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Computer Calculation of Prestressed Concrete Bridges

Projet de ponts en béton précontraint à l'aide de l'ordinateur

Computergestützte berechnung von Spannbetonbrücken

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Summary

The paper deals with the software for a computer calculation of prestressed concrete bridges. First the main features, programming details and file organization are described briefly. After sketching the users' profile and the practical experiences that were found working with the system, conclusions are drawn about the communication between man and machine and about the professional responsibility for computer calculations.

Résumé

Le rapport traite d' un système très complet de programmes pour le projet de ponts en béton précontraint à l'aide de l'ordinateur. Les caractéristiques principales, des détails de programmation et l' organisation des archives est présentée. On essaie d'établir le profil de l' utilisateur et on décrit les expériences acquises lors de l'utilisation de ce système. Les conclusions traitent de la communication homme-machine et de la responsabilité de l' homme pour l'exactitude des calculs exécutés par l' ordinateur.

Zusammenfassung

Der Bericht behandelt ein umfangreiches Programmsystem für die elektronische Berechnung von Spannbetonbrücken. Es wird kurz der Leistungsumfang, Programmierdetails und die Dateiorganisation beschrieben. An eine Skizzierung des Anwenderprofils und der praktischen Erfahrungen, die mit dem System gewonnen wurden, schliessen sich Schlussfolgerungen zur Kommunikation Mensch-Maschine und zur Verantwortung für die Richtigkeit von Computerberechnungen.

1. INTRODUCTION

The requirements by the engineers concerning the accuracy and extent of computer calculations for prestressed concrete bridges increase ever more and computer programs appear to be an indispensable means.

The following paper deals with a software having been used since the year 1968 and being improved time by time. The programs were used many times for many different structures by many different users, concerning their ability to set up the input data and to understand the results. These experiences give way to make some generalizing statements on the application and use of such systems under real life conditions.

2. SYSTEM PERFORMANCE

2.1. General Remarks

As above said the computer can be only an aid for the engineer when designing a bridge. Therefore the general layout of the system was not done in a way that the computer grinds out a fully calculated and optimized bridge after feeding in input datas and parameters. An automatic and wholly integrated system surely would confine the freedom and the imagination for the design and the construction through the engineer and hinder the development of new ideas due to the necessary assumptions and rules of design that would have to be built into such a system. However, referring to the system described in this paper, the engineer can interrupt the computations at many states, repeat certain steps, maybe with altered input data, and drive the calculation of his bridge through the system like a car's driver on a crooked road. By doing so it is made sure that the engineer does not lose the immediate contact with the calculations and with the methods and algorithms being used in the programs.

The stock datas are the dimensions of the crossections, the magnitude and the coordinates of the prestressing force and the topological description of the structural overall system. They are fed in at the beginning, stored on a disc, and can be altered by ordinary procedures at any state of the work.

2.2. Short Description

Using the softwere dealt with in this paper the calculation of a complete prestressed concrete bridge can be carried through, beginning with the basic values of the crossection (area, static moments, moments of inertia etc.)and coming up with the behaviour of the structure under service and ultimate load conditions at the very end.

2.2.1. Structural System

It can be a plane frame or a plane girder grid. 3-dimensional frames are bent into a plane for finding the forces and reactions in the substructure. In dealing with the superstructure the columns are substituted by torsion bars with

$$I_x = I_y \,, \quad I_d = 2(1+\nu) I_x \,.$$

(Checks have shown the validity of this assumption for practical purposes many times.)

2.2.2. Shape of Crossection

T-shaped beam (load distribution to be known)
Single hollow box
Double hollow box

2.2.3. Input

Dimensions of crossection
Topological description of the structural system
Magnitude and coordinates of the prestressing force
Loads
Materials' properties

2.2.4. Results

Values of crossection (F, y_s, W, I, I_d)
Formwork levels
Dead load and prestressing forces and moments
Internal forces and deflections under dead load, wind, lowering of supports, temperature, earthquake (quasistatic method)
Lines of influence and their evaluation for bending, torsion and shear, considering corresponding single loads on grids, selecting the governing live load mix according to the Austrian building code B 4oo2

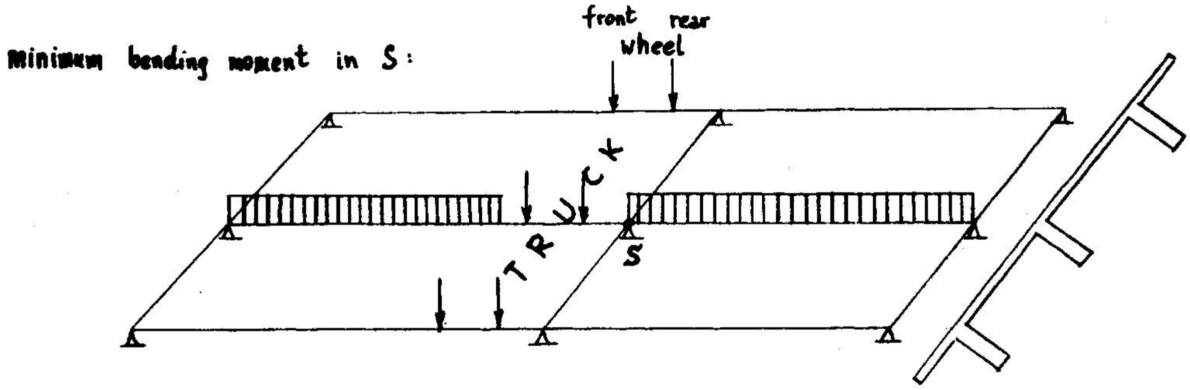

Fig.1: T-shaped beam: taking into account corresponding single loads by evaluating the lines of influence

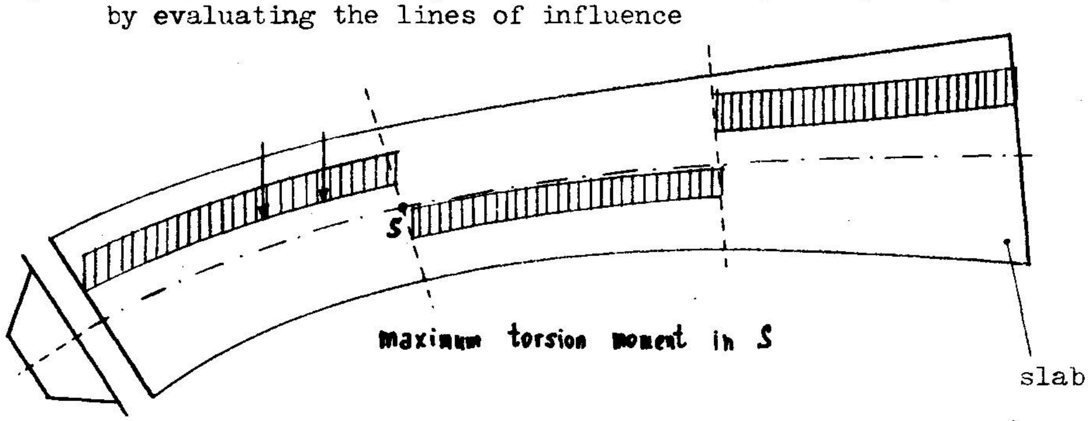

Fig.2: Box: selecting the governing live load mix (f.i. for MT)

Superposition and storage of the internal forces governing the states of construction and the final state under service load
Free cantilever states of construction
Timedependent development of prestressing forces, prestressing paths
Service load behaviour (bending stresses, shear stresses)
Ultimate load behaviour (ultimate moment, shear)
Stability of columns and the frame, 2nd order theory

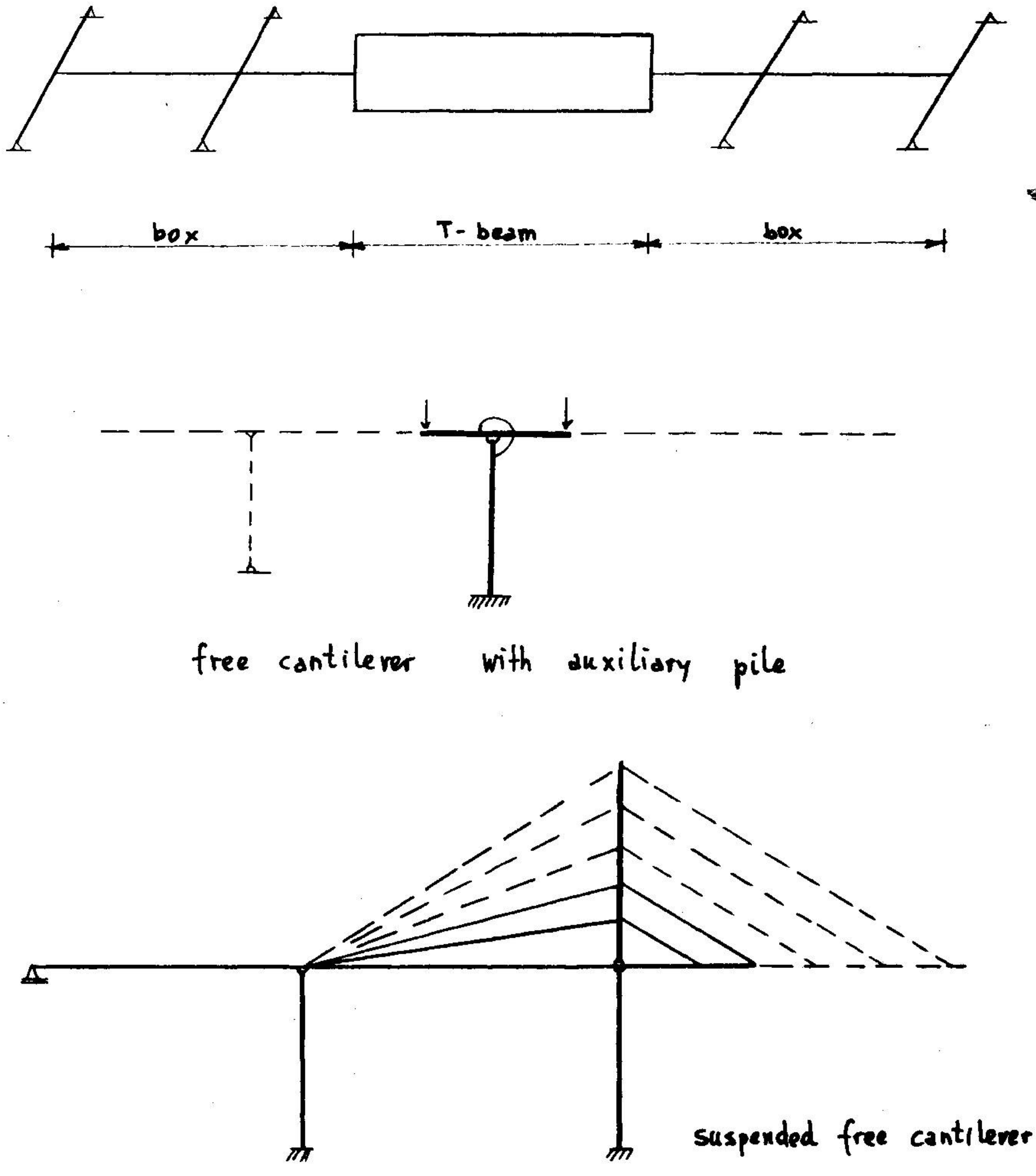

Fig.3: Examples of structural systems having been computed by the system

3. PROGRAMMING DETAILS

3.1. Programming language

The entire system was written in ALGOL. It consists of 36 programs with about 11.ooo statements altogether. The choice of ALGOL was given by coincidence and this was the biggest obstacle for a greater improvement and proliferation. The mainframer do not comply with the ALGOL specifications in many ways, as you know, and machine dependent implementations can be found many times. The specific language used for the system was ALGOL (SIEMENS) 3oo. For the below mentioned machines a conversion was planned but not done due to the enormous work that would have to be put in:

IBM /37o
CDC 3ooo,6ooo
UNIVAC 11oo
SIEMENS 7ooo

The greatest incompatibilities were found in the file handling and in the paper peripheries, due to the weakness of ALGOL concerning the input/output procedures. As is well known the basic deficiency of ALGOL is the lack of well defined and handsome input/output statements.

3.2. File layout

Fig.4 shows a makro data flow chart. There are 3 stock files:
- the GTV (geometry-, topology-, prestressing-) file
- the ESD (elastomechanic system data-) file and
- the MQT (bending-, shear- and torsion-) file.

The input for modeling the structure representing a specific state of construction (object structure), the load datas, the superposition commands and the commands for the evaluation of the lines of influence are to be considered as object datas. By doing so it is possible to build up the MQT-file stepwise by adding up the internal forces given in the specific states of construction and by choosing the live load mix leading to the extreme live load stresses.

The MQT-file consists of the following elements:

- dead load
- permanent load
- dead load creep redistribution
- prestressing
- prestressing creep redistribution
- max. live load bending
- min. live load bending
- max. additional load bending (wind, lowering of supports, temperature, earthquake)
- min. additional load bending
- max. live load shear
- min. live load shear
- max. live load torsion
- min. live load torsion

Each element consists of the 3 values for bending moment, shear force and torsion moment.

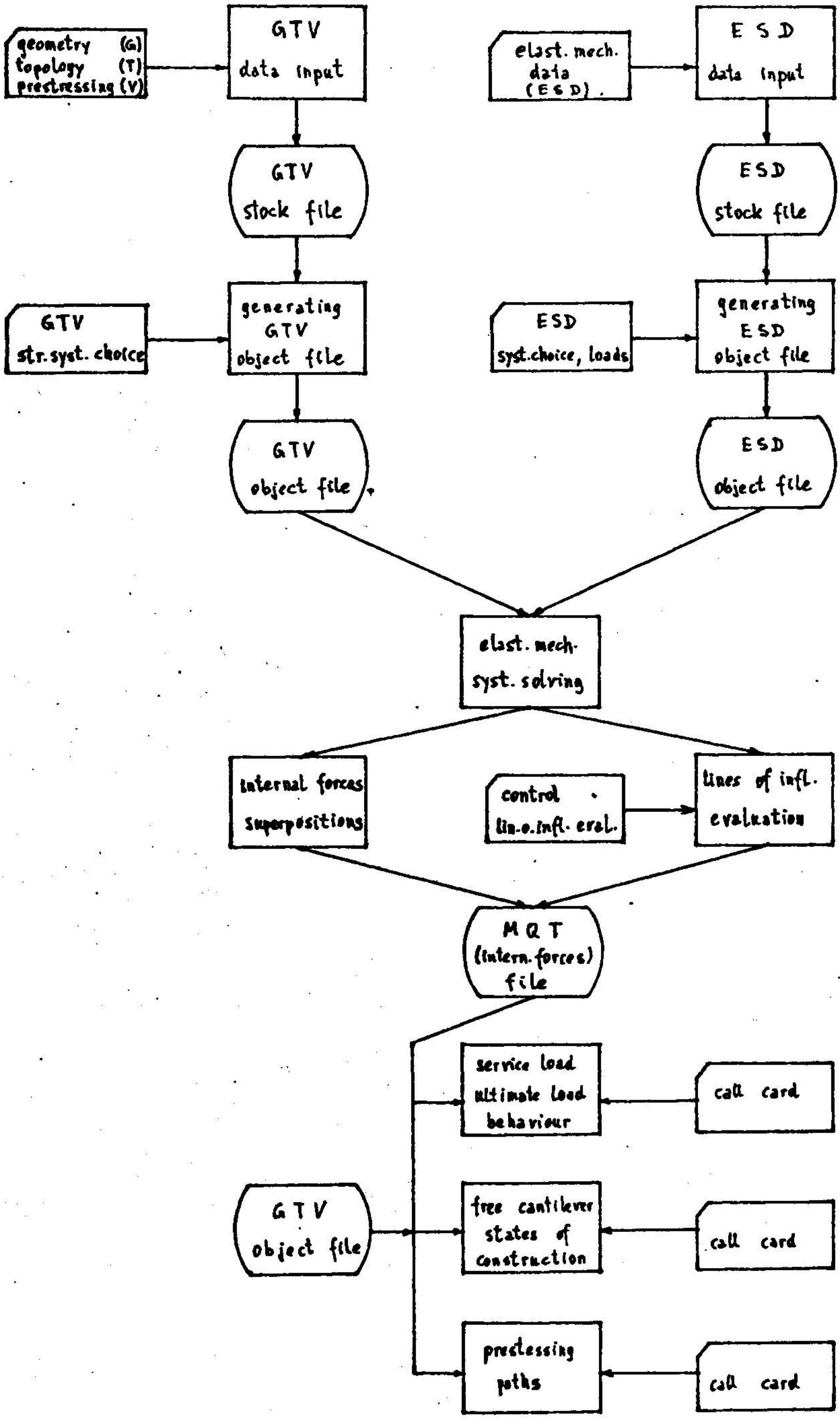

Fig.4: Makro data flow chart

The service load behaviour and ultimate load behaviour can be found easily by tapping the GTV-object file and the MQT-file taking into account the respective state of construction. In order to find out the maximum stresses under service load (for bending and shear), the calculations are made using the respective internal forces of the MQT-file. Fig.5 shows the makro flow chart and may give an idea about the flexibility of the system.

4. CONCLUSIONS ABOUT THE RELATION MAN-MACHINE IN DESIGN AND CALCULATION

4.1. Users' profile

From the beginning the system was developed for the use by 3 design departments at different cities of a large Austrian construction company. The 3 departments were staffed as follows:

Dept.1	Dept.2	Dept.3
7 university engineers	5 university engineers	6 university engineers
1o high school engineers	6 high school engineers	6 high school engineers
SIEMENS 3o4	SIEMENS 3o5	DIEHL ALPHATRONIC
closed shop operation	open shop operation	open shop operation

The SIEMENS 3o4 and 3o5 are middle computers, DIEHL ALPHATRONIC is a desk calculator (not running the system described here of course).

Dept.1 used the system seldom arguing that the closed shop operation does not allow a quasi-interactive handling of the machine. Furthermore was said the system does not allow for finding a quick and less accurate solution when working on a tender. That led to the development of a new small system on a NOVA 122o, a small computer, by dept.1. The NOVA was standing 2 floors above the SIEMENS.

Things were completely different in dept.2. Due to the open shop operation it was possible to modify the system in short time for specific purposes and it was used for every tender and for each structure that was under construction. The pressure to deal with the programs and to understand their programming motivated the engineers in dept.2 enormously.

Dep.3 was equipped with a desk calculator that could be used for rather small and subordinate calculations. Quick calculations for tenders were done at a near computer center in the same city. But some scruples were left that the preliminary calculations for tenders were not carried through confidentially. Therefore later on, the calculations were mostly done on the desk calculator, even if necessary with great inconveniences. Just difficult structures were sent to dept.1 to be run through the system.

Because the costs of developing such a software were high and the profit from the application could not be quantified it was decided to offer the use of the system to third persons. After some advertising there were some 3o customers, especially consulting engineers and design departments of other construction companies. They used the system many times more than the 3 departments altogether. The only restriction was that a customer working on a tender and simultaneously competing with the own company could not be served.. a matter of course.

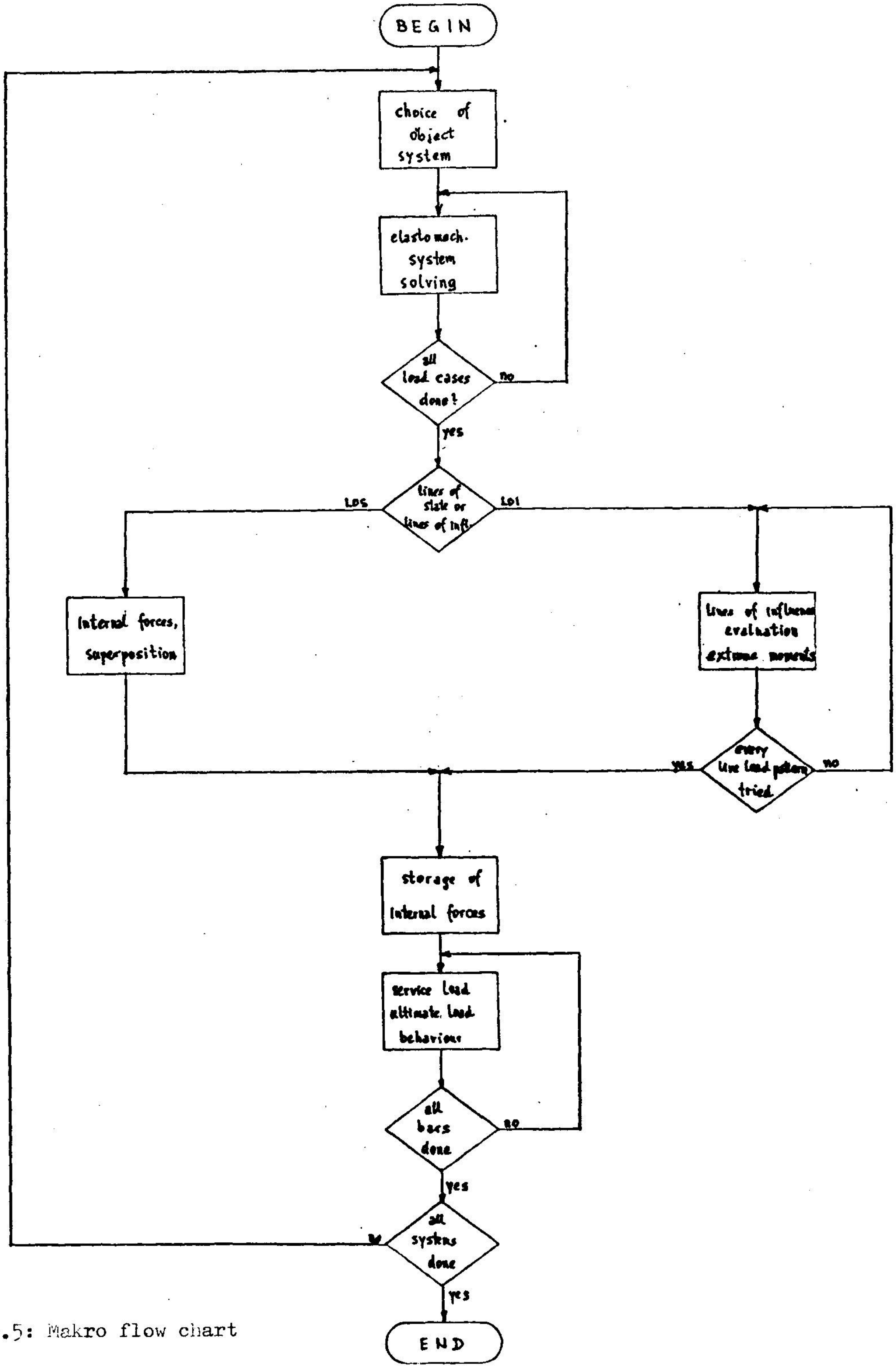

Fig.5: Makro flow chart

The users could be divided rather easily into 2 kinds:

The first kind of users was sending structural sketches, sketches of loads and the choice of materials (sometimes not even that) and left the choosing of the structural system and the setting up of the input up to the computer center. That required a deep understanding of structural behaviour from the computer man concerning the choice of the structural system, support conditions, rotational restraints and arrangement of auxiliary bars. This kind of user also did not bother to read the manuals and often times it was necessary to explain the results personally.

The second kind of users, the smaller amount, was sending input sheets filled up correctly and completely as was outlined in the manual. For this sort of people the input sheets were quasi the keys of the operator's console or the screen. They gave no problems at all.

The use of such a large and compound system required a high professional responsibility. The programs were tested before use widely that one can say almost no serious mistake occurred during the years. The mistakes were either wrong input or wrong file handling. In a covering letter (slip) to the results the customers were asked to check the input data and to control the results for plausibility. Errors of the computer center were undone by repeating the job without charge of course. A furthergoing liability or claims of compensation were excluded.

4.2. Conclusions

From the experiences that were made in 8 years of service we would derive the following rules:

On the interaction man-machine:

- The closer the computer comes to the user, the simpler the machine and the software can be handled, the more available the computer is, the better it can be used for the design and optimization of a structure. The small inhouse scientific computer is superior the terminal to a large outdoor computer.
- The larger and more compound a software system, the more reliable is a calculation under surveillance of qualified people, let us say people in a special service center. Finite element programs on small computers are wonderful but dangerous.

On the professional responsibility for calculations:

- A program without complete and detailed description by a manual should not be allowed to be used at all (lack of codes!).
- Input data have to be listed 1:1 (echo print). More complicate structural systems are to be plotted.
- Automatic plausibility checks help locating input errors or programming errors. Unfortunately they are found in few programs only.

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