the procedure can help to provide convenient concrete bar reinforcement design and working drawing design.

The second section in the pillar working drawing design menu is the sectional elevation working drawing and the third section is the overall plane drawing demonstration. The sectional elevation provides construction details such as the truncation, lapping, anchoring length of encrypted etc. Accordingly, a large amount of drawing sheets is needed to draw the pictures. The plane demonstration directly and comprehensively shows the plane layout which combines the standard detail of construction. The plane drawing is simple which is widely adopted by working units. Therefore, the working drawing in this system is established based on the plane demonstration to select the pillar and draw other working drawings.

The procedure provides two approaches to modify the support: the plane approach and elevation approach. Click the button of modifying support users can modify the pillar support. Using the cursor mouse to select the pillar you want to modify and then click the red triangle or circle which represents the pillar support and the red triangle shall change into red circle. If you choose the red circle, the circle will also change into triangle. The interface for plane demonstration changing the pillar support shows in Fig. 3.

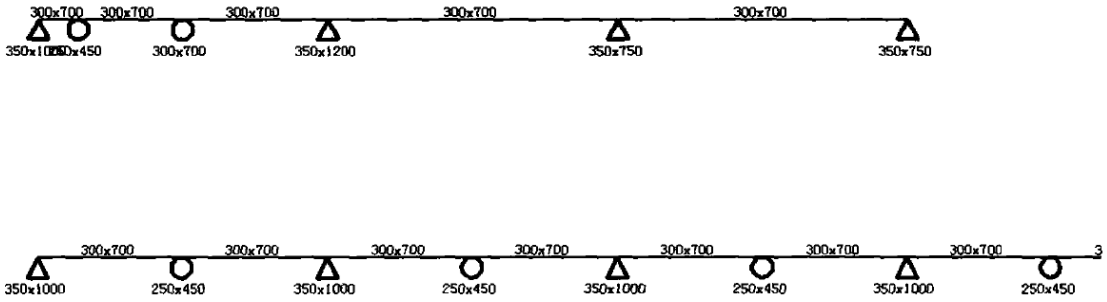


Fig. 3 Sketch map for pillar support modification in the elevation form

Conclusions

This paper adopts the modern design philosophy facing objects, to comprehensively study the reinforcement calculation and the working drawing problems. Concerning the demerits of structured programs, it puts forward the idea to develop working drawing software development based on the software design approach and software development environment.

This system, as a compound module of PKPMZo05 has been promoted to the market. It is worth paying attention to is that the reinforcement design and flexible working drawing which can meet the regulations and real project requirement are widely welcomed by technicians.

The research results of pillar working drawing CAD system include:

Firstly, it realizes the integration of various working drawings and guarantees the consistency, completes the function analysis of 2004 edition PKPM working drawing module and the function design for 2005 edition pillar working drawing module.

Secondly, it improves the reinforcement calculation module of concrete pillar to make the reinforcement result meet the requirement of project. What's more, it can help to flexibly modify the reinforcement with the bar selection system as the core. This system conducts the bar selection design based on various requirements of concrete components so as to guarantee the compliance of bar selection result.

Thirdly, it completes the optimization design for working drawing system and improves the working efficiency of technicians. Besides, the new working drawing system integrates various working drawing modules in the PKPM software to optimize the drawing process and complete the working drawing system. Moreover, this system can also design various working drawing demonstrations such as overall graphic demonstration, elevation drawing demonstration and pillar list demonstrations etc which are flexible and replace the scattered working drawing modules of 2004 edition PKPM software or before.

Fourthly, it adopts mature software technology to realize the working drawing pillar construction. The working drawing CAD system integrates various modules of 2004 edition PKPM software. The new module inherits the original excellent functions and at the same time adopts mature software technology to realize the expansion of working drawing function.

The research, updating and development of concrete pillar working drawing CAD system basically comes to an end and the new system realizes concrete reinforcement design, working drawing, structure adjustment and test etc. Comparing to the previous edition of PKPM, the new system is comprehensive and flexible with better usability. However, we have to know that the system cannot be perfect, and there should be plenty room for development.

Acknowledgment

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