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Development of an Arch Bridge CAD System

Principes d'une conception assistée par ordinateur pour un pont arc

Entwicklung eines CAD-Systemes für Bogenbrücken

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SUMMARY
In this paper the concept, principles and structure of a System under development are presented. The management and establishment of the database, method of design optimization and algorithms are discussed.

RÉSUMÉ
L'article présente le concept général, les principes de base et la structure d un système pour la conception assistée par ordinateur de ponts – en cours de développement. La gestion, l'établissement de la base de données, les méthodes d'optimalisation et les algorithmes sont présentés.

ZUSAMMENFASSUNG
In diesem Artikel werden die Konzeption, Prinzipien und Struktur eines CAD-Systemes für Bogenbrücken dargelegt. Einige Probleme bei der Entwicklung wie die Verwaltung und das Aufbauen der Datenbank, Methoden der optimalen Programmierung und des Algorithmus, werden diskutiert.

1. INTRODUCTION

In China the application of the computer to highway bridge design was began recently at beginning of 1970s, but has grown very fast. During the last ten years or so great results were achieved. Computers, especially microcomputers, have spread out over our native land. Many effective on bridge analysis and design application software programs, which provide powerful tools for engineers, have been developed. The situation regarding highway bridge design has presented a new face. Design has been speeded up and its quality has been improved. In addition to that, the computer has also helped us to design and construct new types of bridges, for example cable-stayed bridges.

But the existing software has a lot of shortcomings. They are mainly for calcula ions such as structural analysis, such tasks are essentially operations on numbers. In order to further improve the existing application software for bridges, the design offices have a great interest to drawing and human-computer interaction. Therefore development of a bridge CAD system is an urgent need.

Since 1986, under the direction of the Ministry ofC ommunication an integrated highway bridge CAD system is being developed. A complete bridge CAD system should include each design stage, various bridge types, structure analyses and calculations, graphics and drawing, etc. So that to establish an integrated system we must develop a large number of programs.

The ARCAD System (Arch Bridge CAD) System is an application software, in o her words a subsystem, of the integrated CAD system. Chinese arch bridges have an ancient history, and is now adopted widespreadly . Developing arch bridge CAD system is a significant joh.

The objects of ARCAD System are concrete (non-reinforced or reinforced) and stone arch bridges with purposes of design automatization and drawing. It can be recalled hy the integrated system as a part of it, on the other hand, it can be operated all alone as a indepedent system.

2. BASIC CONCEPT

There are arch bridges of many and varied kinds in common use nowadays in China -- plate arch, box arch ,spine arch and so on, with filled solid or various hollow structure on arch. The system should be suited to various types of bridges.

Because of wide engineering practice over a long period of time, a rich deposit of design experiences for arched bridges exises, both theory and design method are mature and reliable, a complete set of standard drafts for short and middle span arch bridges was brought to success. Therefore, as a matter of fact for most short and middle span bridges the standard drafts are used. On the other hand, designing long span arches is related to more factors,and the standerd draft is not used. Considering that there are two categories of design method, the CAD for each category should be realized in a distinctive way.

For standard arched bridges having short and middle spans, the index way is employed. Processing and arranging the data of standard drafts and engineering information to form the graphic data, stored in a database. In the database the graphic processing information also was stored; thus the system will have functions of selection and making up arch type, using an analogy method to achieve designing drafts and output the results. Fig. 1 shows the chart flow of the index CAD.

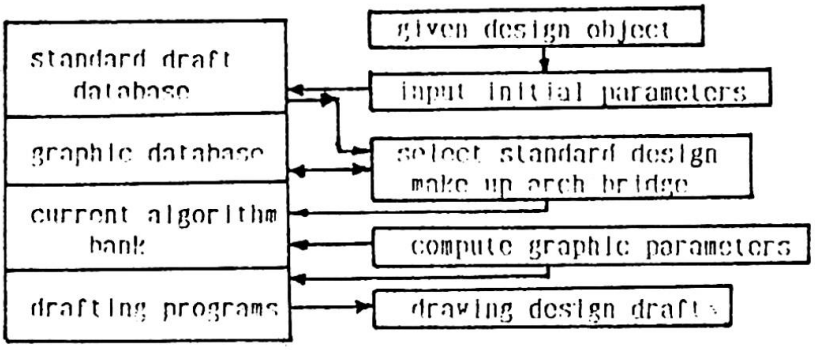

Fig. 1 Index CAD

For non-standard arch bridges the method of automatic design and plotting by means of optimization is taken. The process of the design automatization system is shown in Fig. 2.

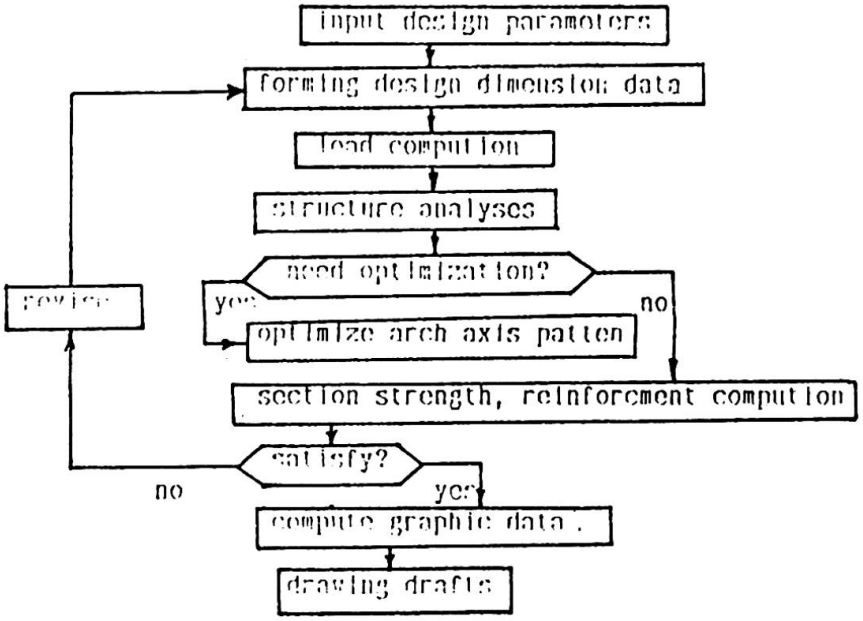

Fig. 2 design automatization CAD

Expect that while setting the structure to generate dimension data the interactive operation will be used partly, the batch processing is the basic method of execution.

3. FUNCTION ARRANGEMENT

The functions of ABCAD System are as listed below:

1) To generate data for design and calculation

* On the basis of design factors, the parameters of section and pattern of the arch axis inputted by the designer to automatically generate the data modelling the dimensions of bridge and physical characteristics of the material.
* To layout the structure for an arch interactively, forming the dimension data of the structure and data about distributive state of dead load.

* To form the geometric characteristics and coordinates of elements for finite element analysis, dividing elements automatically.

2) Structure analysis

* Finite element solution for general plane frame
* Traditional simplified methods in Chinese common practice for arched bridge

3) Optimization of pattern of arch axis.

* To minimize the eccentricity of the arch axis to line of the pressure under dead load.

4) Design of cross section.

* To check the strength according to results of structure analyses.
* To design and check reinforcement automatically for RC arch bridge.

4) automatically drawing and graphing.

* To draw and plot general arrangement draft of the arch bridge.
* To show the arrangement of reinforcement and bars in detail.
* To display and plot some computional results by graphics.

5) Printing engineering documents and tables.

* Tables of the basic design data
* Tables of coordinates of arch axis and arch upper and lower edges
* Bill of materials, tables of engineering quantity
* Computional results of sectional forces and stresses, displacements of arch.

All documents and tables are in Chinese.

4. STRUCTURE OF SYSTEM

The design automatization software for arch bridges is divided into nine module blocks according to its function:

* Input management, given design factors
* Generating dimension data
* Structure analyses
* Optimization of pattern of arch axis
* Print documents
* Generating graphic data
* Drawing drafts
* Computing and plotting engineering quantity.

All basical data and intermediate data are stored in a database by form of database file, the function modules link each other by these database files. The blocks and data flow chart are shown in Fig.4.

5. PROBLEMS CONCERNED WITH DEVELOPING

5.1. Database management

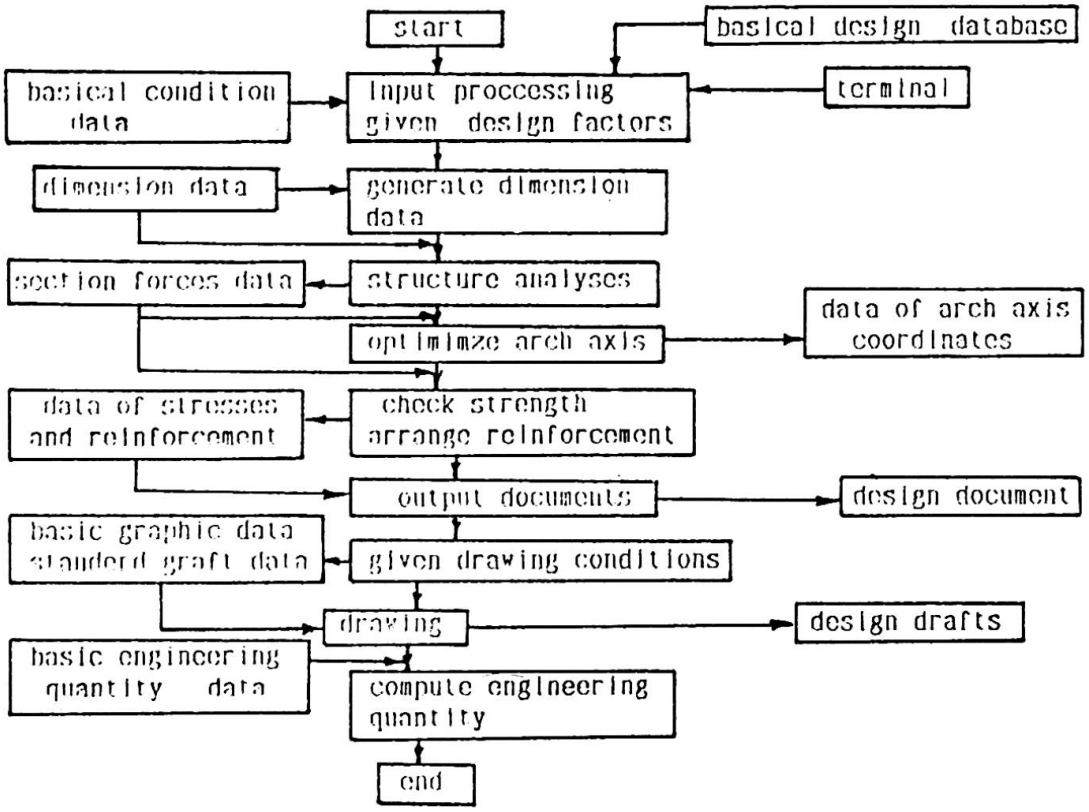

Fig. 3 Flow chart of data and modules

Because the procedure of bridge design is a repeatedly modified progressive approach, dealing with a wide range of factors and a large quantity of information, the data of bridge CAD system have the following distinctive features:

1) The design information is varied basically in types of numeric, geometric and characters.
2) When the design work intensifies,the quantity of information will increase rapidly.
3) The data information has transmissibility and share together.
4) There is a great amount of input and output.

It is apparent that the data of the integrated CAD system must be managed by a united common database management system to enhance data independence, lower superfluousness and ensure correctness of data. At present, the technique of application database in CAD systems is not in a ripe condition. There is no available specialized engineering database management system (EDMS) for bridge CAD system, as a result EDMS has to be developed first. In comparision with current database management systems (DBMS) EDMS have a lot of different characteristics in some respects, for example:

* Data model and structure, which mirror engineering prototypes and their relationships.
* Given power of defining and processing the complicated engineering data structure.
* Propagation of revising the engineering data.

Considering that to develop an EDMS by oneself needs large expenditure of time and labour, to develop ABCAD System using current DBMS (e.g. RMS, etc.) is the most realistic way at the moment. The DBMS has matured relatively, is provided with a rather great capability of describing complex data structures and operating language of rather

unified format, having a whole set of perfect service programs to guarantee the reliability of data [1].

The fuctions of DBMS are able to satisfy the greater part of requirements for the ABCAD System. Therefore, before the EDMS is accomplished the DBMS is used in an initial developing stage.

2. Data structure

The data concerned with arch bridge design is rather miscellaneous and varied, included geometric, physical, design factors and rules of Code etc. In the ABCAD System the structure of common data identifies with the whole integrated system. The more complex data in that for modelling dimension and shape of arch bridge. To differentiate the data with respect to levels the tree shape structure is used. The data structure tree of the dimension data of arch bridge is shown as bellow in Fig. 4.

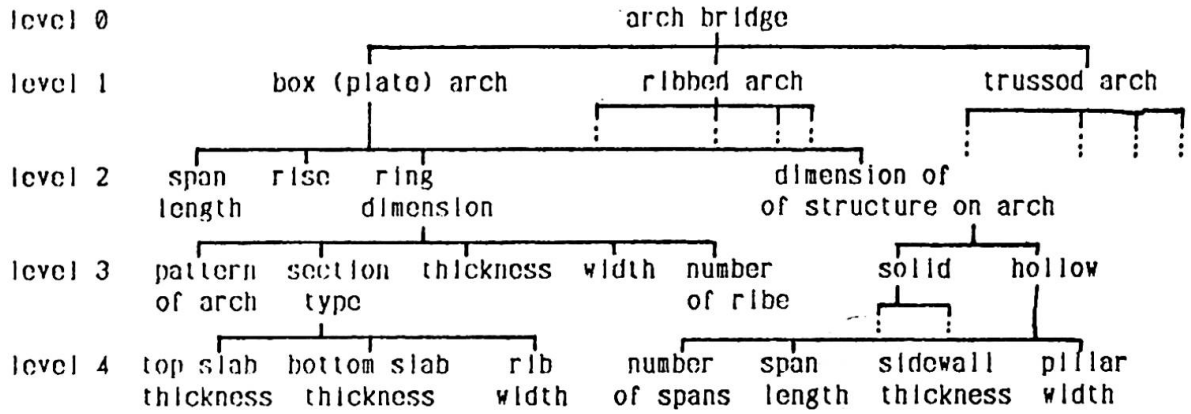

Fig. 4 Dimension data tree of arch bridge

5.3. Main algorithms

1) The thickness of arch ring is determined by designer-computer interaction using empirical equations and experience data stored in database.

2) Fundamentals of structure analysis are plane beam finite elememt solution, while the conventional methods for arched bridges in common practice of China are given. Temperature stresses, elastic stability, concrete shrinkage and additional calculations are computed by the traditional simplified methods.

3) The pressure line under dead load is regarded as the datum line when optimizing the pattern of arch axis, using cubic spline fitting through linear programming.

4) The section strength is determined in accordance to the rules of Codes JTJ 022-85 [2] and JTT 023-85 [3].

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