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Computer Aided Design of Bridges Using STRAINS and KABE Systems

Project des ponts à l'aide de l'ordinateur et des systèmes STRAINS et KABE

Mit den Systemen STRAINS und KABE hilft Computer beim Brückenprojektieren

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Summary
The applications of two systems to facilitate the design of prestressed concrete bridges are presented. Examples of applications of STRAINS, a structural analysis system - to calculate the internal forces and KABE, a prestressed concrete design system - to determine the cable trajectories and the prestressing force are discussed. The examples of printer output and three colour BENSON drawings are given.

Résumé
On présente l'application de deux systèmes STRAINS et KABE qui facilitent l'établissement des projets de ponts en béton précontraint.
STRAINS : pour le calcul statique, KABE : pour la détermination des forces de précontrainte et de la position des câbles. Quelques exemples de sorties numériques et graphiques - trois dessins faits sur la table autotraçante BENSON sont présentés.

Zusammenfassung
Es werden zwei Systeme vorgestellt, die das Projektieren von Spannbetonbrücken erleichtern. Anwendungsbeispiele von STRAINS, einem Programm zur Berechnung der Schnittkräfte, und KABE, einem System zur Bestimmung von Kabellagen und Spannkräften werden behandelt. Beispiele der numerischen und der mehrfarbigen graphischen Ausgabe werden gezeigt.

1. INTRODUCTION

STRAINS /Structural Analysis Integrated System/ is a package of automatically operated programs for the analysis of the internal forces and displacements in the skeletal, surface or massive elastic structures. It was developed in 1970-75 with the aim to assure widest acceptance and good maintenance over a long period of time. It has two versions: STRAINS 71 and STRAINS 75. They differ by the scope of the problems which can be solved and by the hardware required to operate the system. [1], [2], [5].

KABE is a computer system for the design of prestressed bridges. It is available in two versions: KABE 73 and KABE 76. The difference between the versions is that the 76 version is equipped with the devices to facilitate data preparation. [3], [4], [6]. Both systems operate on ODRA 1300 series computers which are an equivalent of ICL 1900 series and are running under the ICL operating systems. To run STRAINS 71, KABE 73 or KABE 76 a 32k word core memory is required and 4 to 6 Magnetic Tape units, but not the random access memory. STRSINS 75 requires access to disc memory. Both systems operate in batch mode: they are simple yet effective, user-oriented and friendly.

2. CHARACTERISTICS AND FUNCTION OF THE SYSTEMS

2.1 General characteristics of both systems.

Both systems were intended for use in the Design Offices as well as in Civil Engineering Faculties: they had therefore to deal efficintly both with large and small size problems. Both of them have user-oriented languages.

2.2 STRAINS

The system is intended for the calculation of internal forces and displacements in trusses, frames /both plane or space/, gril lages, plates, plates in bending, shells, solid three dimensional structures and structures composed of bars and shell elements. It can deal efficiently both with large and small size problems of analysis, leaving out only the not so often encountered problems of more than 6000 Degrees of Freedom to be computed using other systems of analysis.

STRAINS is not only user oriented but is also very friendly. The command GENERATING causes an incremental metod of data generating to be used.

In the extreme case of the regular, straight line grids, the entire data needed for the node numbering and the definition of nodal coordinates can be given in just three lines for any plane structure and in four lines-for a space structure.

Similar generator can be applied to the description of the topology.

In the case of more complicated, but regular grids the user can either devise his own data genetaring program or use data prepared independently and input it via the magnetic or paper tape, using the command EXTRA INPUT.

The problem-oriented language compiler checks the input data for errors and in the cases they occur, a message is output.

Geometrical and topological errors can be spotted at a glance in a picture output on the line printer. The errors can be corrected by writing just a few lines.

The data can be easily modified, changed, added or deleted in subsequent computer runs.

In fact, this is the nearest one could get to the interactive mode, without actually having the necessary hardware.

The form of the printouts /both formats and tables/ is automatically adjusted.

When the user wants to limit the amount of printouts, he can specify the required results.

The scale of the line printer sketch as well as the scales of the plotter drawings are automatically adjusted, so thet only one command DRAW is needed.

In the rare cases only when the drawing output is expected to be / or found to be / unsatisfactory, the user can give his own specifications concerning the scale and - in the case of space structures-the viewing angle.

The graphical output received special attention.

In the case of Finite Element Analysis, a map of stresses can be produced on the line printer.

Owing to the fact, that not all computer users have direct access to the plotters and also to save computer time, the graphical output of STRAINS is registred on a Magnetic Tape and processed off-line on a plotter /in our case it is a BENSON 122 drum plotter/.

A two-level program structure has been devised, hovewer, to make the graphical output device - independent.

Some examples of the graphical output available are shown in the examples.

At the moment STRAINS-75 is operational on ODRA 1300 series, ICL 1900 and 2900 series computers. In particular, it runs very well under George 2 and George 3 operating systems,and on ICL 2903 mini, although in this last case the computing times are fairly slow owing to the 1900 emulator.

STRAINS-75 is installed in some 11 out of the 15 Civil Engineering Faculties in Poland and in about 15 other computing centres, serving regularly some 30 Design Offices and occasionally further 40 or 50.

2.3. KABE

The other system developed at the Institute for Highway and Bridge Design, is KABE-76 - a system for the preliminary design of the prestressed concrete bridges.
The statical scheme of the bridge is a multi-span beam.

It may have varying cross section along the span.

The system can cope with any shape of cross-section as long as it can be described using less than a 100 points with straightline connections between them.

Each span is automatically divided into 10 equal parts: all 10 cross sections at these points can be different from each other. The dead loads include self weight, continuous load along the entire span /due, for istence to road surface or track ballast/ and point loads /due to pipe hangers/.

The moving loads include the standard road - rail - or tramway loading as well as "special loading", consisting of up to 30 point loads of arbitrary magnitude and spacing.

The results at each of the 10 points along every span include:

- cross section propertes
- envelope lines for Bending Moments, Shear Forces and support reactions for each type of the moving load
- maxima and minima for the combinations of loads
- parameters of the permissible cable zone
- prestressing cable trajectory
- extreme values of the prestressing forces
- stresses in top and botton fibres
- quantities of the prestressing steel and concrete for each of the four values of the prestressing force.

The system is composed of a problem-oriented language compiler and 9 programs, of which one provides the graphical output.

In the initial stages, system KABE was very much different from STRAINS and had no problem-oriented language.
The experience gained during the several years of using both systems brought KABE more into line with STRAINS as far as user-system interface is concerned. From the point of view of hardware, KABE is similar to STRAINS in that it is operational on ODRA 1300 and ICL 1900 and 2900 series and runs well under GEORGE 2 and GEORGE 3 operating system.
32 K words core capacity only is required.

The latest development of KABE is its inclusion in a large system for checking the strength of the existing bridges under extra-ordinary loading. KABE is used to compare, point-by-point, the Bending Moment and Shear Force envelopes under the standard and under the special loading. In case the values of special loading envelopes exceed those of standard loading, the warning is output and the bridge is considered unsafe for that particular special load.

3. EXAMPLES OF APPLICATION

3.1 STRAINS

3.1.1 The analysis of the internal forces in a space frame bridge.

A space frame bridge in which same nodes are pin-jointed was analysed. The structure consists of 143 joints and 296 bars. The fragments of the program are shown in Table 1. The printer sketch is shown in Fig.1

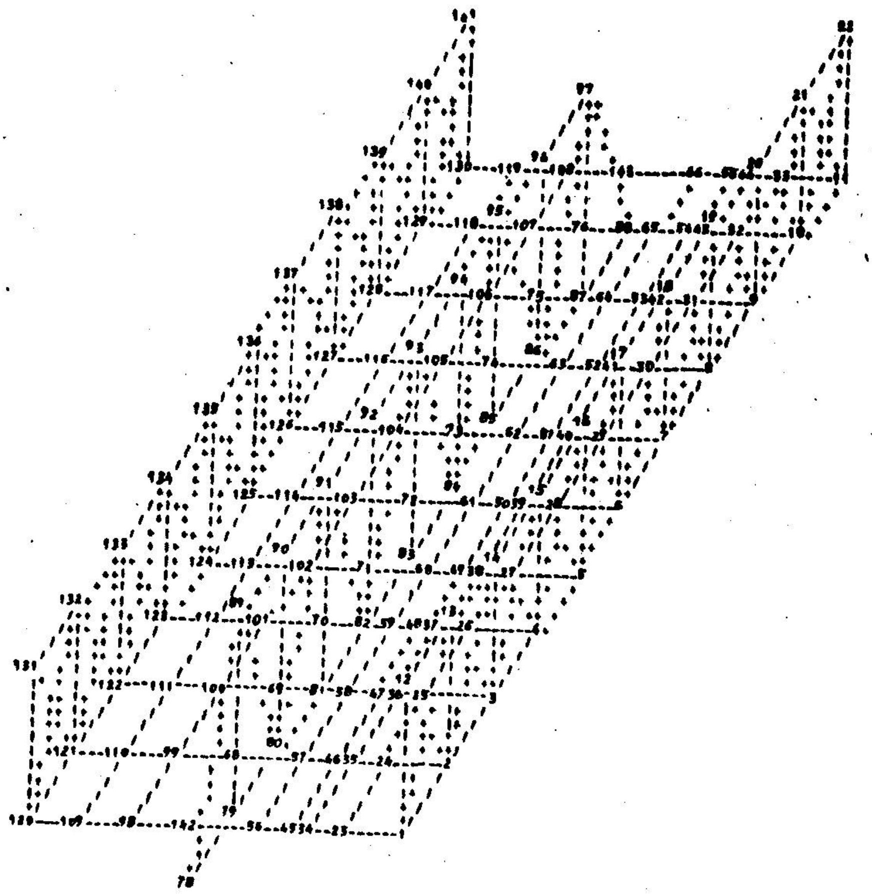

Fig. 1. The printer sketch of a large steel bridge frqme.

```
'STRUCTURE' MOST T-2
'TYPE''SPACE FRAME'
'JOINTS'143
'ELEMENTS' 296
'STIFNESS METHOD'
'GEOMETRICAL DATA'
'JOINT COORDINATES'
1,1120,0,0,
2,1120,361,0,
3,1120,722,0,

'SYSTEM OF ELEMENTS'
1,1,2,
2,2,3,

296,117,128,
'PROPERTIES'
'ELEMENTS''E''V''ALPHA'
'ALL'2100000,0.3,0,
'ELEMENTS''A''IY''IZ''IX'
4,41,42,191,210,98.8,11889,22691.56,

9,121,122,123,124,125,126,127,128,129,222.4,46803,47541,420,
'ALLREST'303,2,568930,5711,765,
'BOUNDARY CONDITIONS'
1,120,'FIXED IN' 'Y' 'Z'
78,142,'FIXED IN''X''Y''Z'

'LOAD DATA'
'JOINT LOAD'
1,11,'Z',1875,
2,10,'Z',2860,

106,119,'Z',7220,
33,44,55,66,'Z',3610,
'GEOMETRICAL OUTPUT'
'JOINT ROTATIONS'
'JOINT DISPLASEMENTS'
'INTERNAL FORCES'
'SOLVE'
'END'
```

Table 1. A fragment of STRAINS program.

3.1.2 The analysis of the internal forces in the web of a prestressed concrete beam.

A diafragm of a box section highway bridge was analysed. Out of a complete set of the results consisting of printouts, printer graphics and the graphical output, drawing obtained on BENSON 122 graph plotter are shown in Fig. 2, 3 and 4.

3.1.3 Analysis of a plate in bending type of viaduct

A plate in bending viaduct was analysed. A printer scatch of stress distribution is shown on Fig.5.

3.2 KABE

3.2.1 An analysis of a prestressed concrete highway bridge.

An analysis is carried out of the internal forces under the Polish Standard Road Loading and calculation of the excentricity and the prestressing force.

Fragment of program is shown on Table 2. The results are output on the printer and graphplotter.
The drawings of the beam cross section influence lines of bending moment and the cable trajectory are presented in three colours as the graphical output /Fig.6,7,8/.

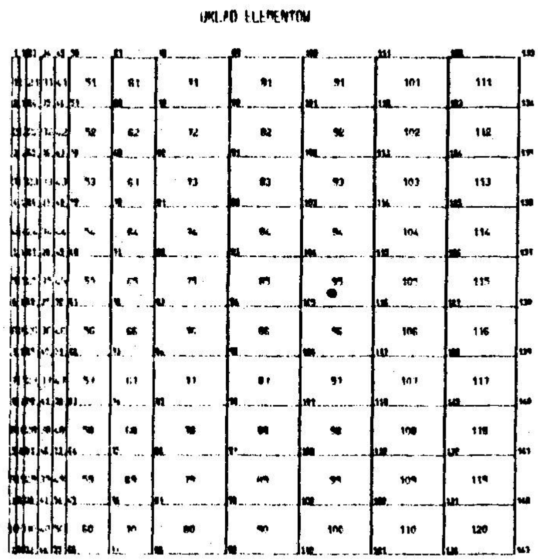

Fig.2. Division into finite elem.

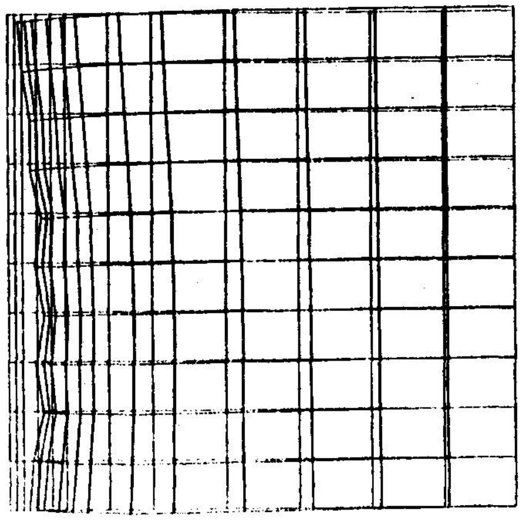

Fig.3. Deformation of the web

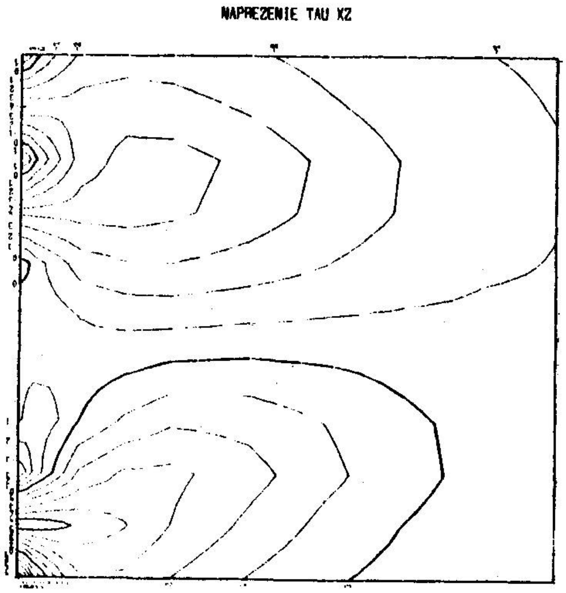

Fig.4. TAU XZ stress distribution

3.2.2 An analysis of a prestressed concrete railroad bridge

An analysis of internal forces under Polish Standard Railroad Loading and calculation of the excentricity and the prestressing force is carried out. The results are output on the printer and graph plotter. The printer sketch of the beam cross section is show on Fig. 9.

```
    TRANSLATOR JEZYKA *KABE* IDIM PW        DATA:06/06/78
   *MOST DROGOWY,PRZYKLAD NR 1,PRZEKROJ SKRZYNKOWY,
   *LICZBA PRZESEL 3
   *DANE GEOMETRYCZNE
   *ROZPIETOSCI 56 70 56
   PRZEKROJE POPRZECZNE
   *PARAMETRY PRZEKROJU 1
   LICZBA WEZLOW 21
   *WSPOLRZEDNE    NR X Y
   1 0 0
   2 13,5 0
   *CIAGLE 2,52,2
   *CIAGNIK D
   *KROK ITERACJI 0,5
   *OBCIAZENIA NIERUCHOME
   *PRZESLOWE CIAGLE
   *WSZYSTKIE PRZESLA 3,0
   *WYNIKI
 *SPREZENIE
   *OTULINA DOLNA 0,15
   *OTULINA GORNA 0,2
   *KONIEC
```

Table 2. A fragment of KABE program.

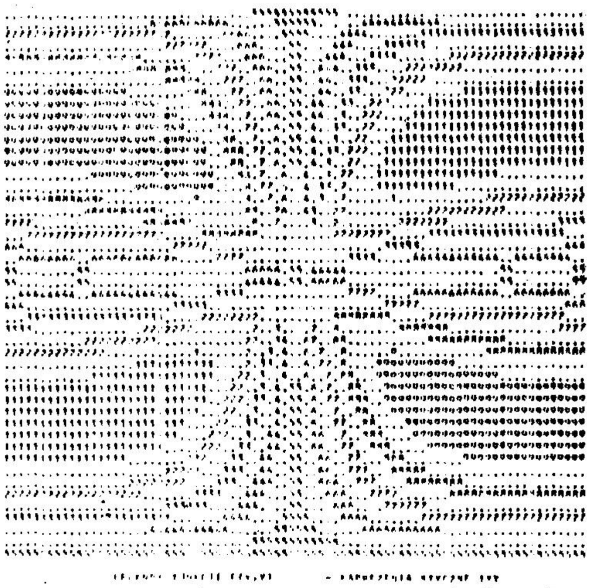

Fig.5 A printer sketch of TXY stress distribution

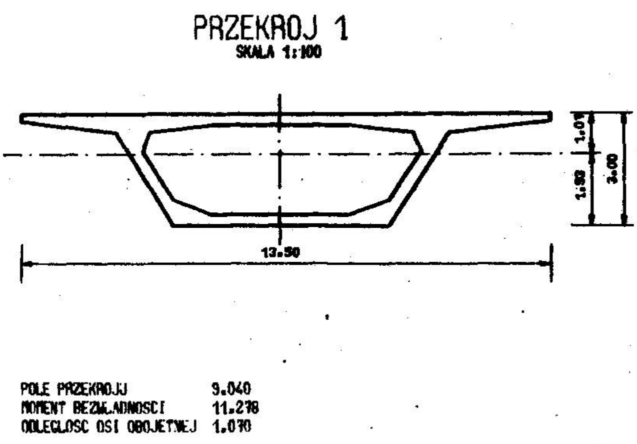

Fig.6 A drawing of the beam cross section

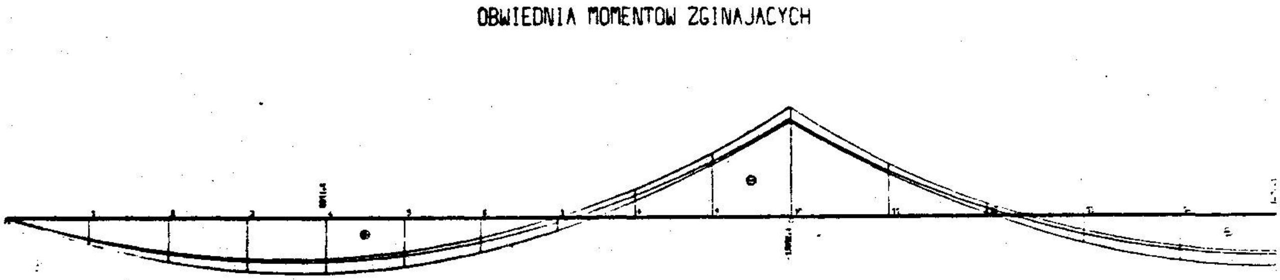

Fig.7. A bending moment diagram.

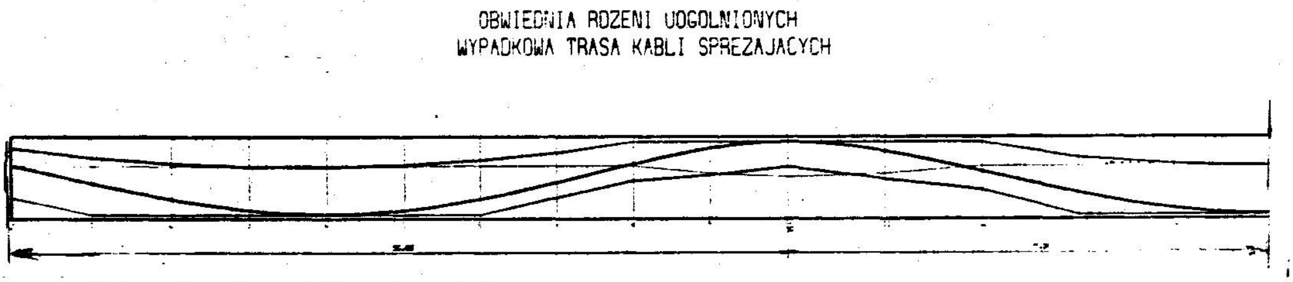

Fig.8. A cable trajektory in prestressed beam.

4. CONCLUSIONS

Both systems, STRAINS and KABE afford a very good interface between desigmer and computer. They are suitable to the medium size computers.Thanks to the problem-oriented languages they are friendly and easy in application.

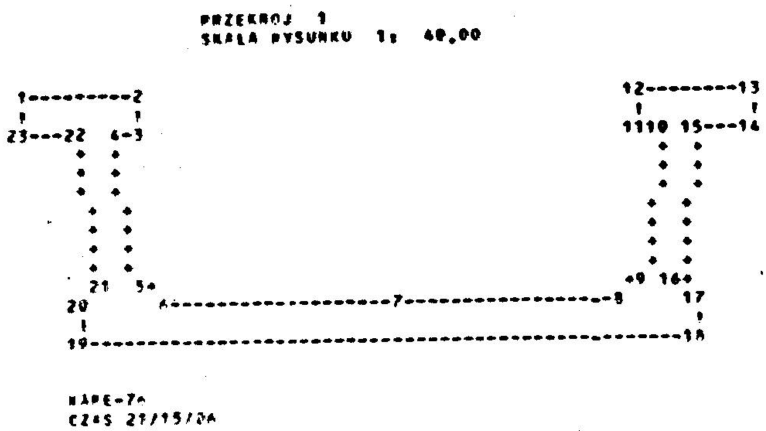

Fig.9. A printer sketch of the beam cross section.

Thanks to the two parallel language versions they may be used in other countries where, instead of the Polish language, other language versions could be used.

Thanks to the printer sketches and three-colour plotter output, the results produced by both systems are very easy to grasp and any mistakes can be easily located.

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