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16. Abstract

Computer program BMCOL51 performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads. Enhancements are made to an existing FORTRAN code using currently available hardware and software. The original code runs on a minicomputer with alphanumeric terminals, while the enhanced version runs on a microcomputer with an improved user interface that includes panel-oriented input and extensive use of graphics. Low-level assembly language routines are written to provide functions for manipulating screens, while calls to a commercial software package provide functions for graphical capabilities. The existing code is integrated with the new program as a subroutine, but no other modifications are made to facilitate avoidance of new error sources. Panel-oriented input eases the user's burden of creating and editing problems. Graphical representation of input data allows error-checking before execution of the code. In addition to the conventional numerical presentation, output data from analysis is also displayed graphically. A menu structure controls access to various capabilities of the software package. FORTRAN 77 is used as the primary language for new code development.

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Graphically-Oriented Analysis of Beam Columns with Movable Loads on Microcomputers

by

Paul N. Roschke
Assistant Research Engineer

Brian Epperson, Syed Aftab
Graduate Research Assistants

Research Report 1183-1

on

User-Oriented Analysis Packages for Bridges
Research Study No. 2-5-88-1183

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

The United States Department of Transportation
Federal Highway Administration

December, 1988

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3136

METRIC (SI*) CONVERSION FACTORS

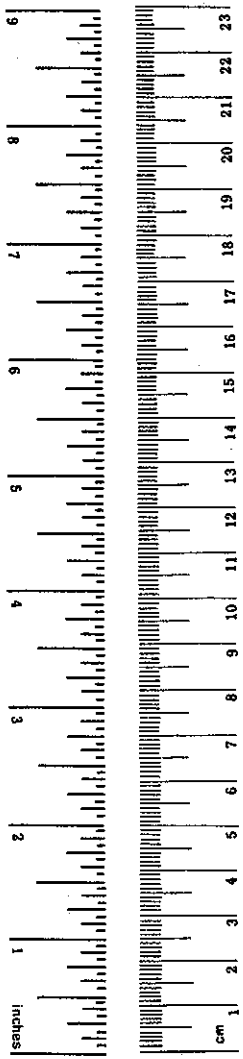
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

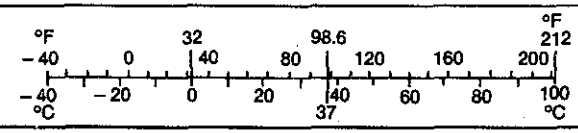


APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

Computer program BMCOL51 performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads. Enhancements are made to an existing FORTRAN code using currently available hardware and software. The original code runs on a minicomputer with alphanumeric terminals, while the enhanced version runs on a microcomputer with an improved user interface that includes panel-oriented input and extensive use of graphics. Low level assembly language routines are written to provide functions for manipulating screens, while calls to a commercial software package provide functions for graphical capabilities. The existing code is integrated with the new program as a subroutine, but no other modifications are made to facilitate avoidance of new error sources. Panel-oriented input eases the user's burden of creating and editing problems. Graphical representation of input data allows error-checking before execution of the code. In addition to the conventional numerical presentation, output data from analysis is also displayed graphically. A menu structure controls access to various capabilities of the software package. FORTRAN 77 is used as the primary language for new code development.

DISCLAIMER

KEY WORDS
Beam, Column, Computers, Finite-element, Software, Graphics, Microcomputers

ACKNOWLEDGMENTS

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IMPLEMENTATION STATEMENT

Results of this study are available for immediate implementation by the Texas State Department of Highways and Public Transportation. Other states may want to realize benefits from this study.

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I. BACKGROUND AND SIGNIFICANCE OF WORK

Since the time when many of the current bridge analysis codes in use by SDHPT were written, substantial advancements in hardware and software have been made. Both minicomputer and microcomputer equipment with large memory and graphics capabilities have been installed for use by bridge engineers. Faster compilers and graphics routines are available for software modification.

In view of these changes, the purpose of this research is to use currently available hardware and software to enhance existing analysis programs toward optimum usefulness for design engineers. As a general method of approach, languages and routines which are within the mainstream of engineering and scientific computation are employed. In light of SDHPT maintenance requests, FORTRAN 77 is used as the primary language for new code development, and it remains the mainstay of numerical calculations. Special-purpose, low-level routines are written in assembly language. They are isolated for facile identification should future hardware dependent changes require maintenance of these portions of the code. This report describes enhancements to an analysis code, BMCOL51, which performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads.

This is the first in a series of reports that document enhancements to four existing analysis codes used at SDHPT. This report describes modifications to analysis code BMCOL51.

II. INTRODUCTION

Computer program BMCOL51 simulates a beam-column subjected to movable loads [1]. While the original code performs its intended analytical functions, it is written without programming enhancements, such as color graphics, which can simplify data input at the preprocessing stage and graphically summarize output. Engineers currently must sift through large quantities of numerical data in order to interpret results. Other than painstakingly "checking" by hand, no facile means of verifying geometry, material, and support locations is available to an analyst before execution of the code.

The current analysis code has been enhanced towards optimum usefulness for design engineers. Analysis portion of the code is left unmodified to avoid introduction of new error sources. Capability to directly manipulate screens has been included to provide a highly interactive system which is easy to use. Panel-oriented input provides a simplified way of entering data. Graphical capabilities complement panel-oriented alphanumeric input by providing a quick,

visual verification of data. Output from the analysis is available in both alphanumeric or graphical form. Comprehensive error trapping is also provided.

These additions to the BMCOL51 code provide the user with a program that is not only executable at the engineer's own desk (saving numerous trips to remote terminal locations), but also through panel-oriented input and graphics capabilities, allow error checking before the analysis code is executed. Graphical output also provides rapid access to important design parameters, without having to interpret large quantities of numerical data.

In what follows, salient features of the new, complete BMCOL51 code are described by means of narrative and photographs taken from a microcomputer screen. A sample session guides the first time user in execution of a typical problem. Finally, an installation procedure is described which transfers the program from diskette media to an executable location on a microcomputer.

III. DESCRIPTION OF PROGRAM

The new software package for BMCOL51 utilizes a menu structure for accessing and controlling execution of the program. Various capabilities of the software are divided into the following six (6) modules:

1. FILE INFORMATION
2. EDIT/INPUT DATA
3. PREVIEW GRAPHICS
4. RUN ANALYSIS
5. ALPHANUMERIC RESULTS
6. GRAPHICAL RESULTS

These major subdivisions of the program are integrated together under a master menu structure which allows the user easy access to various capabilities of the program. Pertinent file information (current input file, current output file, and problem number) is also displayed on the main menu (Fig. 1). The original BMCOL51 analysis code is integrated into the menu structure by means of the module RUN ANALYSIS.

These six modules and their subdivisions are described in the following sections.

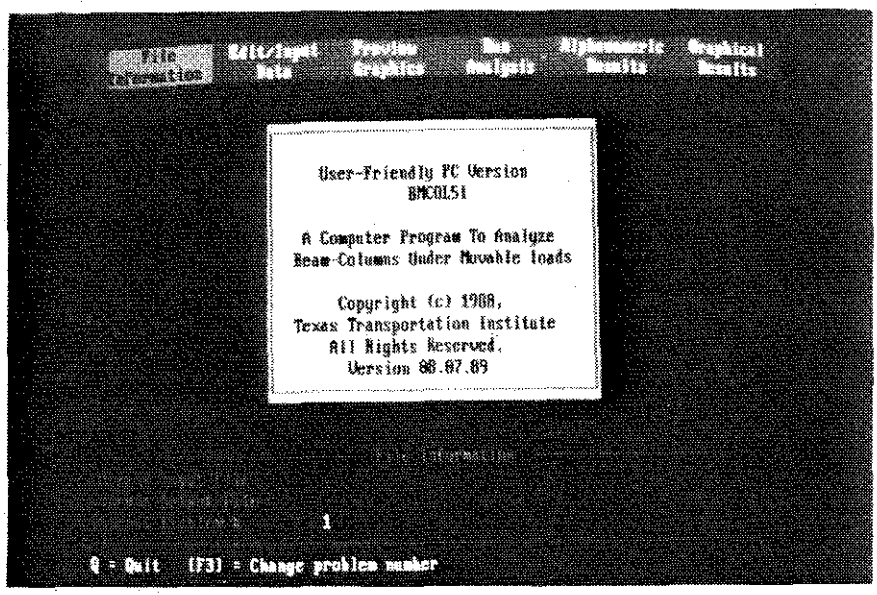

Fig. 1 Main Menu and Screen Layout

1. FILE INFORMATION

In order to execute BMCOL51, an input file which describes geometry, material, loading, etc. must be prepared. Names for these files must follow naming conventions specified by the Disk Operating System (DOS). After execution, results of the analysis are placed in an output file for subsequent review, printing, or plotting.

The FILE INFORMATION module aids the user in preparation and manipulation of input and output files. Five selections are available to the user from within this module's menu (Fig. 2):

a) **Change Input File** - The user specifies which input file is to be used by entering a filename by means of the keyboard. The default filename for this case is left blank, until the user assigns a specific filename.

b) **Change Output File** - The name of the current output file is specified by selecting this option. The default filename for this case is left blank, until the user assigns a specific filename.

c) **Change Problem Number** - This option allows the user to assign problem numbers within the input file (see Reference 1 which refers to the unlimited

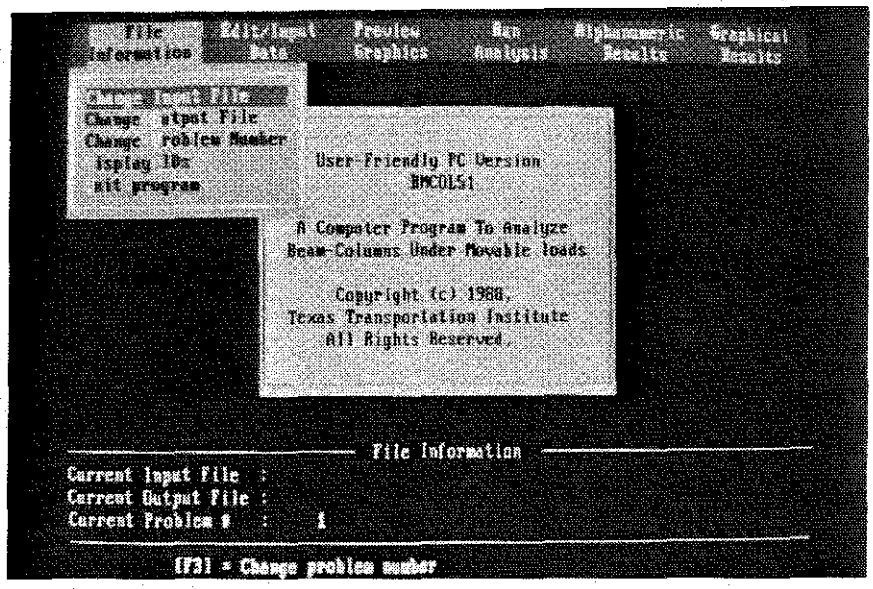

Fig. 2 Submenu "File Information" Module

number of problems allowed). Because this option is used so often, a keyboard function key (F3]) is programmed so that its use allows for changing problem numbers from within any menu module. The default problem number is one (1).

d) Display Problem ID - This option displays problem identification numbers in the current input file along with each problem number's description (Fig. 3).

e) Quit - Program execution can be terminated using this option. Pressing the letter "Q" from within the main menu also performs the same function.

It should be noted that for the first three options, all changes in file information, are immediately updated on screen and internally within the code. For this reason, file information displayed on the main menu is always up to date.

2. EDIT/INPUT DATA

This module provides for creation of new input data files and modification of existing data files. The first six entries in this submenu allow the user to

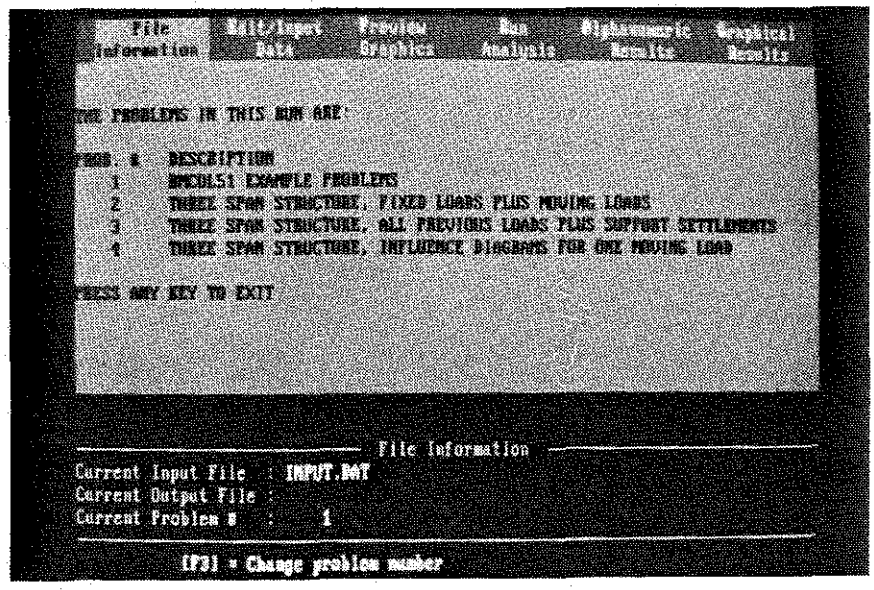

Fig. 3 Problem ID Display

view and/or edit data for the six input tables referred to in Ref. 1 (Fig. 4). Examples of these tables are shown in Section IV, Sample Session.

When any one of the tables is selected, data from that table for the current problem number is displayed. The user can easily move between fields on any screen by using the up, down, left, and right cursor keys. The current field is highlighted. If the user begins typing a new value for the current field, it is written to a buffer which is simultaneously displayed at the top left of the screen. When the user presses the enter key, the value in the buffer is written to the current field. If the user presses any of the cursor keys, the value displayed in the buffer is written to the current field and the highlight is moved from the current field to a new field, depending on which direction was previously indicated by the cursor key. If at any time while the user is typing data into the buffer, the [Esc] key is pressed, the buffer is cleared and no changes are made to data on the screen.

Another way to modify data on the screen is to press the [F2] function key. This transfers data in the current field to a buffer which is displayed at the top left of the screen where it can be edited. Once data has been transferred to the buffer, left and right cursor keys can be used to move within the buffer.

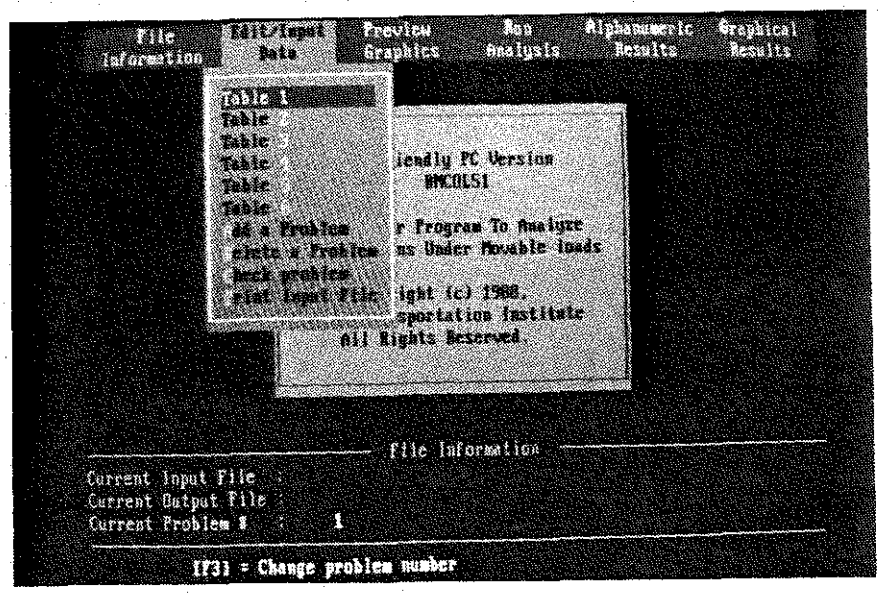

Fig. 4 Submenu "Edit/Input Data" Module

The [Delete] key erases the character above the cursor, while the [Backspace] key erases the character immediately to the left of the cursor. Numbers or letters typed will be inserted at the current cursor position. As before, if the [Enter] key is pressed, data in the buffer is transferred back to the current field. If the [Esc] key is pressed, the buffer is cleared and the original data remains unchanged.

An input file can contain more than one problem as described in Ref. 1. Problems can be added or deleted from the input file by means of this submenu. When the user selects **"Add a Problem,"** the program prompts the user for the problem number to add, and then adds this problem to the input file (Fig. 5). When the user selects **"Delete a Problem,"** the program prompts the user for the problem number to delete and then removes the specified problem from the input file.

Error checking of the input file can be accomplished through the **"Check Problem"** option. This option checks the current problem in the current input file for errors and displays any errors that occur (Fig. 6). The user can then quickly change the input data as described above to correct these errors.

The input file can be sent to a printer from within BMCOL51 by selecting the last option on this submenu, **"Print Input File."** Options LPT1, LPT2, COM1,

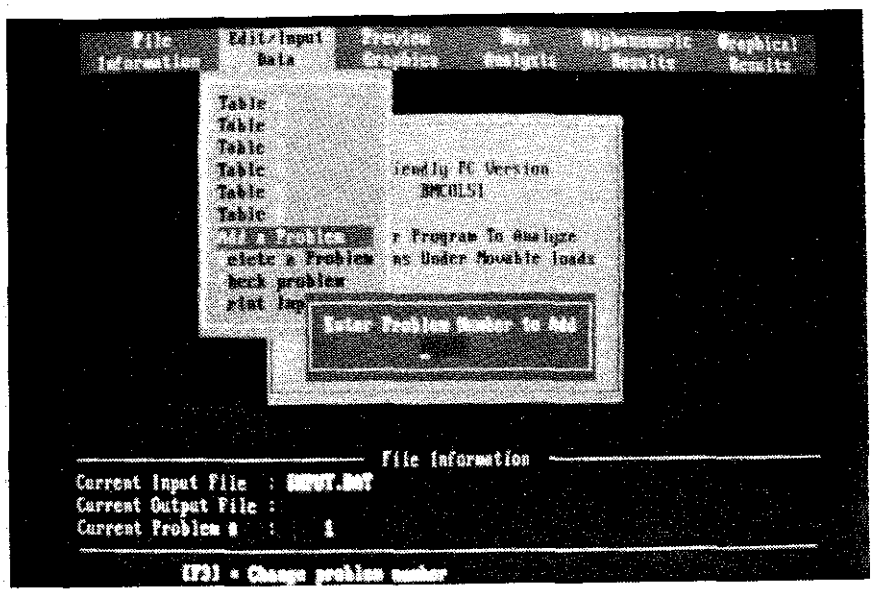

Fig. 5 Addition of Problem to Input File

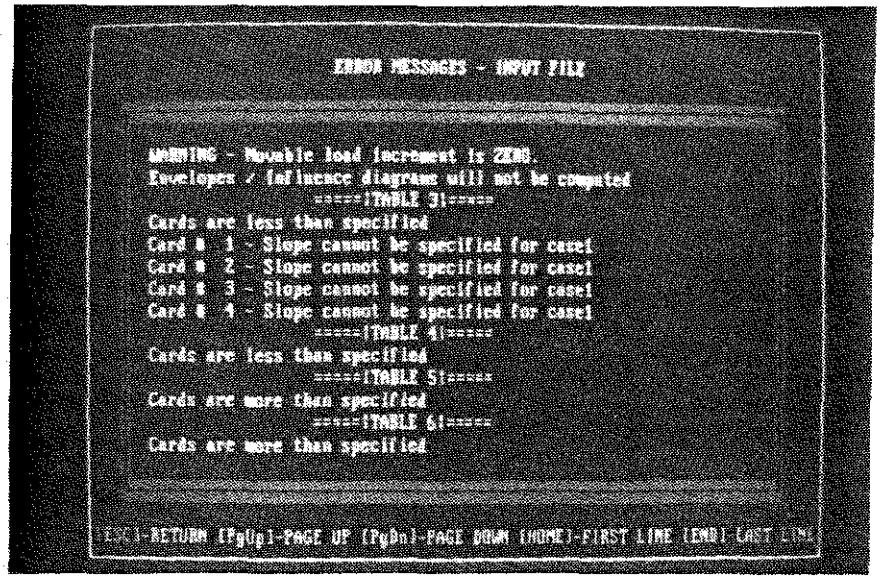

Fig. 6 Error Messages - Input File

and COM2 in the submenu (Fig. 7) refer to the communications port assigned to the printer connector from within DOS.

3. PREVIEW GRAPHICS

This module reads the current input file and reports important input data in graphical form. It provides the user with a quick visual check of the input data so that simple errors can be detected before execution of the analysis code. No logic is provided in this module to check errors for input as required by the BMCOL51 analysis code. The input file is read and the data is simply displayed (for format checks of input file refer to **"Check Input FIle"** option in **EDIT/INPUT DATA** module). The module is subdivided further as follows (Fig. 8):

a) **Support Geometry** - This option displays (1) the beam and its supports and (2) the fixed loads acting on the beam. Three types of supports are shown on the beam. The first type is a fixed support which is shown as a knife edge. Rotational restraints are shown as circular springs while spring supports resisting displacements are shown as conventional springs. Station numbers of the supports, as well as direction and magnitude of axial loads acting at the ends of the beam, are shown.

Fixed loads acting on the beam are shown as point loads located at discretized station numbers. Magnitudes read from Table 4 of the input file are interpolated to get these discretized loads [1]. Sign conventions are identical with those used in the original BMCOL51 code. Magnitudes of absolute maximum and minimum are also displayed for quick reference. If no fixed loads are specified, the graph is replaced with a message indicating this fact.

b) **Flexural Stiffness** - This is a graph of the flexural stiffness of the beam along its length. The flexural stiffness values from the input tables are also interpolated to get actual magnitudes [1]. Magnitudes at each station are then connected linearly to complete the graph. Maximum and minimum values are also shown. Station numbers of supports are displayed along the x-axis.

c) **Movable loads** - Movable load data is shown in this graph. Numerical values of the movable load are displayed at discretized station numbers for the entire load. Sign conventions used are identical with those of the original code [1]. Absolute maximum and minimum values are also displayed. In case no movable load is specified, a message is displayed to this effect.

An example of the usage of this module is described in Section IV (Sample Session).

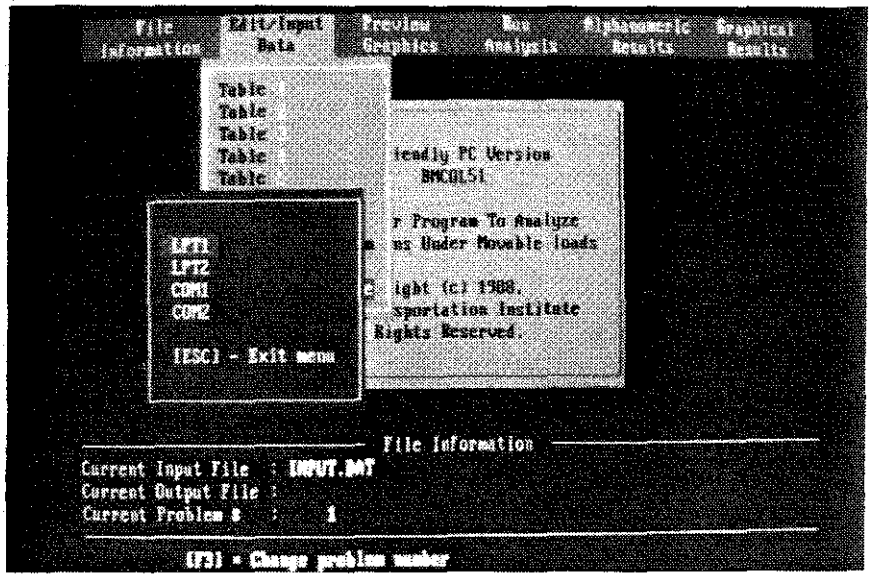

Fig. 7 Port Selection Screen

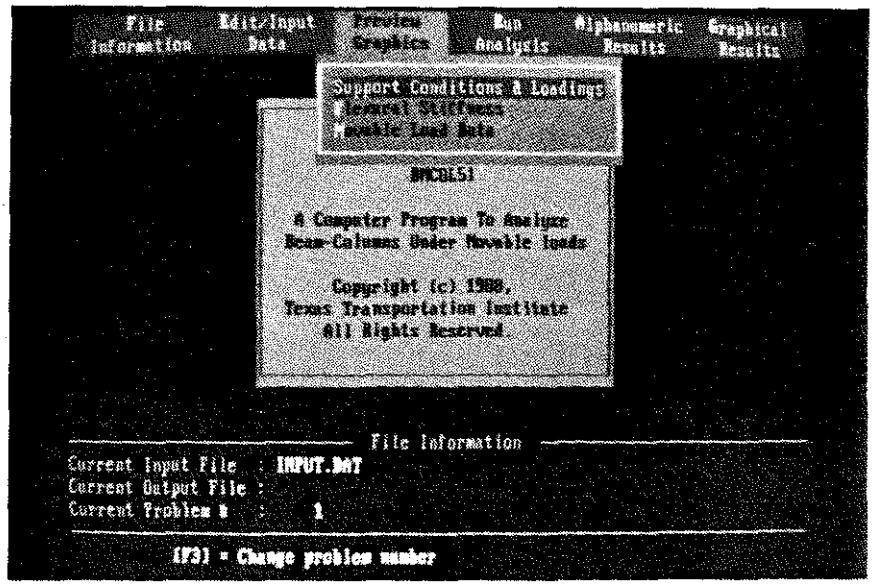

Fig. 8 Submenu "Preview Graphics" Module

4. RUN ANALYSIS

Selection of this option triggers execution of the analysis code with the specified input data file. In this implementation, the original BMCOL51 analysis code is a subroutine which runs at the command of this menu selection. Although modification to BMCOL51 is minimal, the READ and WRITE statements have been changed to allow reading and writing to the specified input and output files, respectively. If input and output files have not been specified, they can be input at this stage.

A message is overlayed on the display screen to keep the user informed as to the problem number currently being solved. Error messages check the validity of the input and output files specified by the user. No other changes have been made to the code itself in order to avoid introduction of new error sources.

Execution time varies, depending on the number of problems in the run as well as the size and complexity of these problems. Typical runs such as the Sample Session analysis require approximately six seconds on an IBM PS/2 Model 80 running at 16 megahertz.

5. ALPHANUMERIC RESULTS

This module allows the user to view alphanumeric results output by the analysis part of the code. Alphanumeric results are useful if the user needs to determine the exact value of a result at a particular point, while graphical results are more useful for visualizing overall behavior of forces or deflections over the entire length of the beam.

Results of BMCOL51 are divided into seven (7) tables, whose numbering follows that of Ref. 1. Table 7 contains deflections, slopes, moments, shear forces, and support reactions due to fixed loads. Table 8a contains envelopes of maximum deflections and moments. Table 8b contains envelopes of maximum shear and reactions. Tables 10a, 10b, 10c, and 10d specify influence diagrams for deflection, moment, shear, and reaction, respectively (Fig. 9).

The user can select an individual table for viewing from the menu. Each table is presented on a separate screen and allows the user to scroll through data using up and down arrow keys, and [Page Up] and [Page Down] keys. Each table also shows the problem number. A printout of the specified output file can be obtained by selecting the **"Print Output File"** option in this module. Printing is set up for a 132-column printer. After printing is complete, the user has the option to either keep or delete the output file.

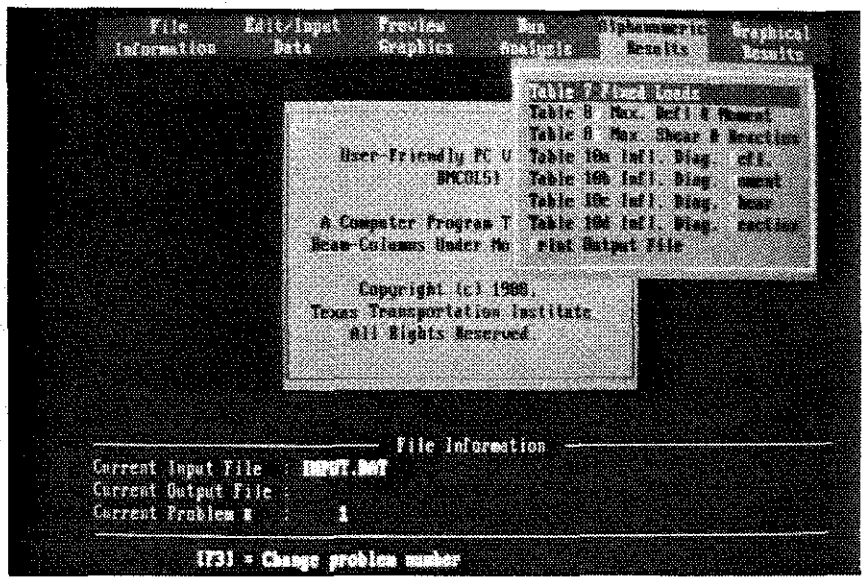

Fig. 9 Submenu "Alphanumeric Results" Module

6. GRAPHICAL RESULTS

Graphical output from results of the analysis is presented under this option. Two fundamental kinds of graphs are provided: (1) an envelope diagram, and (2) an influence diagram. These graphs display four different parameters: deflection, moment, shear, and reaction (Fig. 10). Indicated on each graph are maximum and minimum values of the parameter plotted. The graphs also include problem identification and number, parameter plotted, X and Y axis scales, and station numbers of supports.

a) Envelopes of Maximum - Two variables for each parameter are graphed in this category. One is the envelope of maximum values and the other is the envelope of minimum values. The maximum is represented by a red curve while the minimum is represented by a white curve (for meaning and definition of the maximum and minimum, refer to Ref. 1). These values are plotted against beam length which is expressed by station numbers. The envelope diagram differs slightly for the reaction parameter. In this case values are plotted as bar graphs at support stations.

b) Influence Diagram - Influence values are computed for a particular parameter at stations specified by the user. After selecting the parameter whose

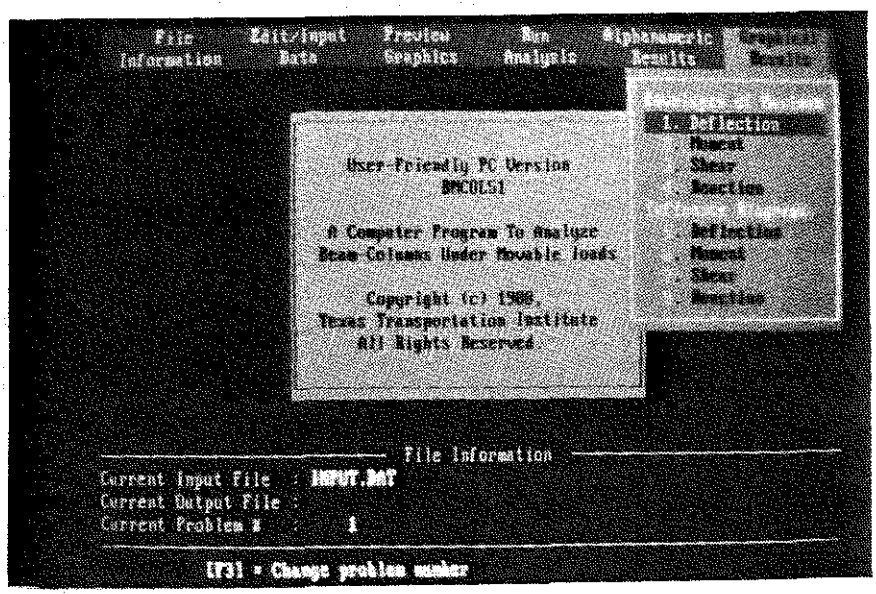

Fig. 10 Submenu "Graphical Results" Module

influence diagram is desired, the user selects a station previously specified in the input file. As in the case of envelope diagrams, these values are plotted versus the beam length which is expressed by station numbers. Curves are displayed in red. The value at a certain station represents the value of the parameter at the selected station when station zero of the movable load coincides with the station being read from the graph [1]. Included in the legends is the station number for which the graph is plotted.

c) Plotting options - Hardcopy plots for these graphs can be obtained by accessing plot options after a graph is displayed on the screen. Three options are available for obtaining hardcopy plots:

1. Screen Dump - Plots can be dumped from a screen to a printer by using this option. Printers supported are Epson, IBM, Okidata, HP LaserJet, and those fully compatible with one of the above types (Fig. 11). Hardcopy obtained is in black and white and takes from several to many minutes to complete. Additional information about hardware requirements is described in Appendix B (Essential Graphics Library).

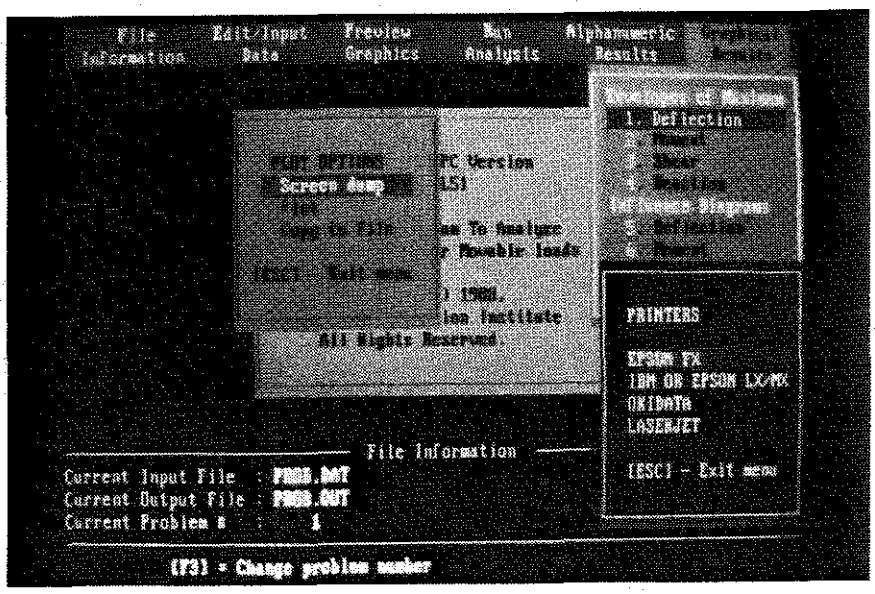

Fig. 11 Screen Dump - Printer Selection Screen

2. Plotter - All plotters that support the Hewlett-Packard Graphics Language (HPGL) are supported. For envelope diagrams, three types of plot parameters are recognized: the maximum curve, the minimum curve, and the axes and legends. In the case of influence diagrams, there are two parameters: the curve, and the legends and axes. These parameters are assigned default pen numbers and pen speeds (cm/sec), which may be changed if desired by means of an additional submenu (Fig. 12). Areas between curves and axes are not filled with color for hardcopy output.

3. Copy to File - This option can be used to copy a graph to a file. This file can be copied to an output device at a later time to obtain the hardcopy completely independent from the enhanced BMCOL51 software package. Plotter defaults can also be changed by means of a special submenu.

IV. SAMPLE SESSION

This sample session is a description of the steps required to create and execute a simple beam problem. The run contains one problem which is described in detail below [1].

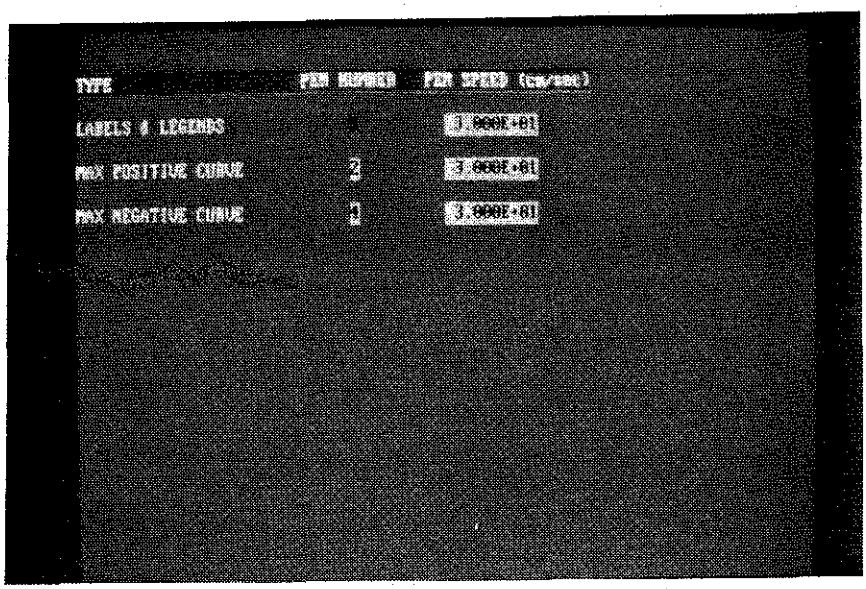

Fig. 12 Plot Parameter Selection Screen

The example structure is a two-span continuous railroad girder which is 86 feet long. The girder, deck system, ballast, and rails place a total dead load of 1000 lbs. per linear foot on each girder. A "live" or movable load of a portion of one track loading is also carried by each girder. The girder is supported with no restraint at the center support, but the end supports are fixed against translation. Due to temperature expansion, an axial longitudinal force of 33,000 lbs. is applied to each girder. Figure 13 shows these different loads acting on the structure.

Before creating and executing this problem, the general scheme for using menus is described below.

MENU SCHEME

An option can be selected from the main menu by either using the direction arrow keys to highlight a desired option, or by pressing the highlighted letter of the option desired. Once the option selected is highlighted, the [Enter] key can be pressed to invoke the submenu within that option. Procedures for selecting an option from a pull-down menu are the same as for the main menu, except that the [Up] and [Down] arrow keys are used to move from one option to another. Using the [Left] and [Right] arrow keys within a pull-down menu allows

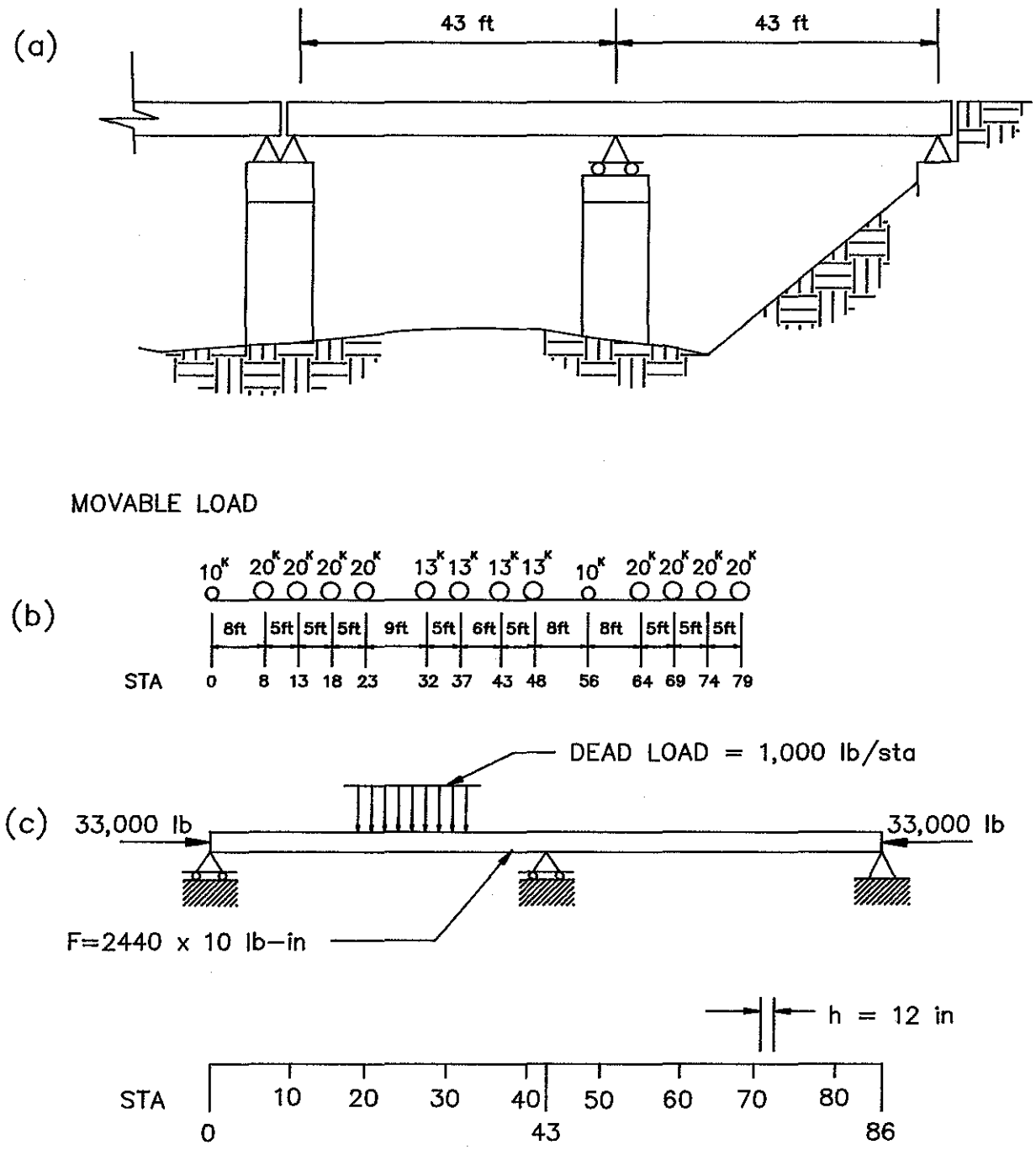

Fig. 13 Sample Problem – Geometry and Loading

movement from one pull-down menu to the next. The option highlighted within this new pull-down menu is the most recently selected option in that menu. The [Esc] key can be used from within a submenu to return to the main menu.

In the description that follows, selection of an option will imply the use of this scheme without specific mention.

STEP 1 - FILE INFORMATION

Default filenames for the input and output files are left as blanks, respectively. Let the new file containing this problem be called PROB.DAT and the output file PROB.OUT (user should make sure these files do not exist in the current directory). To change filenames, select **FILE INFORMATION** and invoke the submenu within this option. Select **"Change Input File"** and enter PROB.DAT, using the keyboard when the program prompts for the filename (Fig. 14). Similarly, to change the name of the output file, select **"Change Output File"** and enter PROB.OUT.

STEP 2 - EDIT/INPUT FILE

Once the filenames and problem number have been selected, the data can be entered into the appropriate tables. For this example, the following data is entered:

TABLE 1 Program Control Data - Since there are no previous problems, the fields specifying data to be held should be left blank. For the number of cards for Tables 2 through 6 enter 1, 3, 1, 14, 4, respectively. Enter 1 in the last four fields (Deflection, Moment, Shear, Reaction) to plot all the data (Fig. 15).

TABLE 2 Constants and Movable Load Data - Enter the following data for Table 2 (Fig. 16):

Number of Increments	86
Increment Length	12
Number of Increments in Pattern	79
Start Station	-80
Stop Station	86
Step Size	2

TABLE 3 Specified Deflections and Slopes - Enter the following data for Table 3 (Fig. 17):

Station	Case	Deflection	Slope
0	1	0.000E+00	
43	1	0.000E+00	
86	1	0.000E+00	

TABLE 4 Fixed Loads and Restraints - Enter the following data for Table 4 (Fig. 18):

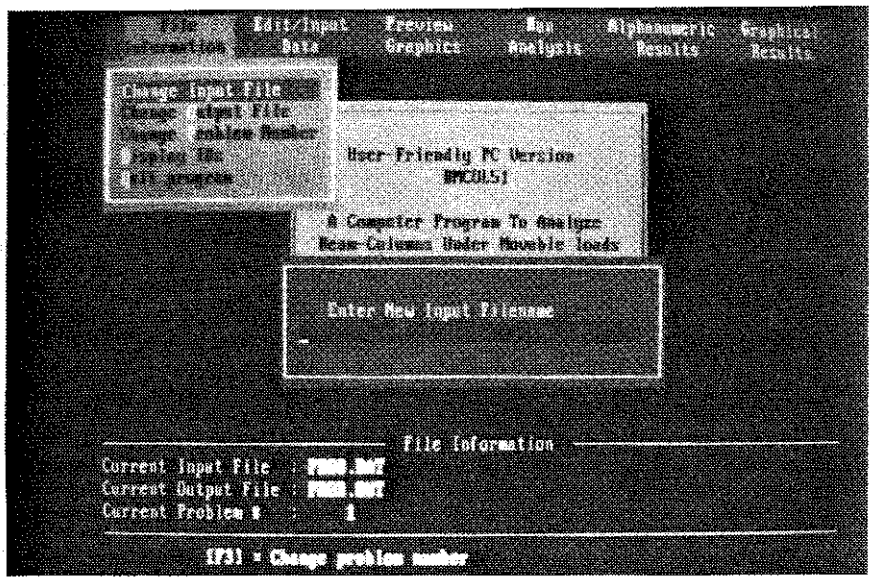

Fig. 14 Specification of Input File

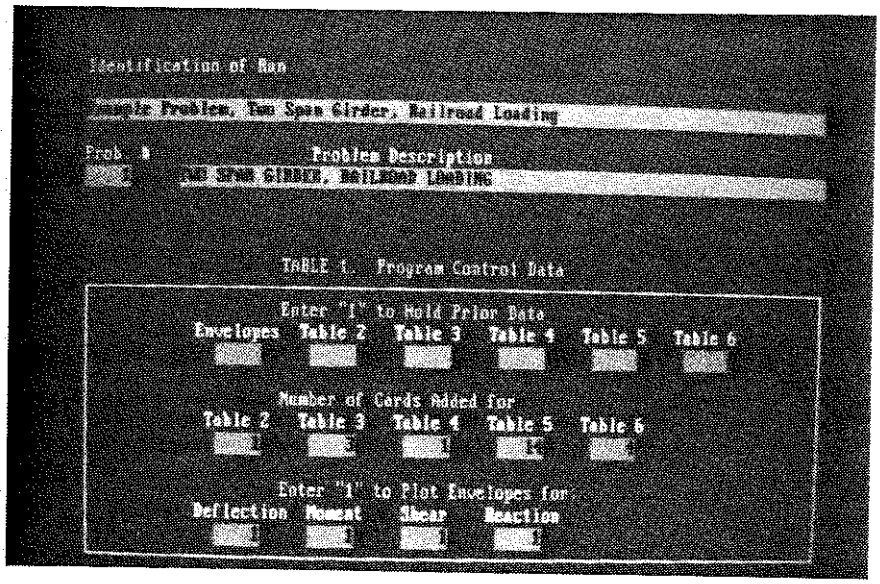

Fig. 15 Table 1 - Input File

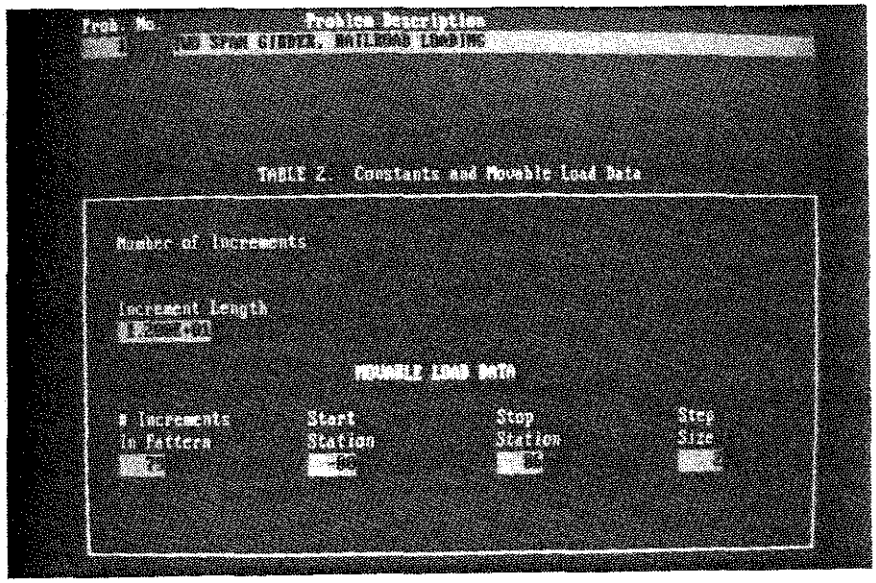

Fig. 16 Table 2 - Input File

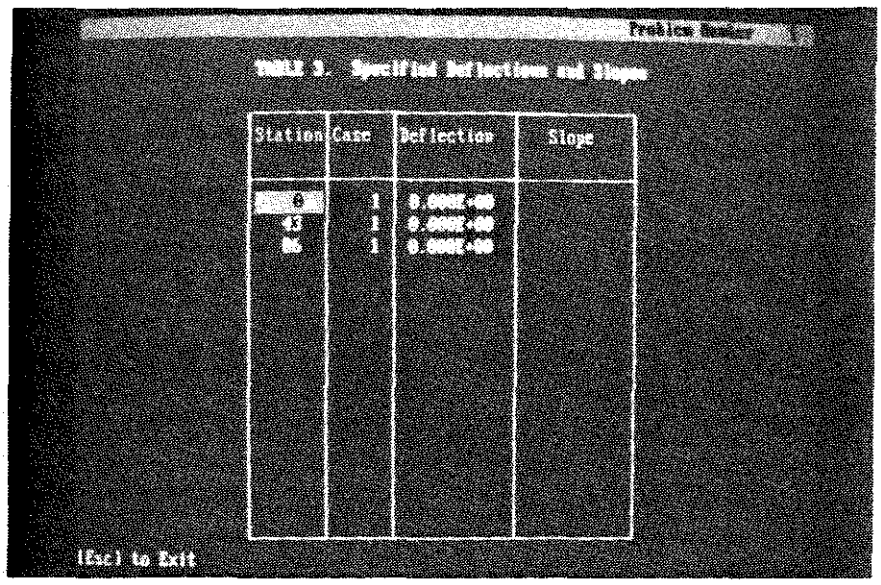

Fig. 17 Table 3 - Input File

From Station	To Station	F Bending Stiffness	Q Transverse Force	P Axial Tension or Compression
0	86	2.440E+11	-1.000E+03	-3.300E+04

TABLE 5 Movable Loads - Enter the following data for Table 5 (Fig. 19):

Station	To Station	Continue	Qm Transverse Force
0	0		-1.000E+04
8	8		-2.000E+04
13	13		-2.000E+04
18	18		-2.000E+04
23	23		-2.000E+04
32	32		-1.000E+04
37	37		-1.000E+04
43	43		-1.000E+04
48	48		-1.000E+04
56	56		-1.000E+04
64	64		-2.000E+04
69	69		-2.000E+04
74	74		-2.000E+04
79	79		-2.000E+04

TABLE 6 Specified Stations For Influence Diagrams - Enter the following data for Table 6 (Fig. 20):

Number of Diagrams	Type of Output	Designated Stations	
2	2	50	70

Once this data has been entered, it can be checked by selecting the **"Check Problem"** option on the menu.

STEP 3 - PREVIEW GRAPHICS

After the problem has been created, it can be visually checked for mistakes by accessing the **PREVIEW GRAPHICS** option. This option provides the user with a rapid check of the problem before the time-consuming execution process. Invoke this submenu and select one of the three submenu options available.

Support Conditions & Loadings - The graph displayed on the screen is shown in (Fig. 21). Use the [Esc] key to return to the pull-down menu.

Flexural Stiffness - The graph displayed on the screen is shown in (Fig. 22). Use the [Esc] key to return to the pull-down menu.

Movable Loads - The graph displayed on the screen is shown in (Fig. 23). Use the [Esc] key to return to the pull-down menu.

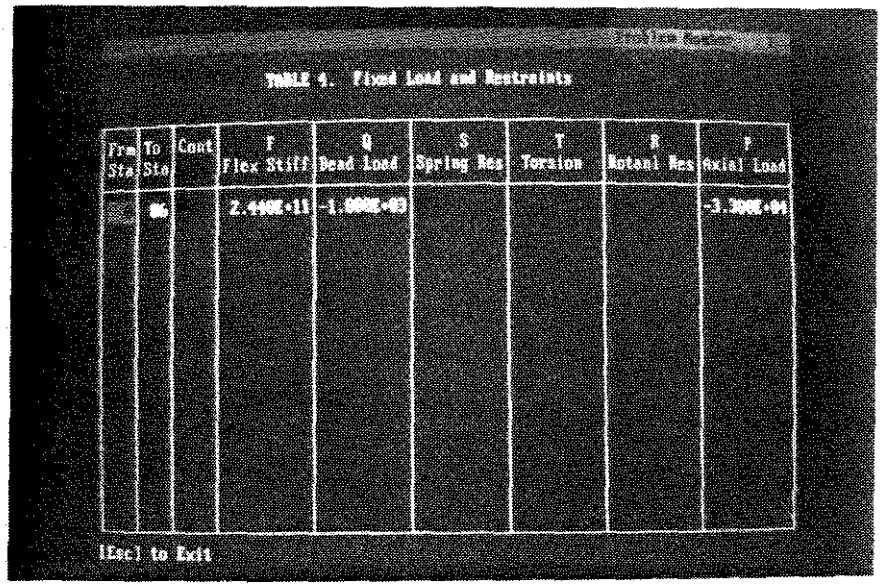

Fig. 18 Table 4 - Input File

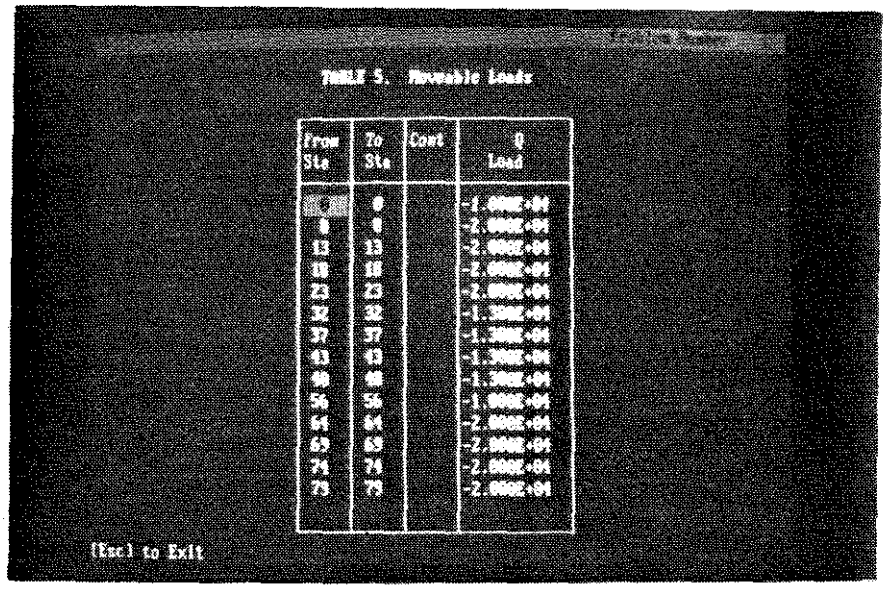

Fig. 19 Table 5 - Input File

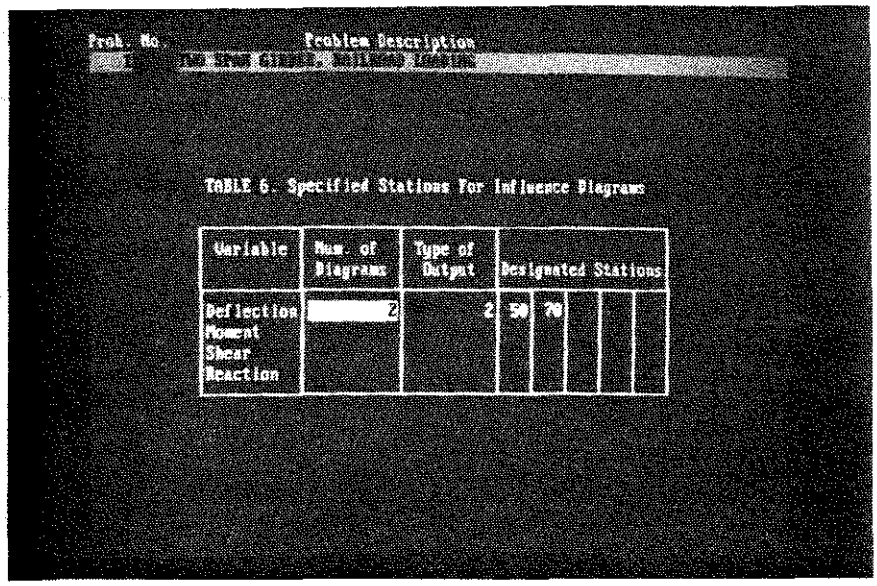

Fig. 20 Table 6 - Input File

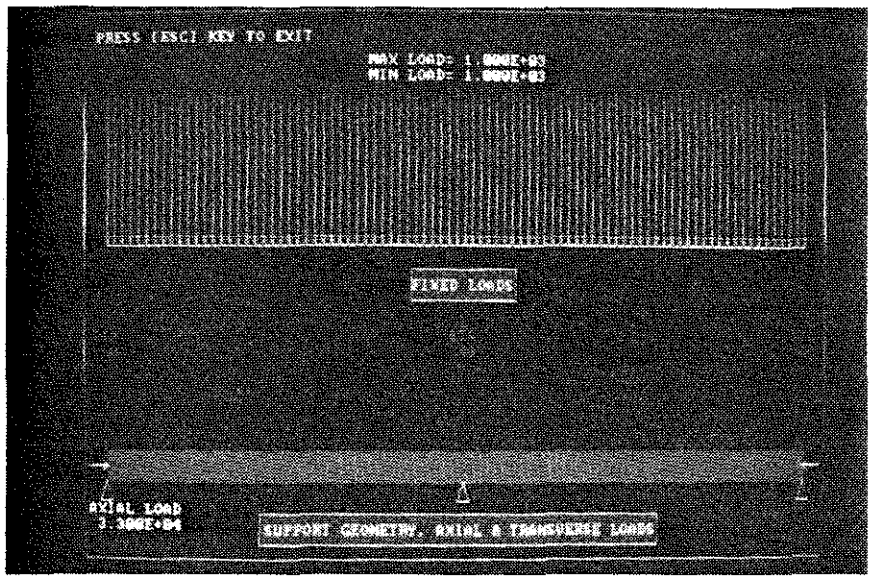

Fig. 21 Support Conditions and Loadings

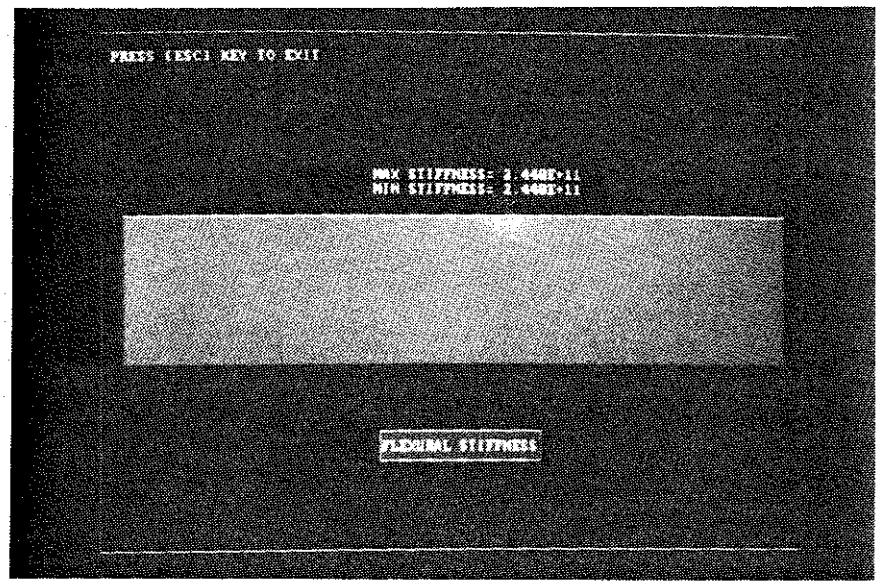

Fig. 22 Flexural Stiffness

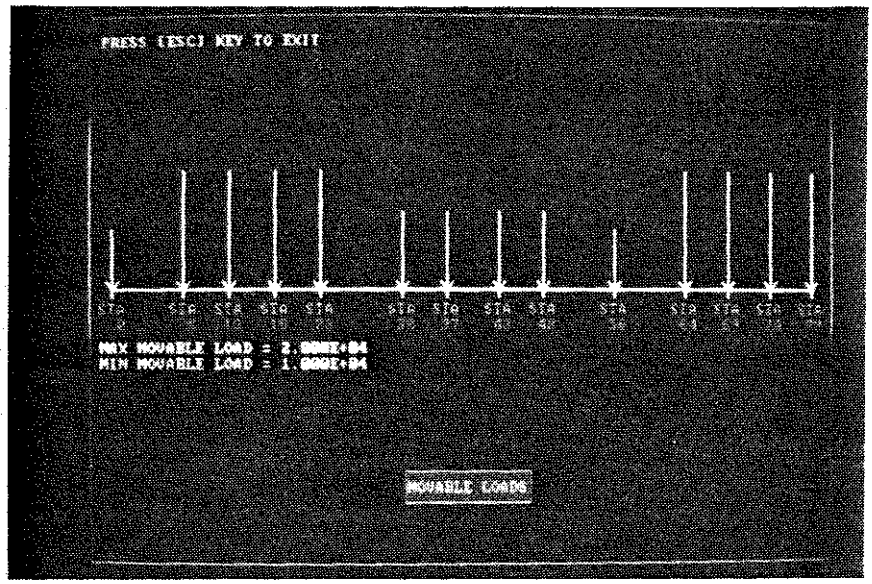

Fig. 23 Movable Loads

Return control to the main menu by using the [Esc] key or [Left] and [Right] arrow keys from within the submenu as described before.

STEP 4 - RUN ANALYSIS

Select this option and execute the input file to obtain the alphanumeric output file. The current problem number being analyzed is displayed on the screen (Fig. 24). Upon completion of the run, this message is erased.

Return control to the main menu by using the [Esc] key or [Left] and [Right] arrow keys from within the submenu as described before.

STEP 5 - ALPHANUMERIC RESULTS

This option presents the output data from analysis in numerical form. After invoking this option, select one of the following submenu options:

Table 7 Fixed Loads - This table is shown in Fig. 25. Use the direction arrow keys to move within this table. Pressing the [Home] key positions the screen on the first line of the table, while the [End] key positions the screen on the last line. [Page Up] and [Page Down] keys can be used to move through the table one page at a time. The [Esc] key is used to return to the previous pull-down menu.

Table 8a Maximum Envelopes for Deflection & Moment - This table is shown in Fig. 26. The same keys are used to move within this table as previously described.

Table 8b Maximum Envelopes for Shear & Reaction - This table is shown in Fig. 27. The same keys are used to move within this table as previously described.

Table 10a Influence Diagrams for Deflection - This table is shown in Fig. 28. The same keys are used to move within this table as previously described.

Table 10b Influence Diagrams for Moment - Since no stations were specified in the input file for moment [1], there are no entries in this table. The program displays a message to the user and waits for a key-stroke to return to the pull-down menu.

Table 10c Influence Diagrams for Shear - Since no stations were specified in the input file for shear [1], there are no entries in this table. The program displays a message to the user and waits for a key-stroke to return to the pull-down menu.

Table 10d Influence Diagrams for Reaction - Since no stations were specified in the input file for reaction [1], there are no entries in this table. The program displays a message to the user and waits for a key-stroke to return to the pull-down menu.

Print Output File - This option is used to obtain a printout of the numerical results from analysis. After this option is selected, the program displays a

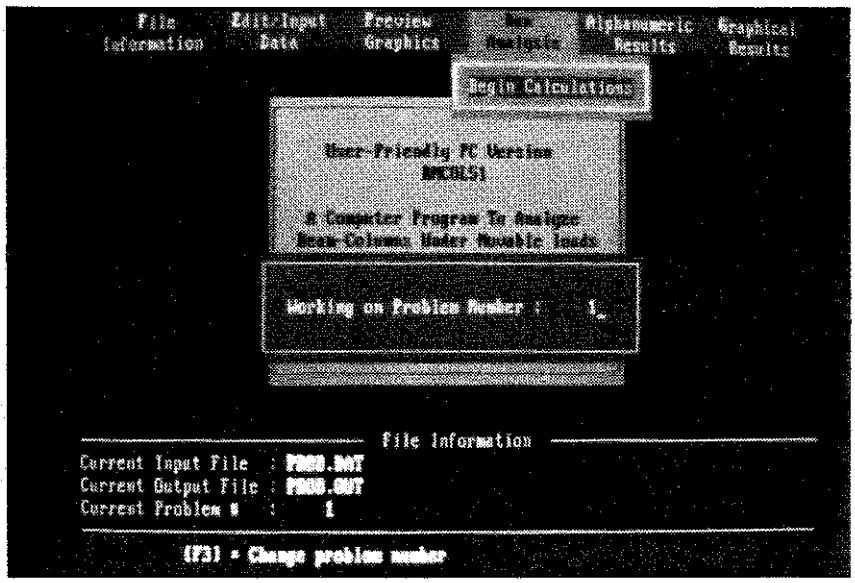

Fig. 24 Screen Display "Run Analysis"

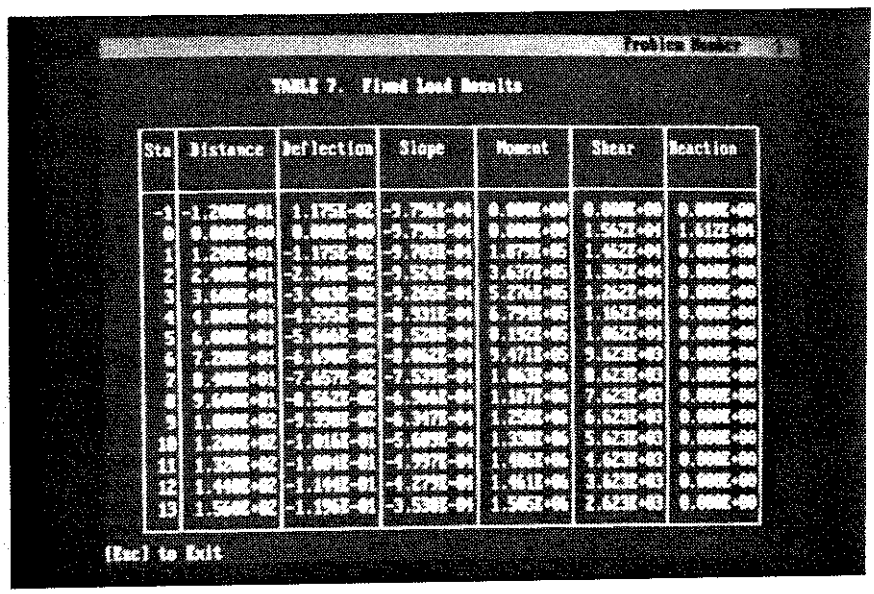

Fig. 25 Table 7 Fixed Loads

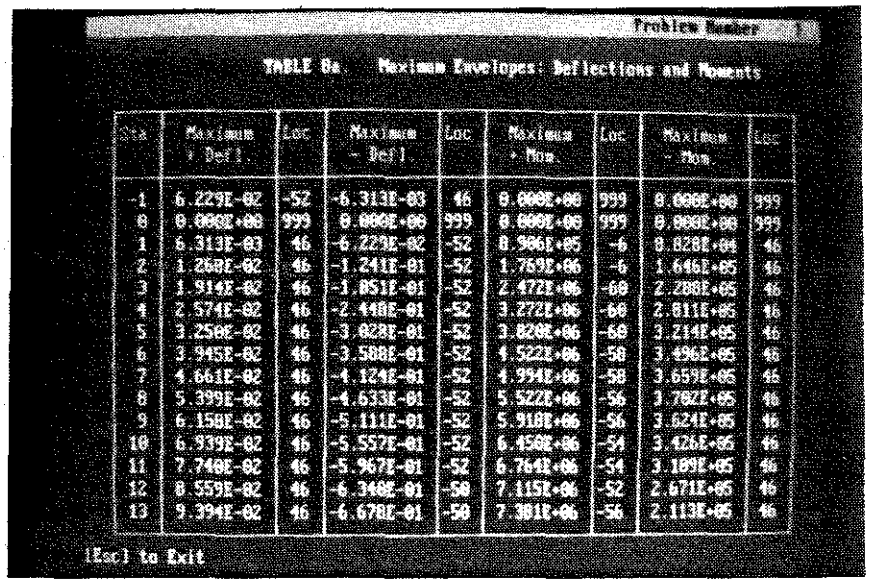

TABLE 8a Maximum Envelopes: Deflections and Moments

Sta	Maximum + Defl	Loc	Maximum - Defl	Loc	Maximum + Mom	Loc	Maximum - Mom	Loc
-1	6.229E-02	-52	-6.313E-03	46	0.000E+00	999	0.000E+00	999
0	0.000E+00	999	0.000E+00	999	0.000E+00	999	0.000E+00	999
1	6.313E-03	46	-6.223E-02	-52	8.506E+05	-6	0.828E+04	46
2	1.268E-02	46	-1.241E-01	-52	1.759E+06	-6	1.646E+05	46
3	1.914E-02	46	-1.851E-01	-52	2.472E+06	-60	2.286E+05	46
4	2.574E-02	46	-2.448E-01	-52	3.272E+06	-60	2.811E+05	46
5	3.250E-02	46	-3.023E-01	-52	3.820E+06	-60	3.214E+05	46
6	3.945E-02	46	-3.588E-01	-52	4.522E+06	-58	3.496E+05	46
7	4.661E-02	46	-4.124E-01	-52	4.994E+06	-58	3.659E+05	46
8	5.399E-02	46	-4.633E-01	-52	5.522E+06	-56	3.702E+05	46
9	6.158E-02	46	-5.111E-01	-52	5.918E+06	-56	3.624E+05	46
10	6.939E-02	46	-5.557E-01	-52	6.450E+06	-54	3.426E+05	46
11	7.740E-02	46	-5.967E-01	-52	6.764E+06	-54	3.109E+05	46
12	8.559E-02	46	-6.340E-01	-50	7.115E+06	-52	2.671E+05	46
13	9.394E-02	46	-6.678E-01	-50	7.381E+06	-56	2.113E+05	46

[Esc] to Exit

Fig. 26 Table 8a Maximum Deflection & Moment

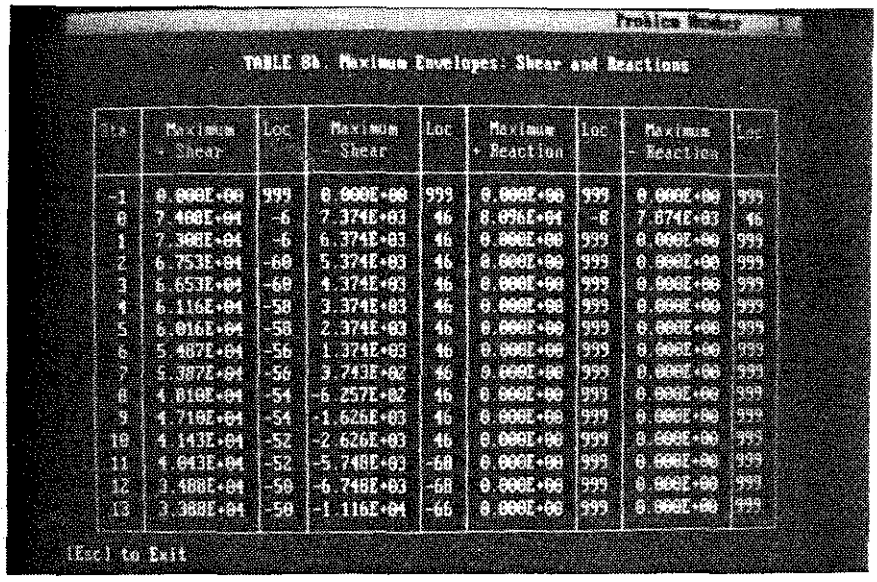

TABLE 8b Maximum Envelopes: Shear and Reactions

Sta	Maximum + Shear	Loc	Maximum - Shear	Loc	Maximum + Reaction	Loc	Maximum - Reaction	Loc
-1	0.000E+00	999	0.000E+00	999	0.000E+00	999	0.000E+00	999
0	7.488E+04	-6	7.374E+03	46	8.096E+04	-6	7.074E+03	46
1	7.308E+04	-6	6.374E+03	46	0.000E+00	999	0.000E+00	999
2	6.753E+04	-60	5.374E+03	46	0.000E+00	999	0.000E+00	999
3	6.653E+04	-60	4.374E+03	46	0.000E+00	999	0.000E+00	999
4	6.116E+04	-58	3.374E+03	46	0.000E+00	999	0.000E+00	999
5	6.016E+04	-58	2.374E+03	46	0.000E+00	999	0.000E+00	999
6	5.487E+04	-56	1.374E+03	46	0.000E+00	999	0.000E+00	999
7	5.387E+04	-56	3.743E+02	46	0.000E+00	999	0.000E+00	999
8	4.810E+04	-54	-6.257E+02	46	0.000E+00	999	0.000E+00	999
9	4.710E+04	-54	-1.626E+03	46	0.000E+00	999	0.000E+00	999
10	4.143E+04	-52	-2.626E+03	46	0.000E+00	999	0.000E+00	999
11	4.043E+04	-52	-5.748E+03	-60	0.000E+00	999	0.000E+00	999
12	3.488E+04	-50	-6.748E+03	-60	0.000E+00	999	0.000E+00	999
13	3.388E+04	-50	-1.116E+04	-66	0.000E+00	999	0.000E+00	999

[Esc] to Exit

Fig. 27 Table 8b Maximum Shear & Reaction

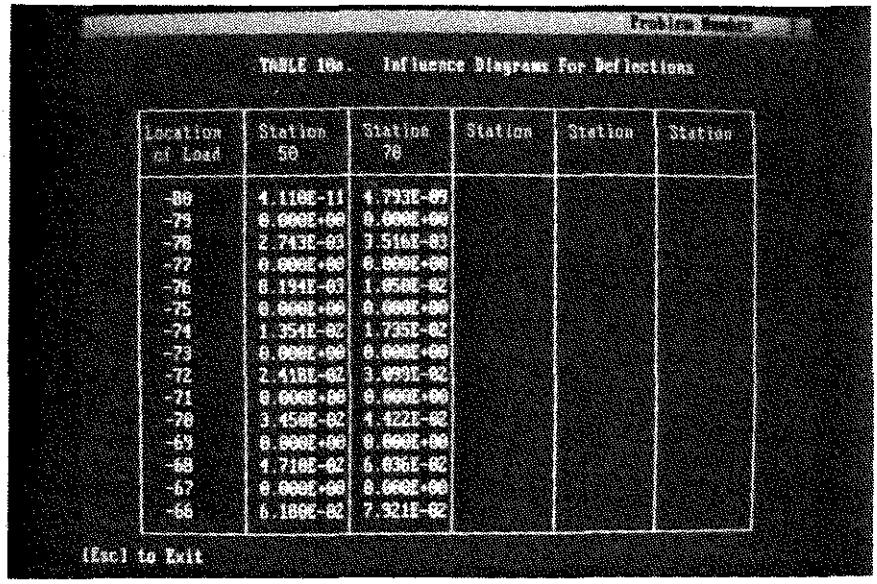

Fig. 28 Table 10a Influence Diagram Deflection

menu of communication ports. Select the port to which the printer is connected to obtain a printout.

STEP 6 - GRAPHICAL RESULTS

Invoke the submenu to begin this option. To choose the type of diagram (envelope or influence), select the parameter whose graph is desired (deflection, moment, shear, or reaction) from within its heading. If a graph is not computed by the analysis code [1], a message will be displayed to this effect.

ENVELOPE DIAGRAMS

Select one of the four parameters available.

Deflection - The graph displayed on the screen is shown in Fig. 29. Use the [Esc] key to return to the pull-down menu.

Moment - The graph displayed on the screen is shown in Fig. 30. Use the [Esc] key to return to the pull-down menu.

Shear - The graph displayed on the screen is shown in Fig. 31. Use the [Esc] key to return to the pull-down menu.

Reaction - The graph displayed on the screen is shown in Fig. 32. Use the [Esc] key to return to the pull-down menu.

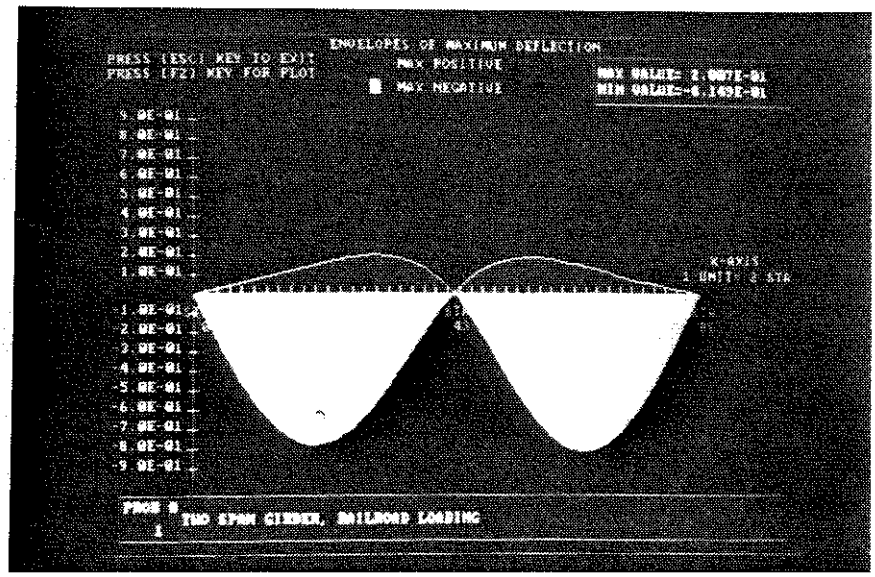

Fig. 29 Envelope of Maximum Deflection

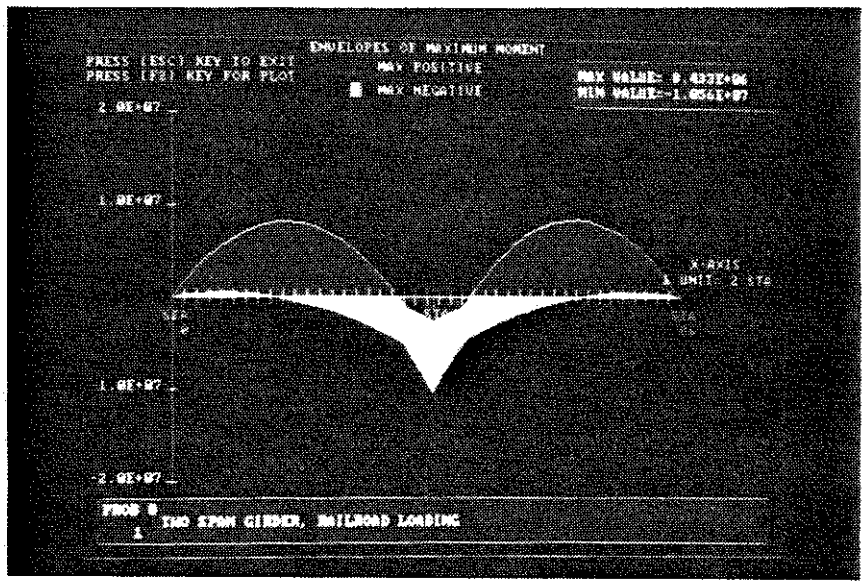

Fig. 30 Envelope of Maximum Moment

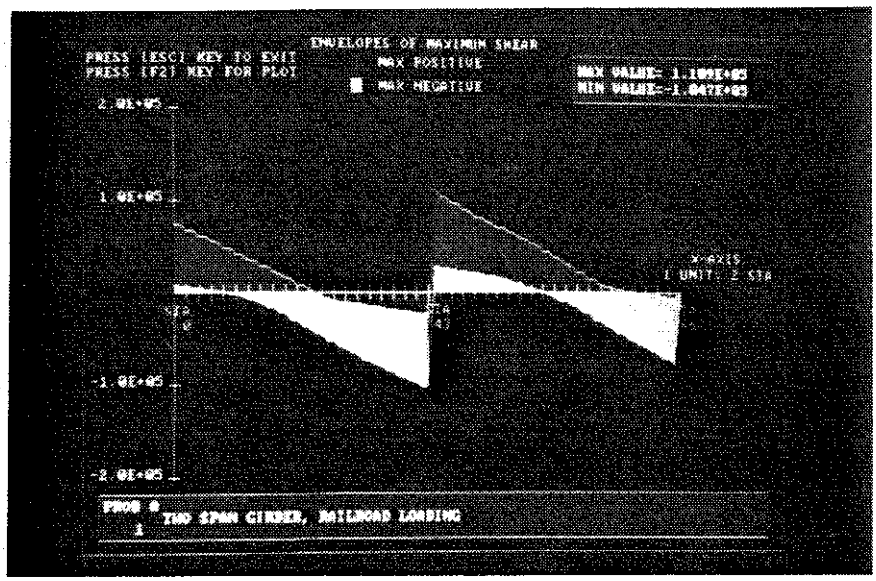

Fig. 31 Envelope of Maximum Shear

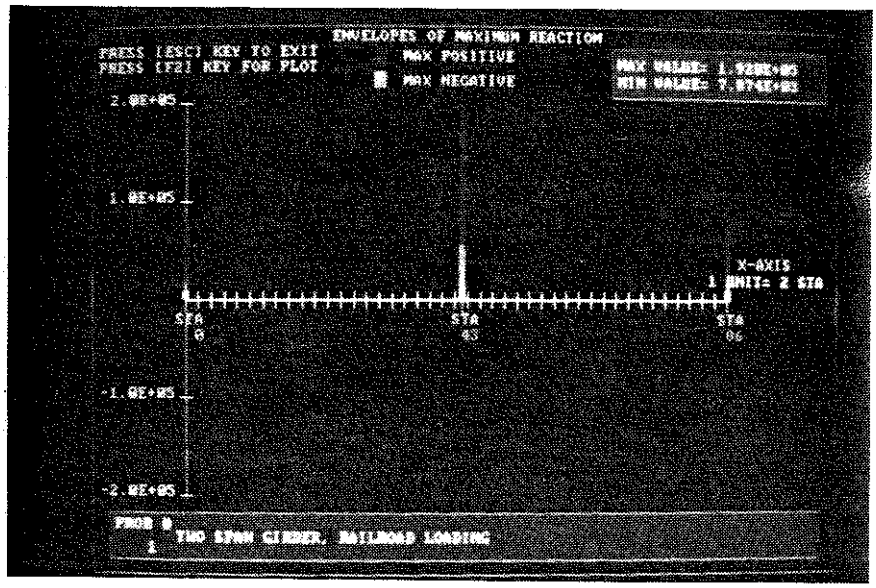

Fig. 32 Envelope of Maximum Reaction

INFLUENCE DIAGRAMS

Select the parameter desired as in case of envelope diagrams.

Deflection - Select this option. A second pull-down menu is displayed which shows the station numbers specified for this parameter (for this example, Stations 50 and 70 were specified) (Fig. 33). Choose one of these stations, say, Station 50. The graph displayed on the screen is shown in Fig. 34. Use the [Esc] key to return to the second pull-down menu. Again choose any station number displayed to view its graph. To return to the first pull-down menu, use the [Esc] key.

Moment - Select this option. Since no stations were specified for this parameter, a message to this effect is displayed. Press any key to return to the pull-down menu.

Shear - Select this option. Since no stations were specified for this parameter, a message to this effect is displayed. Press any key to return to the pull-down menu.

Reaction - Select this option. Since no stations were specified for this parameter, a message to this effect is displayed. Press any key to return to the pull-down menu.

HARDCOPY PLOTS

Hardcopy plots can be obtained once a graph is displayed on the screen. The procedure will be outlined for the influence diagram for deflection at Station 50. The same procedure applies to all graphs.

Select deflection parameter for influence diagrams. From the menu of specified station numbers, select Station 50 (these are identical to the steps previously outlined). The graph will be displayed on the screen as before. Press the [F2] key to select plotting options. The graph on the screen will be replaced by a plotting options menu. Three choices are available as to the kind of hardcopy desired. Select one of these options according to the following:

Screen Dump - Once this option is selected, a second menu will appear specifying printer names supported by the software. Select the type of printer connected to the computer. The graph is displayed on the screen as it will appear on the hardcopy. Once the hardcopy has been completed, the display on the screen will return to the original colored graph.

Plot - Selection of this option leads the program to prompt the user for plot option changes. Press [Y] at this prompt to change or view the defaults. The plot options screen will be displayed at this point. Editing of the default pen numbers and speeds is performed in the same manner as in the editing of input tables (refer to **EDIT/INPUT DATA**). If there is an error in the pen number or speed selected (for example, specifying a pen number greater than 6), the

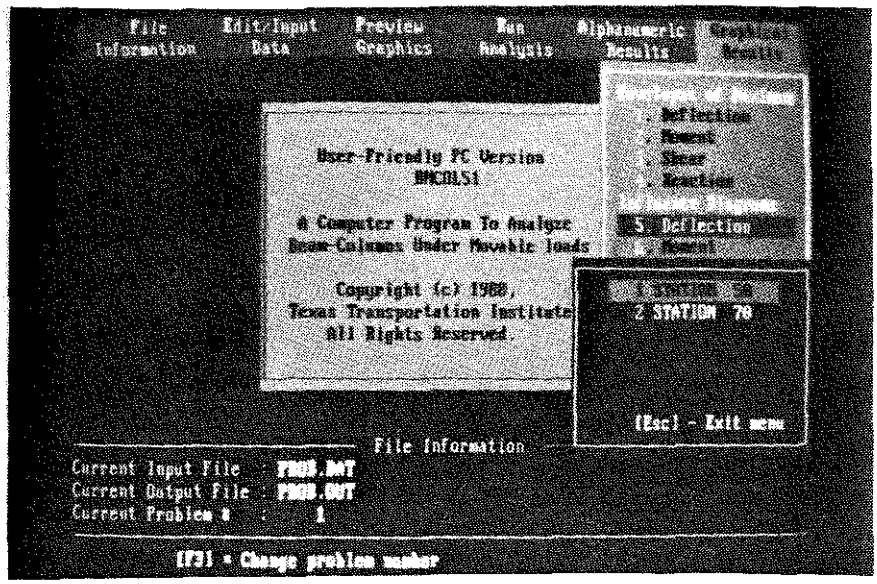

Fig. 33 Influence Diagram Stations Menu

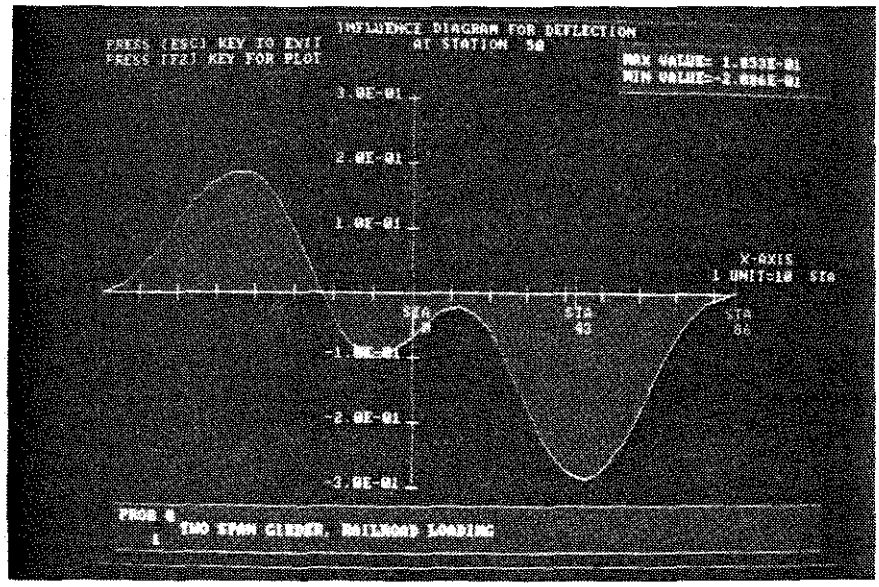

Fig 34 Influence Diagram for Deflection

program will select the most recent pen number and the default pen speed of the plotter being used. After editing or viewing this screen, press the [Esc] key. The program will prompt the user to connect the plotter to the computer (refer to ESSENTIAL GRAPHICS LIBRARY for the port selection description). Press any key other than the [Esc] key (this key will cause a return to the original graph) to invoke the plotter. Once the hardcopy has been completed, the display on the screen will return to the original colored graph.

Copy to File - The program prompts the user for plot option changes. Edit the plot options as described before. Once the main option has been selected, the program will prompt the user for the name of the file to write the plot to. Enter the name desired (for this example, name the file "PLOT.DAT"). The plot will be written to this file and upon completion, the display on the screen will return to the original colored graph.

This plot file is independent from the program. A hardcopy can be obtained by issuing a "copy" command at the DOS prompt. For example, if the plotter is connected to COM1 and the default drive is C, this command will take the form:

```
C:\> COPY   PLOT.DAT   COM1
```

V. WORK FILES

The program uses temporary files called work files for all manipulations. The input file specified by the user is copied to a new temporary file with the same name and a .WKF extension. This is the file used as the input file by the program. All edits are made to this .WKF file, while the original file specified by the user is left unchanged. If "Quit" or "Change Input File" option is selected, the program prompts the user as to whether the work file is to be saved or not. If the user presses [Y], the program prompts for a filename under which the filename is to be saved. Any valid DOS name can be used, including the original filename specified. In this case, the original file is overwritten by the work file. If the user presses [N], the .WKF file is deleted without being copied to another file. The original file, however, is saved.

In specifying an input file the user should NOT use a .WKF extension, because this file is used by the program.

Work files are invoked only if the specified input file already exists. If this is not the case, the program creates the file specified by the user. The user is not provided with the option of deleting this file and it is saved under the specified name.

VI. GENERAL DOCUMENTATION AND INSTALLATION PROCEDURE

HARDWARE REQUIREMENTS

The program BMCOL51.EXE requires certain minimum hardware in order to run.

CPU

This program will run on any IBM PC or 100% compatible.

Memory

640K of memory must be installed on the machine. The program requires a minimum of 520K of free memory in order to run.

Graphics Card

The program requires either an EGA card connected to an EGA monitor, or a VGA card connected to a color VGA monitor.

Disk Drives

The program can be run from a machine with only one floppy disk drive, but a hard disk is strongly recommended.

Math Coprocessor

The program requires a math coprocessor (8087, 80287, or 80387) to be installed in the machine used.

INSTALLATION PROCEDURE

Insure that the computer is equipped with the hardware required to run the program (see hardware requirements above). The program can run on a computer from a floppy disk, but it is advisable to install and execute the program from a hard drive. To install BMCOL51 on a computer with a hard drive, use the DOS COPY command to transfer the executable file from a floppy disk on to a hard drive. For example, to copy the program from a floppy disk in drive A to hard drive C, issue the following command;

```
> COPY  A:BMCOL51.EXE  C:
```

REFERENCES

1. Matlock, Hudson, and Taylor, Thomas P., "A Computer Program to Analyze Beam-Columns Under Movable Loads," Research Report 56-4, Project 3-5-63-56, Center for Highway Research, Austin, Texas, June, 1968.

2. "Microsoft FORTRAN Optimizing Compiler for the MS-DOS Operating System: User's Guide, Version 4.1," Microsoft Corporation, Redmond, WA, 1987.

3. "Microsoft FORTRAN Optimizing Compiler for the MS-DOS Operating System: Language Reference, Version 4.1," Microsoft Corporation, Redmond, WA, 1987.

4. "Microsoft Macro Assembler: Programmer's Guide, Version 5.0," Microsoft Corporation, Redmond, WA, 1987.

5. "Essential Graphics User Guide, Version 1.5," Essential Software Inc., Maplewood, NJ, 1986.