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16. Abstract

Bent Cap (CAP18) is a specialized beam-column program modified for use with AASHTO lane loading rules. It performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads. When Bent Cap is used for design, the following assumptions are built into the solution: (1) all supports are knife edged (pin connected), (2) no axial loads are present, (3) live loadings are varied in accordance with AASHTO rules, and (4) deck slab for slab and stringer construction is hinged over interior stringers. Enhancements are made to the existing FORTRAN code using a user-oriented method of analysis particularly suited to highway bridge bent caps. 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 Nonlinear Analysis of Bent Caps with Movable Loads on Microcomputers

by

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and

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Research Report 1183-4

on

User-Oriented Analysis Packages for Bridges
Research Study No. 2-5-88/9-1183

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in²	square inches	645.2	centimetres squared	cm²
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)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
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)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
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

Symbol	When You Know	Multiply By	To Find	Symbol
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)

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
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)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

°F
-40   0   32   40   80   98.6   120   160   200   212
-40   -20   0   20   37   40   60   80   100
°C   °C

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

ABSTRACT

Bent Cap (CAP18) is a specialized beam-column program modified for use with AASHTO lane loading rules. It performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads. When Bent Cap is used for design, the following assumptions are built into the solution:

(1) All supports are knife-edged (pin connected.)

(2) No axial loads are present.

(3) Live Loadings are varied in accordance with AASHTO rules.

(4) Deck slab for slab and stringer construction is hinged over interior stringers.

Enhancements are made to the existing FORTRAN code using a user-oriented method of analysis particularly suited to highway bridge bent caps. 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

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation. This report does not constitute a standard, specification, or regulation.

KEY WORDS

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

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

Substantial advancements in hardware and software have been made since the time when many of the current bridge analysis codes in use by the Texas State Department of Highways and Public Transportation were written. 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, CAP18, which performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads.

This is the fourth in a series of reports that document enhancements to five existing analysis codes used by SDHPT. This report describes modifications to analysis code CAP18.

II. INTRODUCTION

Computer program CAP18 performs finite-element simulation of a linearly elastic beam-column subjected to fixed and movable loads (Matlock, et al., 1966; Willis, 1975). 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 rapid 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

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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 analysis is available in both alphanumeric or graphical form. Comprehensive error trapping is also provided.

These additions to the CAP18 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, allows 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 CAP18 code are described by means of narrative and gray-scale images of 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 CAP18 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 CAP18 analysis code is integrated into the menu structure by means of the fourth module, RUN ANALYSIS.
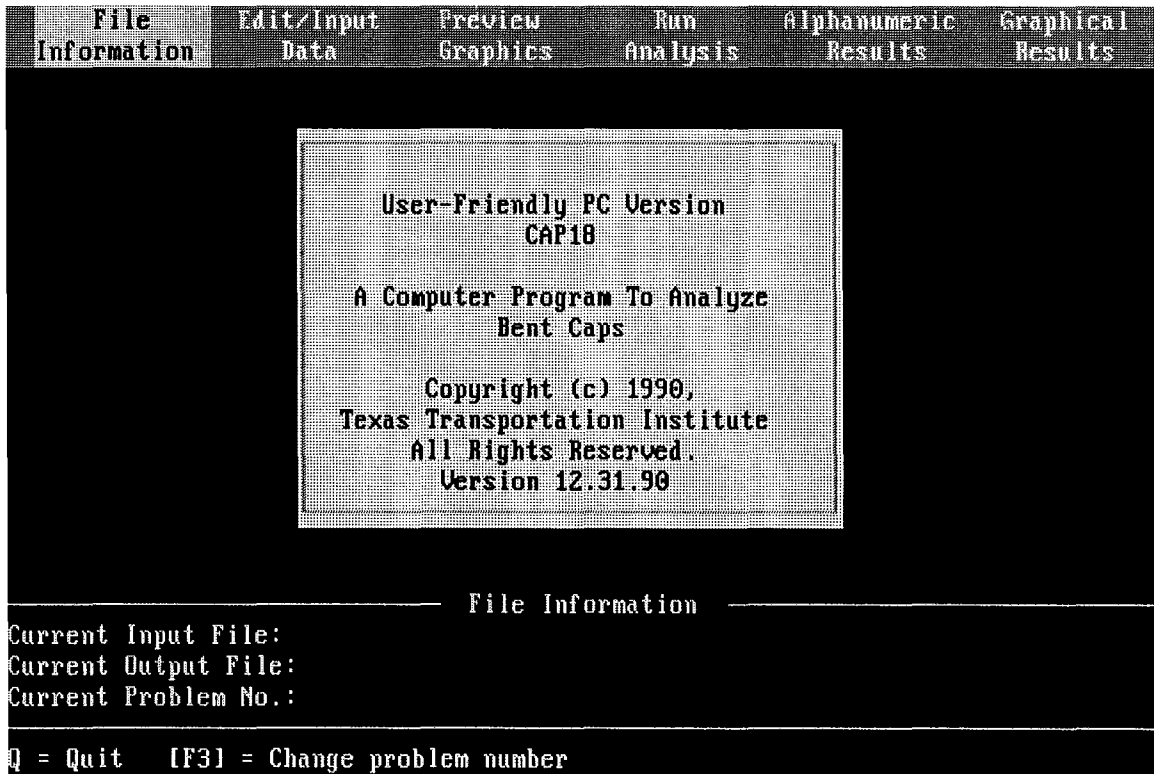
Fig. 1: Main Menu and Screen Layout

The six modules and their sub-divisions are described in the following sections.

1. FILE INFORMATION

In order to execute CAP18, 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.
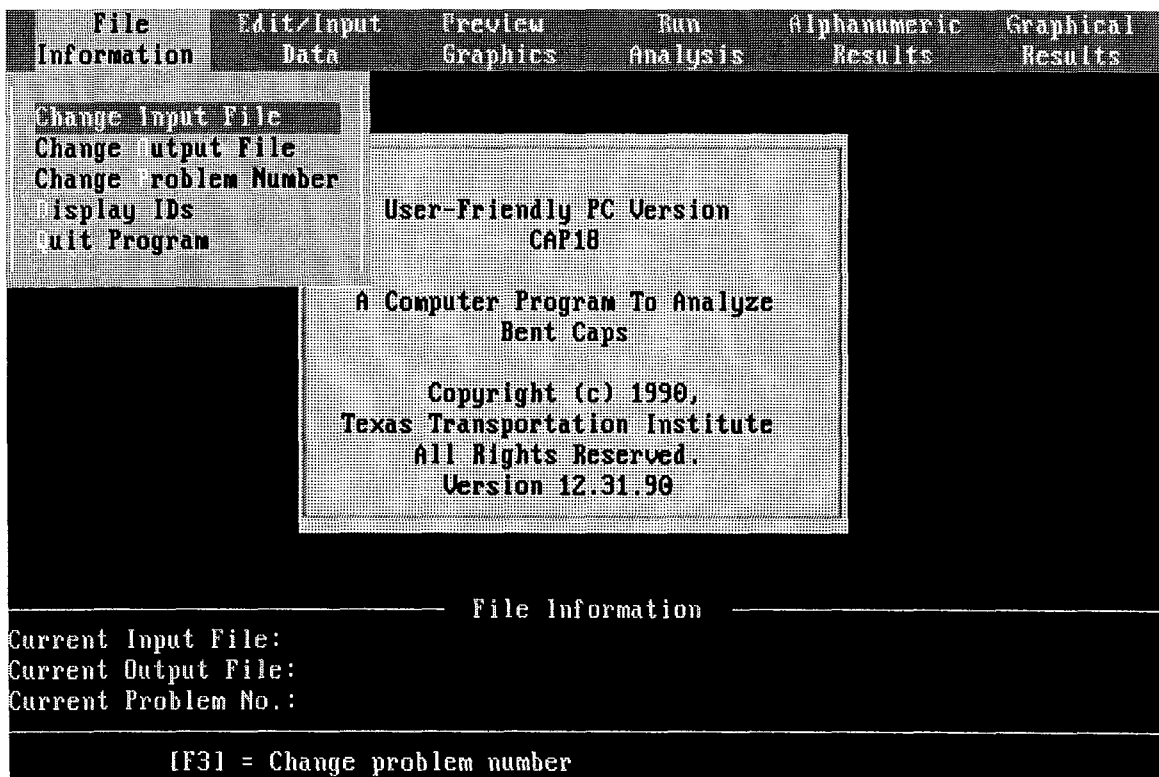
Fig. 2: Submenu "File Information" Module

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 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).

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Fig. 3: Problem ID Display

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 seven entries in this submenu allow the user to view and/or edit data for the problem and data as described in Ref. 1 (Fig. 4). Examples of these tables are shown in Section IV: Sample Session.

When any one of these seven options is selected, data for that entry is displayed. The user can easily move between fields on any screen by using the up, down, left, and right

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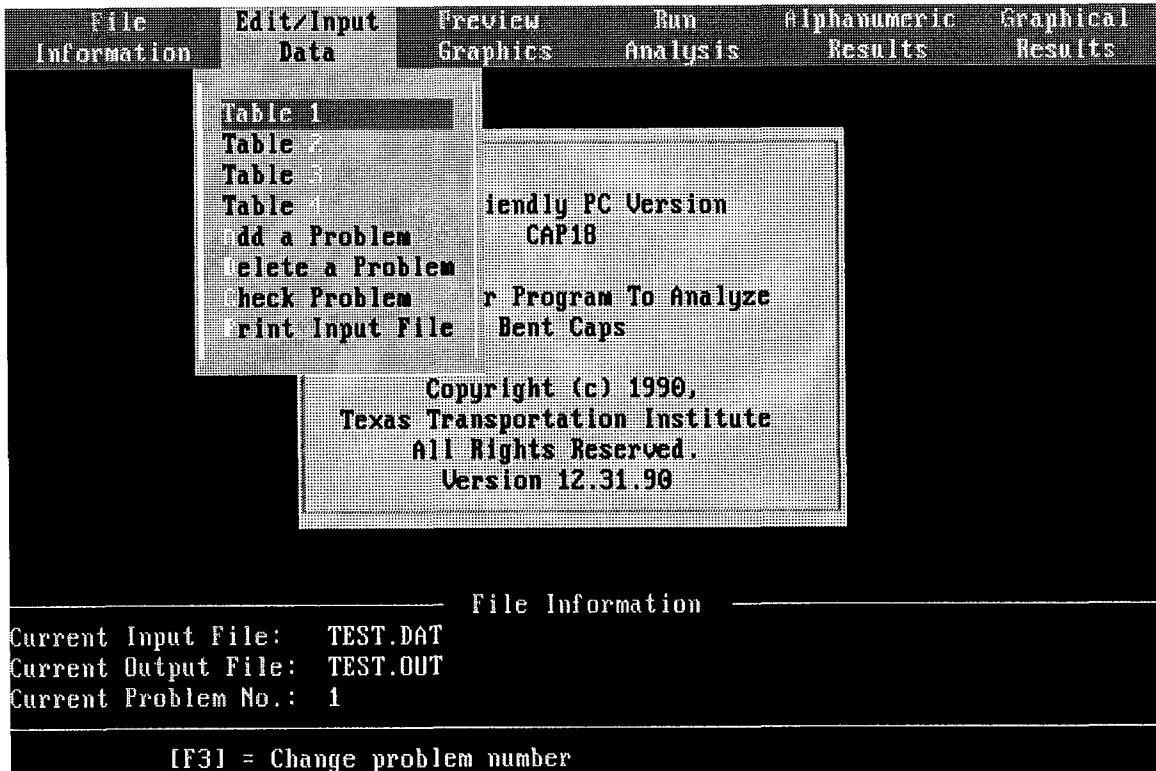
Fig. 4: Submenu "Edit/Input Data" Module

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. 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,

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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). Before editing the input file for this problem, the user must return to the file information module and change the problem number to match the added problem number. 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.
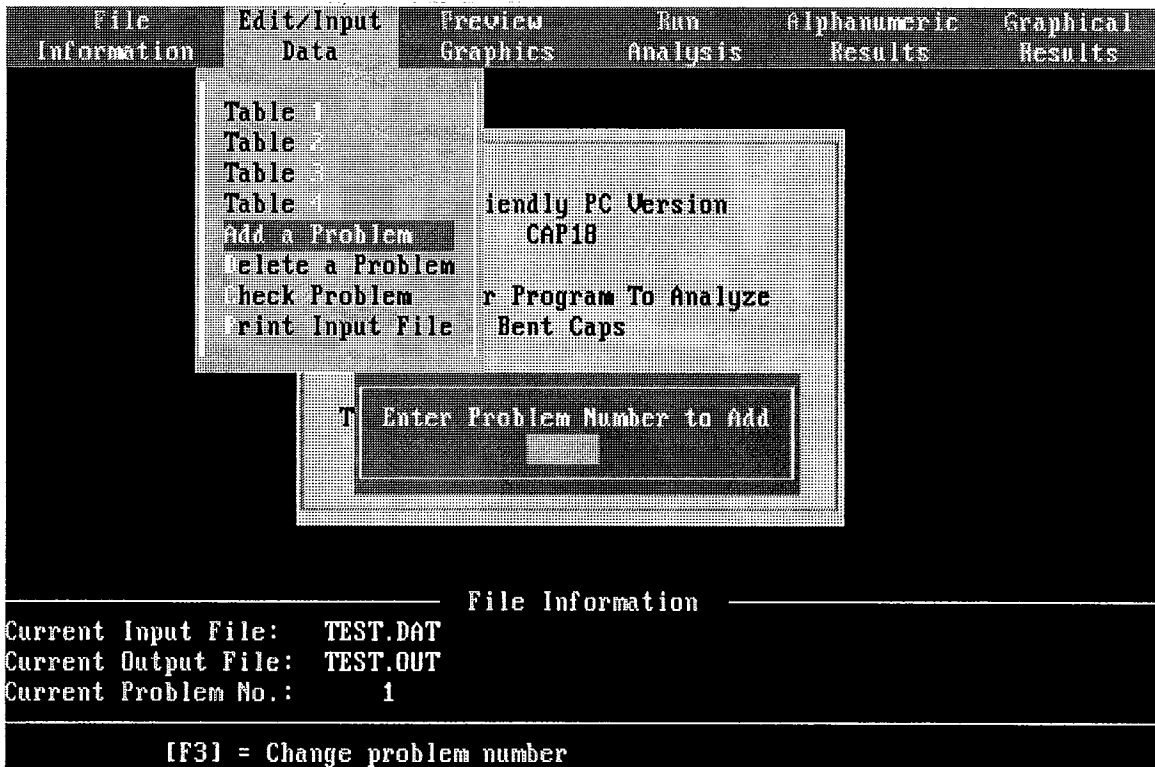
Fig. 5: Addition of Problem to Input File

The input file can be sent to a printer from within CAP18 by selecting the last option on this submenu, **"Print Input File."** Options LPT1, LPT2, COM1, and COM2 in the submenu (Fig. 6) refer to the communications port assigned to the printer connector from within DOS.

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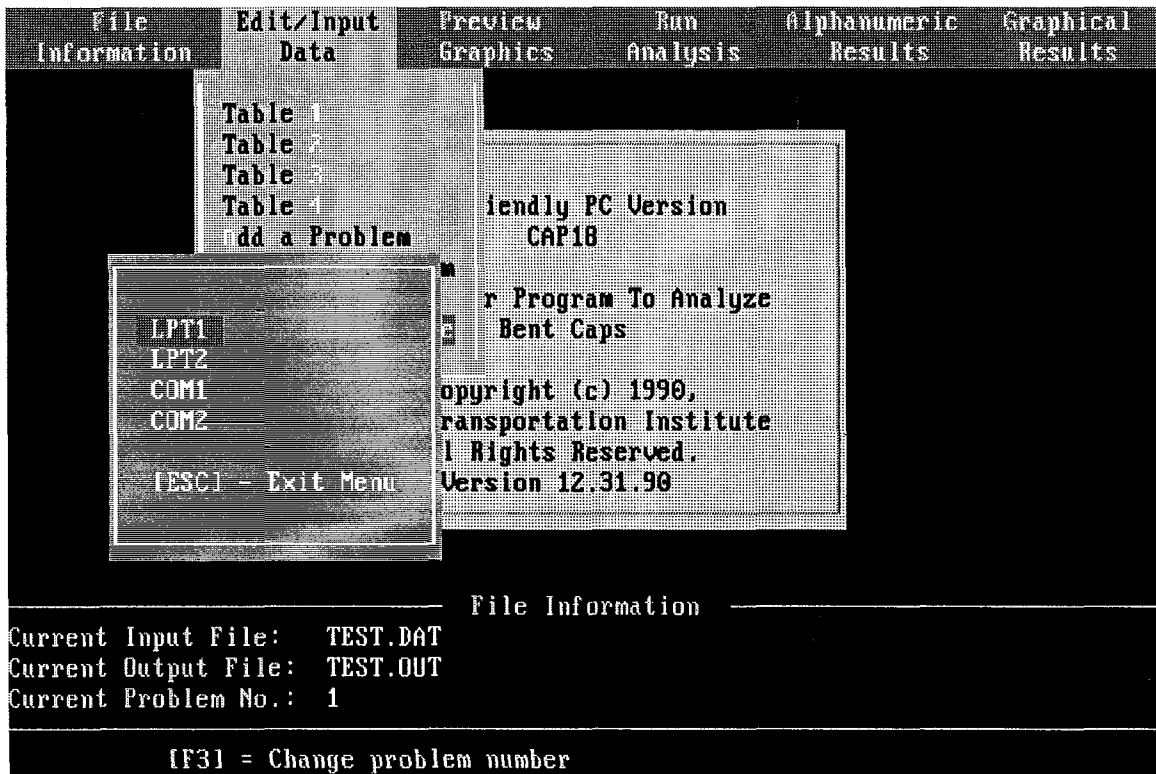
Fig. 6: Port Selection Screen

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 CAP18 analysis code. The input file is read and the data is simply displayed. The module has four subdivisions which are as follows (Fig. 7):

a) **Movable Slab Loads** - Movable load data is shown in this graph. Numerical values of the movable load are displayed at discretized station numbers of the entire load. Sign conventions used are identical with those of the original code (Matlock, et al., 1966). 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.

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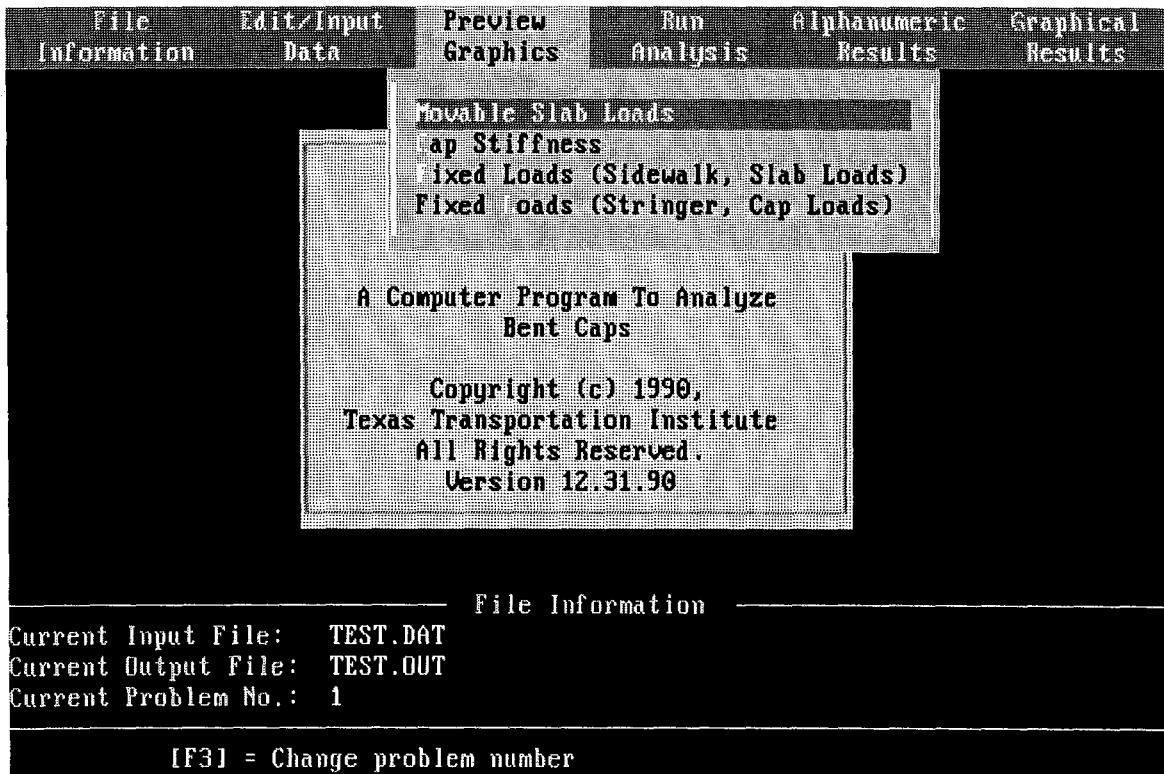
Fig. 7: Submenu "Preview Graphics" Module

b) Cap Stiffness - This is a graph of the flexural stiffness of the bent cap along its length. The flexural stiffness values from the input tables are also interpolated to get actual magnitudes (Matlock, et al., 1966). 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) Support Conditions and Loadings - This option displays (1) the bent cap and its supports and (2) the fixed loads acting on the cap. Two types of fixed loads are shown by selecting two separate options. One is for loads on sidewalks and slabs. The other is for stringers and caps. Station numbers of the supports are also displayed.

Fixed loads acting on the bent cap 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 (Matlock, et al, 1966). Sign conventions are identical with those used in the original CAP18 code. Magnitudes of absolute maximum and minimum are also

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displayed for quick reference. If no fixed loads are specified, the graph is replaced with a message indicating this fact.

4. RUN ANALYSIS

Selection of this option triggers execution of the analysis code with the specified input data file. In this implementation, the original CAP18 analysis code is a subroutine which runs at the command of this menu selection and calls its own subroutines. Although modification to CAP18 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 overlaid 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 from 20 to 30 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 bent cap.

Results of CAP18 are divided into four main series of tables, whose numbering follows that of Ref. 1. Tables with "a" type are output results from working stress analysis. Tables with "b" type are output results from load factor analysis. Tables 4a and 4b give dead load deflections, shear, and moments for working stress and load factor analysis, respectively. Table 5 series show a summary of movable load effects on moment, shear, and reaction. Table 6 series give envelopes of extreme values of moment and shear (Matlock,

et al, 1966). Table 7 series show extreme values of reactions at each control point (Matlock, et al., 1966).

The user can select an individual table for viewing from the menu (Fig. 8). Each table is presented on a separate screen and allows the user to scroll through data using the 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
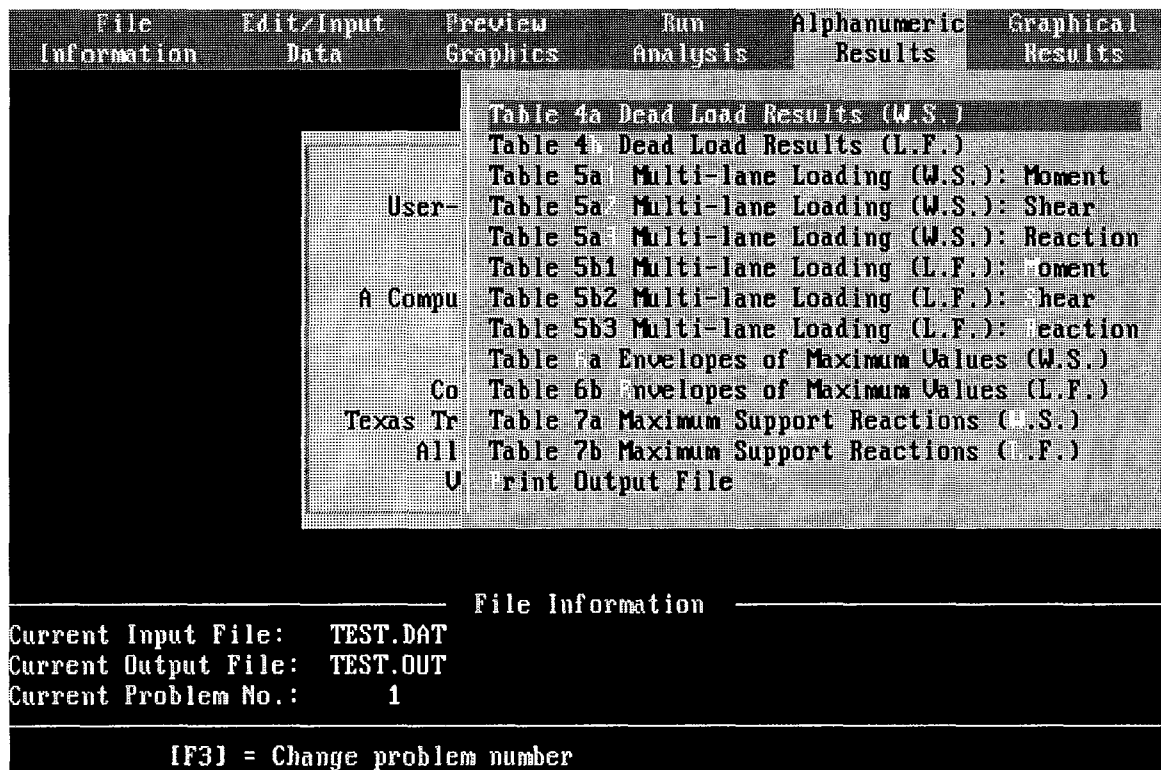
Fig. 8: Submenu "Alphanumeric Results" Module

printing is complete, the user is returned to the Alphanumeric Results menu.

6. GRAPHICAL RESULTS

Graphical output from results of the analysis is presented under this option. Three fundamental kinds of graphs are provided: (1) envelopes of maximum moment, (2) envelopes of maximum shear, and (3) maximum support reactions. These three types

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include graphs generated from both working stress and load factor analysis. The submenu for this module is displayed in Fig. 9. Graphs include problem identification and number, and appropriate scales.

a) Graphics Options - As mentioned above, two sets of graphs are generated according to

| File
Information | Edit/Input
Data | Preview
Graphics | Run
Analysis | Alphanumeric
Results | Graphical
Results |

Dead Load Deflection (W.S.)
Envelopes of Maximum Moment (W.S.)
Envelopes of Maximum Shear (W.S.)
Maximum Support Reactions (W.S.)
Envelopes of Maximum Moment (L.F.)
Envelopes of Maximum Shear (L.F.)
Maximum Support Reactions (L.F.)

User-Friendly PC
CAP18

A Computer Program
Bent Cap

Copyright (c) 1990,
Texas Transportation Institute
All Rights Reserved.
Version 12.31.90

—————————— File Information ——————————
Current Input File: TEST.DAT
Current Output File: TEST.OUT
Current Problem No.:   1

[F3] = Change problem number

Fig. 9: Submenu "Graphical Results" Module

three different parameters: moment, shear, and reaction. Each of these two sets is from either working stress or load factor analysis.

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 cap 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.

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b) Plotting options - After a graph is displayed on the screen, a hardcopy plot can be obtained by accessing the plot options (Fig. 10). Three options are available for obtaining hardcopy plots:
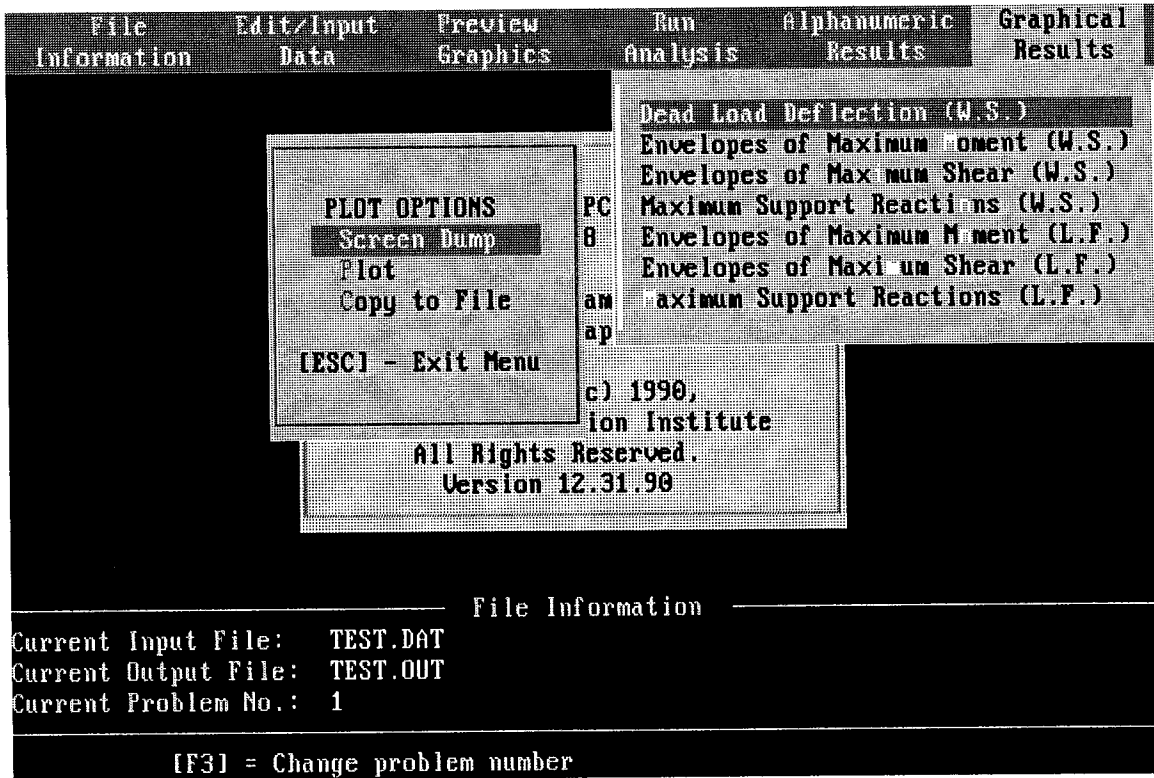
Fig. 10: Graphical Results - Plot Options

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.

2. Plotter - All plotters that support the Hewlett-Packard Graphics Language (HPGL) are supported. Various parameters displayed on the graphs 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.

Fig. 11: Screen Dump - Printer Selection Screen
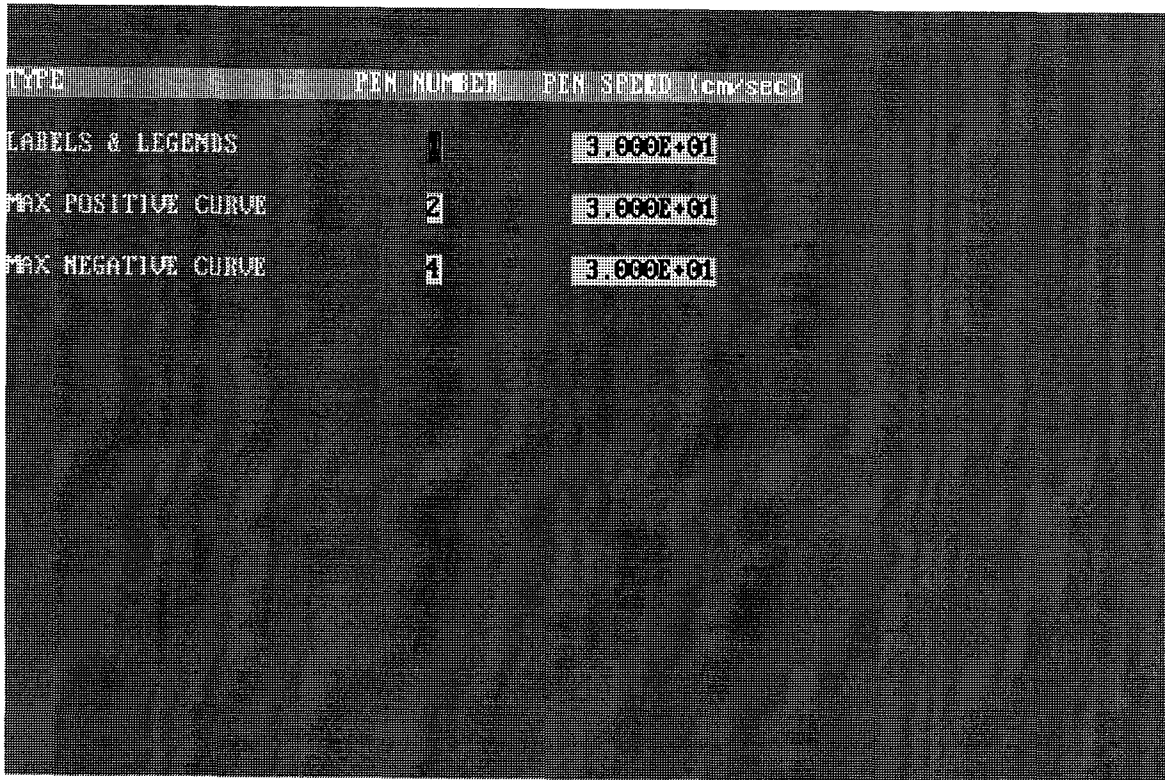
Fig. 12: Plot Parameter Selection Screen

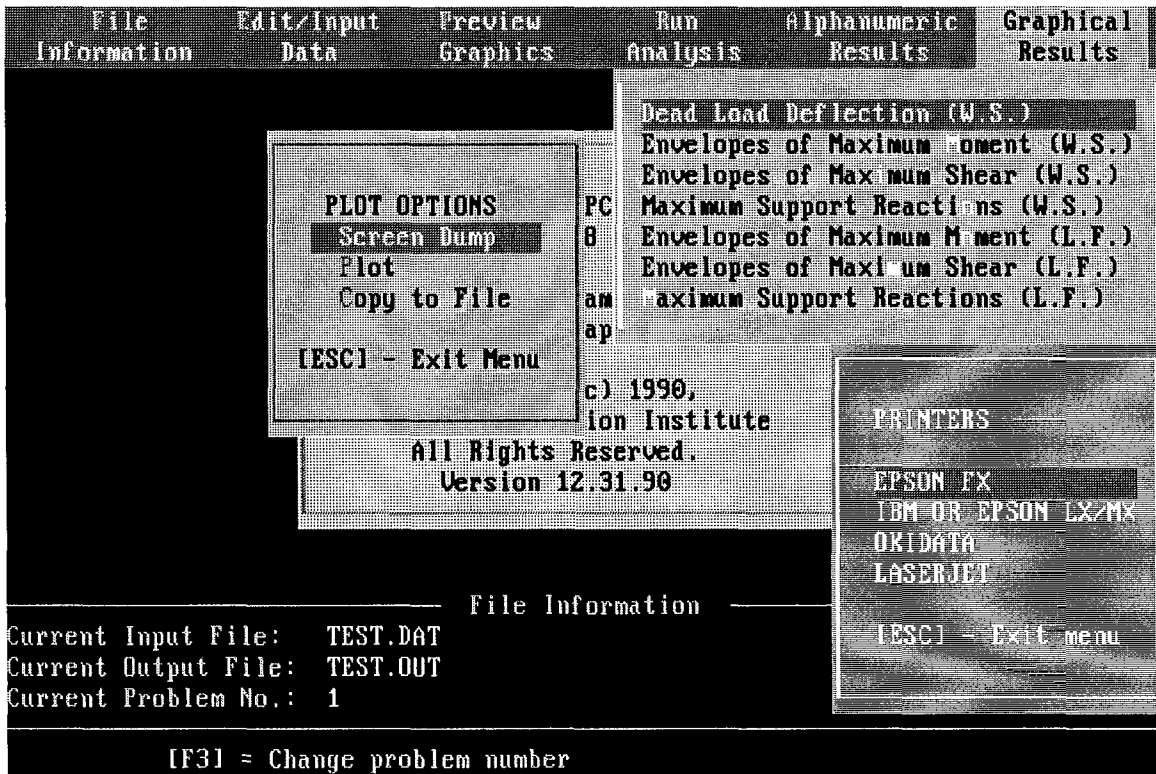Communication between the plotter and the computer can be done by issuing the DOS command **MODE LPT1: = COM1:** (or COM2: depending upon where the plotter is connected). Before any plotting can be done, this link must be set up. This can be done in the AUTOEXEC.BAT file. The plotter is set to be used as a device and, therefore, no screen dumps to a plotter can be used.

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 CAP18 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 typical bent cap problem. The run contains one problem which is described in detail below and in Ref. 1.

The example session shown in Fig. 13 is chosen to illustrate important features of the enhanced CAP18 program. All of the input tables are used in forming the input file.

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 sub-menu 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 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.
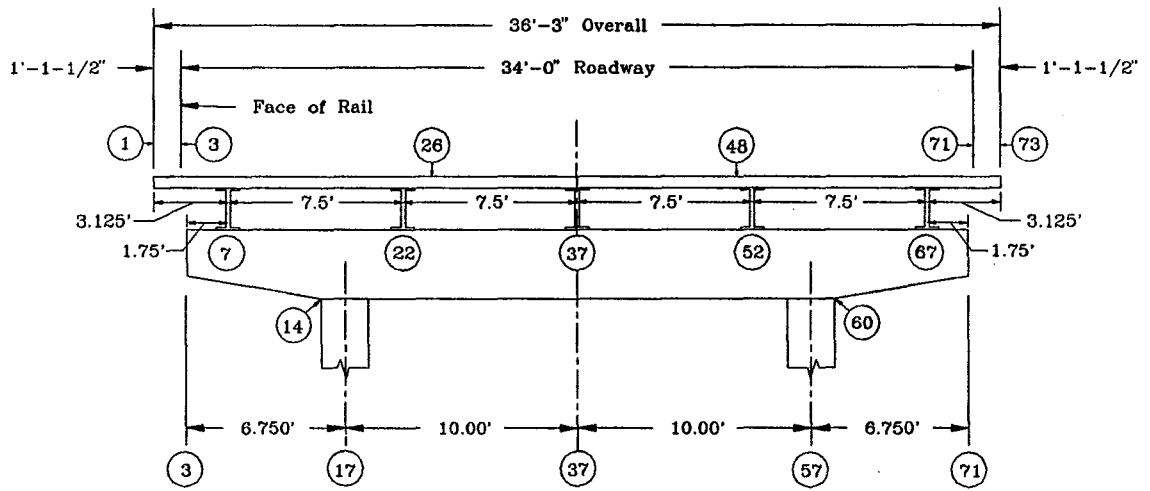
(a) Example Problem Geometry
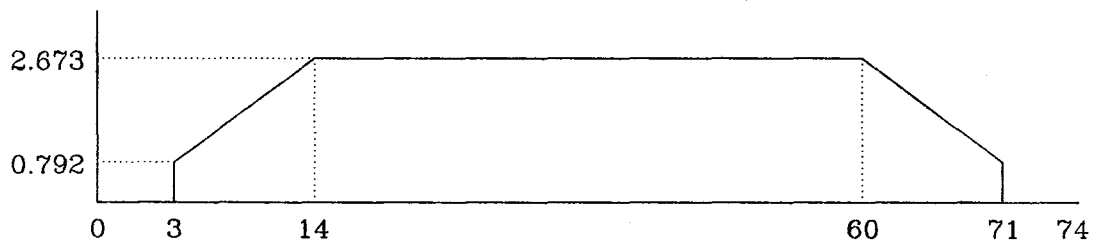
(b) Cap Bending Stiffness (10^5 k–ft^2)
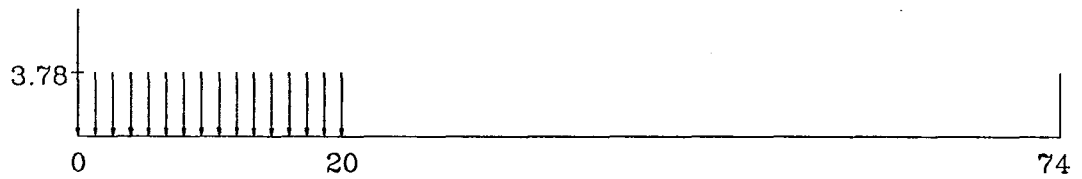
(c) Movable Slab Loads (k)
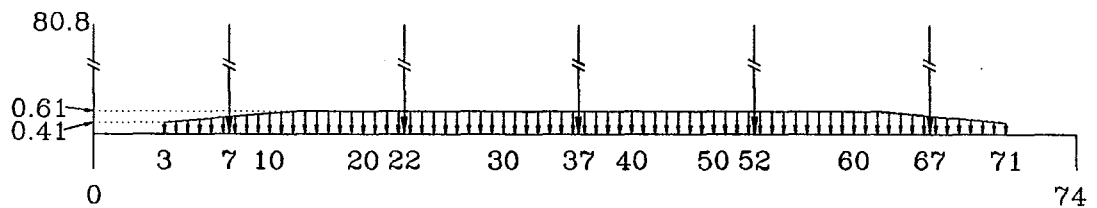
(d) Fixed–Position Cap Loads (k)

Fig. 13: Sample Problem – Geometry and Loading

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

STEP 1 - FILE INFORMATION

Default filenames for input and output files are left as blanks, respectively. Let the new file containing this problem be called TEST.DAT and the output file TEST.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 using the keyboard, enter TEST.DAT when the program prompts for the filename (Fig. 14). Since this is a new file, the user is also prompted for a numerical or alphanumerical identifier by **"Enter New Problem Number."** Enter the number 1. Similarly, to change the name of the output file, select **"Change Output File"** and enter TEST.OUT.
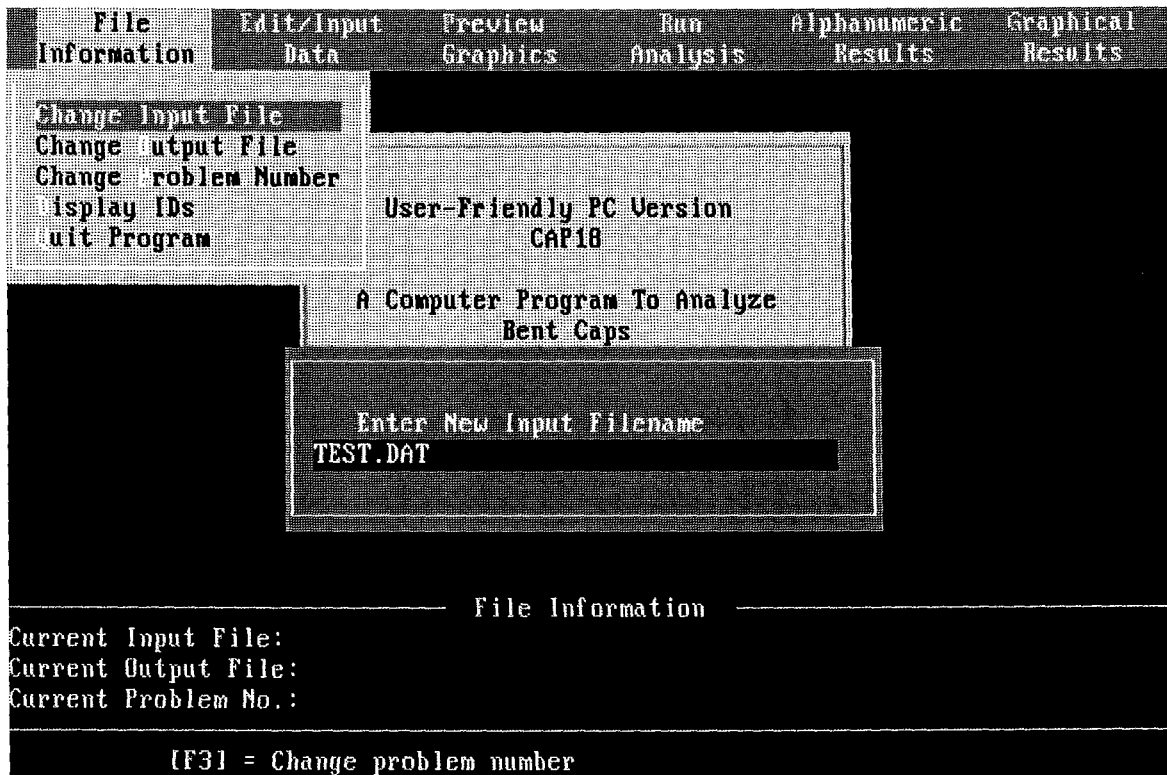
Fig. 14: Specification of Input File

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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, fields specifying data to be held should be left blank. For the number of cards for Tables 2 through 4 enter 2, 7, 10, respectively. Enter 0.0 for the degree of skew angle. The table is shown in Fig. 15.

```
Identification of Run
     LKW                EXAMPLE NO. 1 - NORMAL BENT (ZERO SKEW) JUNE 74
     USE STD. BGP-C-34HS                              KIP FT UNITS
Problem No.           Problem Description
     1    CAP DESIGN

              Table 1.  Program Control Data

         Enter "1" to Hold Prior Data
         Envelopes   Table 2    Table 3    Table 4
         [    ]      [    ]     [    ]     [    ]

         Number of Cards Added for
         Table 2    Table 3    Table 4
         [   2]     [   7]     [  10]

         Enter "1" to Clear Envelopes:                    [    ]

         Plot Options: 0=No Plots, 1=Working Stress Envelopes
                       2=Load Factor Envelopes, 3=Both     [    ]
         Omit Print: -1=Table 4a and Table 4b,
                     -2=Table 5, -3=Both                   [    ]

         Skew Angle, Degrees:                          [0.000E+00]
```

Fig. 15: Table 1 - Input File

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

Number of Increments for Slab and Cap	74
Increment Length, Ft	0.500
Number of Increments for Movable Load	20
Start Position of Movable-Load Station Zero	3
Stop Position of Movable-Load Station Zero	51
Number of Increments between Each Position of Movable Load	1

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Analysis Option (1=Working Stress, 2=Load Factor, 3=Both)   3

Load Factor for Dead Load   1.30

Load Factor for Live Load   2.17

Maximum Number of Lanes to be Loaded   3

List of Load Coefficients Corresponding to Number of Lanes Loaded

1	2	3	4	5
1.000	1.000	0.900		

```
Problem No.              Problem Description
   1      CAP DESIGN


               Table 2.  Constants and Load Data


       Number of Increments for Slab and Cap          74
       Increment Length, Ft                     5.000E-01
       Number of Increments for Movable Load          20
       Start Position of Movable-Load Station Zero      3
       Stop Position of Movable-Load Station Zero      51
       Number of Increments between Each Position       1

       Analysis Option: 1=Working Stress,
          2=Load Factor,   3=Both                       3
       Load Factor for Dead Load                1.300E+00
       Load Factor for Live Load                2.170E+00

       Maximum Number of Lanes to be Loaded             3
       Load Coefficients:
       1.000E+00       1.000E+00       9.000E-01
```

Fig. 16: Table 2 - Input File

```
                        Table 3.  List of Stations

Table 3a:                                      Table 3a
 The numbers of
 1. Lanes   2. Stringers        | Lanes | Strs | Sups | Mmcon | Shcon |
 3. Supports
 4. Moment control points       |   3   |  5   |  2   |   5   |   6   |
 5. Shear control points
                                 Table 3b

| Key of Input Cards |              List of Stations

| Left of Lanes      |   3 |  26 |  48 |
| Right of Lanes     |  26 |  48 |  71 |
| Stringers          | 7.0 |22.0 |37.0| 52.0| 67.0|
| Supports           |  17 |  57 |
| Moment Ctrl Points |  17 |  22 |  37 |  52 |  57 |
| Shear Ctrl Points  |  15 |  19 |  24 |  50 |  55 |  59 |


[Esc] to Exit
```

Fig. 17: Table 3 - Input File

TABLE 3 Lists of Stations - Enter the following data for Table 3 (Fig. 17):

	Num. of Lanes	Num. of Stringers	Num. of Supports	Num. Mom. Contr. Pts.	Num. Shear Contr. Pts.	
Total	3	5	2	5	6	
Lane Left	3	26	48			
Lane Right	26	48	71			
Stringers	7.0	22.0	37.0	52.0	67.0	
Supports	17	57				
Mom. Contr	17	22	37	52	57	
Shear Contr	15	19	24	50	55	59

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Table 4. Stiffness and Load Data

| From Sta.	To Sta.	Contd. if=1	Cap Bending Stiffness	Sidewalk, Slab Loads	Stringer, Cap Loads	Position, Slab Loads
3		1	7.920E+05		-4.125E-01	
	14	1	2.673E+06		-6.188E-01	
	60	1	2.673E+06		-6.188E-01	
	71		7.920E+05		-4.125E-01	
7	7				-8.080E+01	
22	22				-8.080E+01	
37	37				-8.080E+01	
52	52				-8.080E+01	
67	67				-8.080E+01	
0	20					-3.980E+00

[Esc] to Exit

Fig. 18: Table 4 - Input File

TABLE 4 Stiffness and Load Data - Enter the following data for Table 4 (Fig. 18):

Fixed-or-Movable			Fixed-Position Data			Movable-
Sta. from	Sta. to	Contd. if=1	Cap Bending Stiffness $(K - Ft^2)$	Sidewalk, Slab Loads (K)	Stringer, Cap Loads (K)	Position Slab Loads (K)
3		1	7.920E05	0.000	-4.125E-01	0.000
	14	1	2.673E06	0.000	-6.188E-01	0.000
	60	1	2.673E06	0.000	-6.188E-01	0.000
	71	0	7.920E05	0.000	-4.125E-01	0.000
7	7	0	.000	0.000	-8.080E 01	0.000
22	22	0	.000	0.000	-8.080E 01	0.000
37	37	0	.000	0.000	-8.080E 01	0.000
52	52	0	.000	0.000	-8.080E 01	0.000
67	67	0	.000	0.000	-8.080E-01	0.000
0	20	0	.000	0.000	0.000	-3.980E 00

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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 the option provided.

Movable Slab Loads - The graph displayed on the screen is shown in Fig. 19. Use the [Esc] key to return to the pull-down menu.
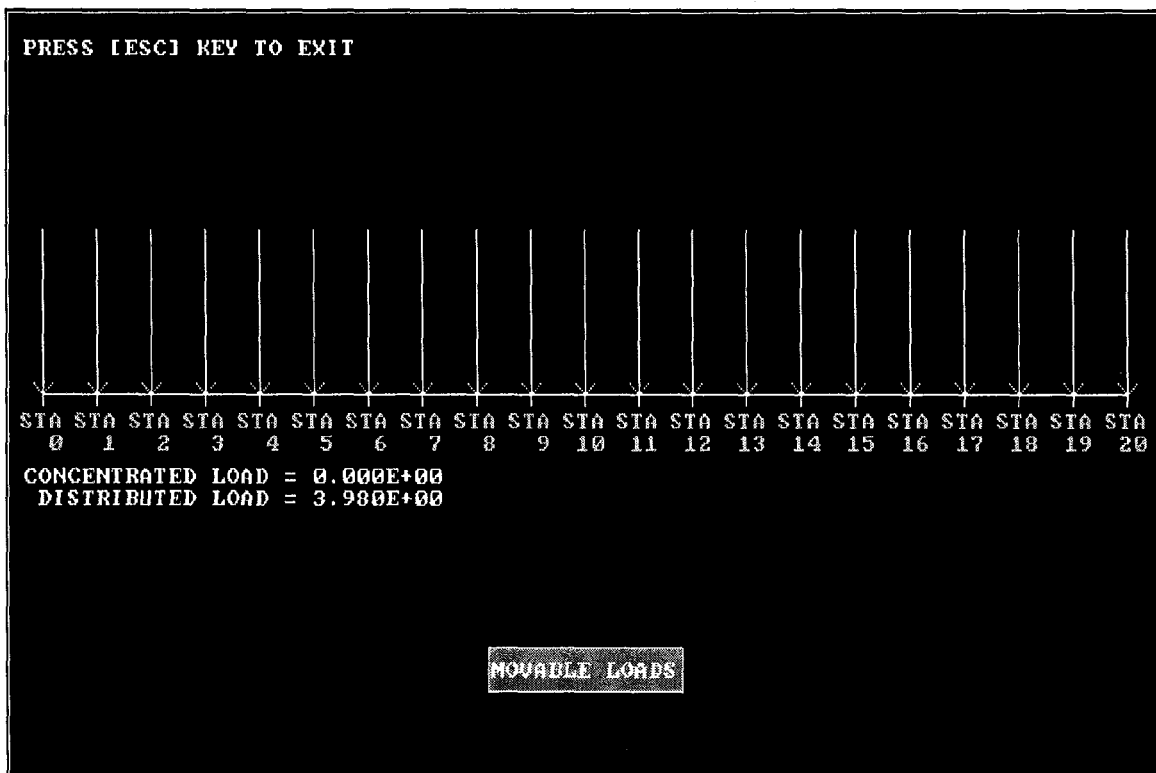
Fig. 19: Movable Slab Loads

Cab Stiffness - The graph displayed on the screen is shown in Fig. 20. Use the [Esc] key to return to the pull-down menu.

Support Conditions and Loadings - The graph for fixed loads on sidewalk and slab is shown in Fig. 21. The graph for fixed loads on stringer and cap is shown in Fig. 22. Use the [Esc] key to return to the pull-down menu.
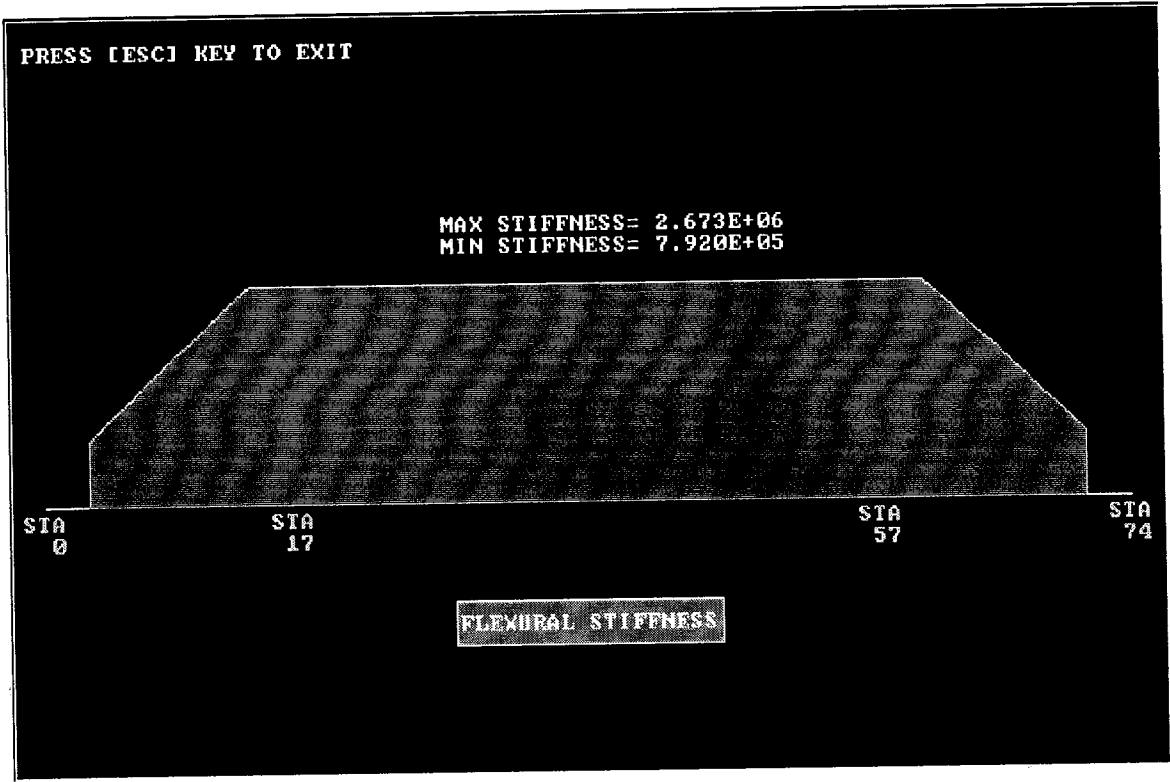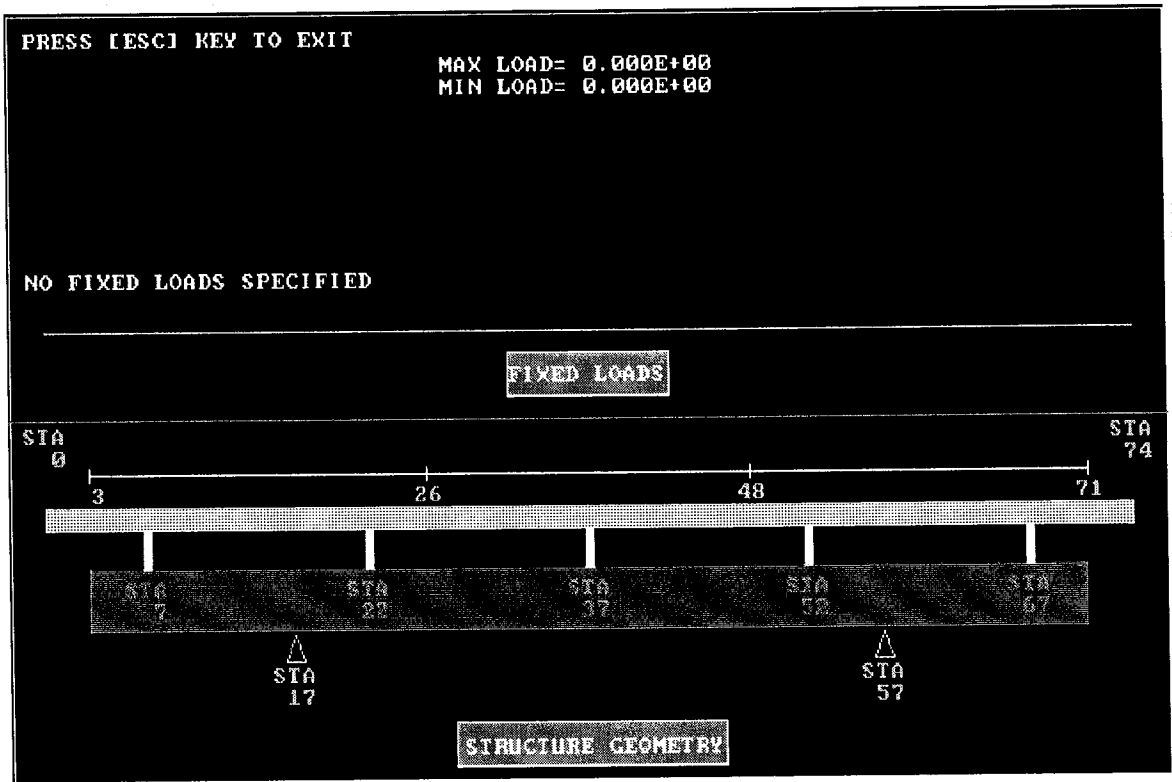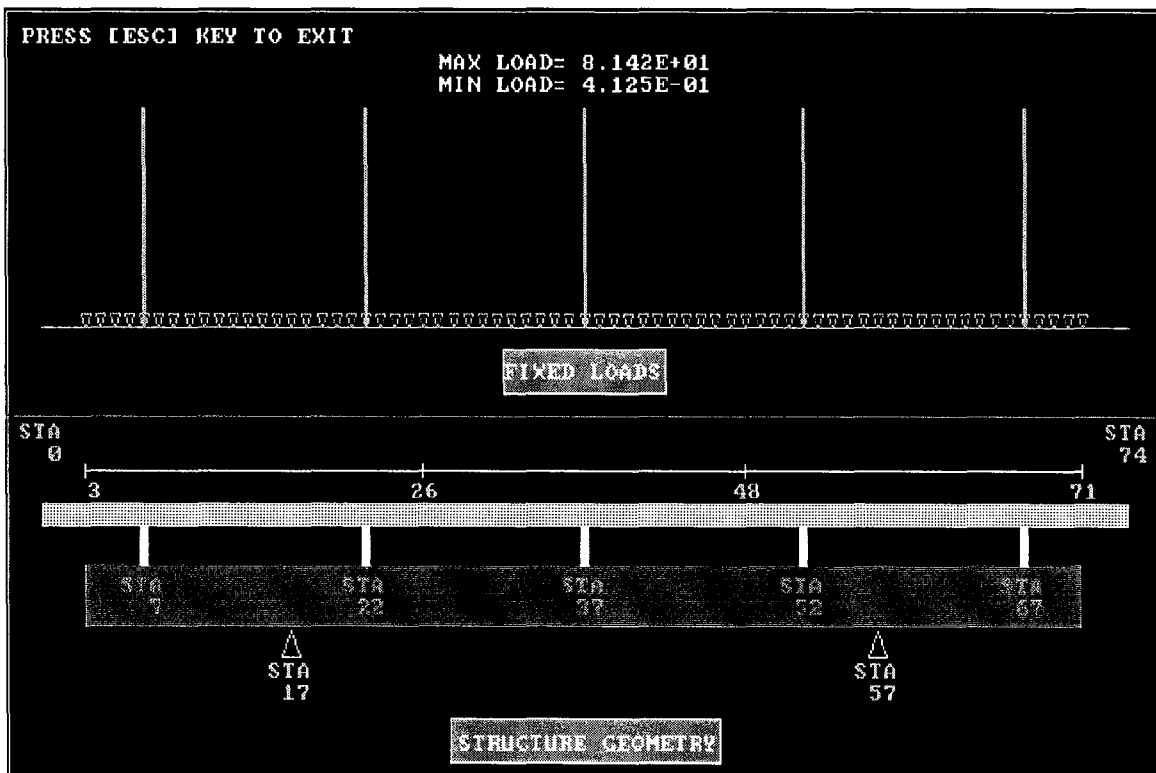
Fig. 20: Cap Stiffness

Fig. 21: Fixed Loads (Sidewalk, Slab Loads)

Fig. 22: Fixed Loads (Stringer, Cap 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. 23). 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. Since output results from working stress analysis are very similar in format to those of load factor analysis, only the set of output tables from working stress analysis are presented here. The user can simply invoke submenu options to see output tables for load factor analysis.

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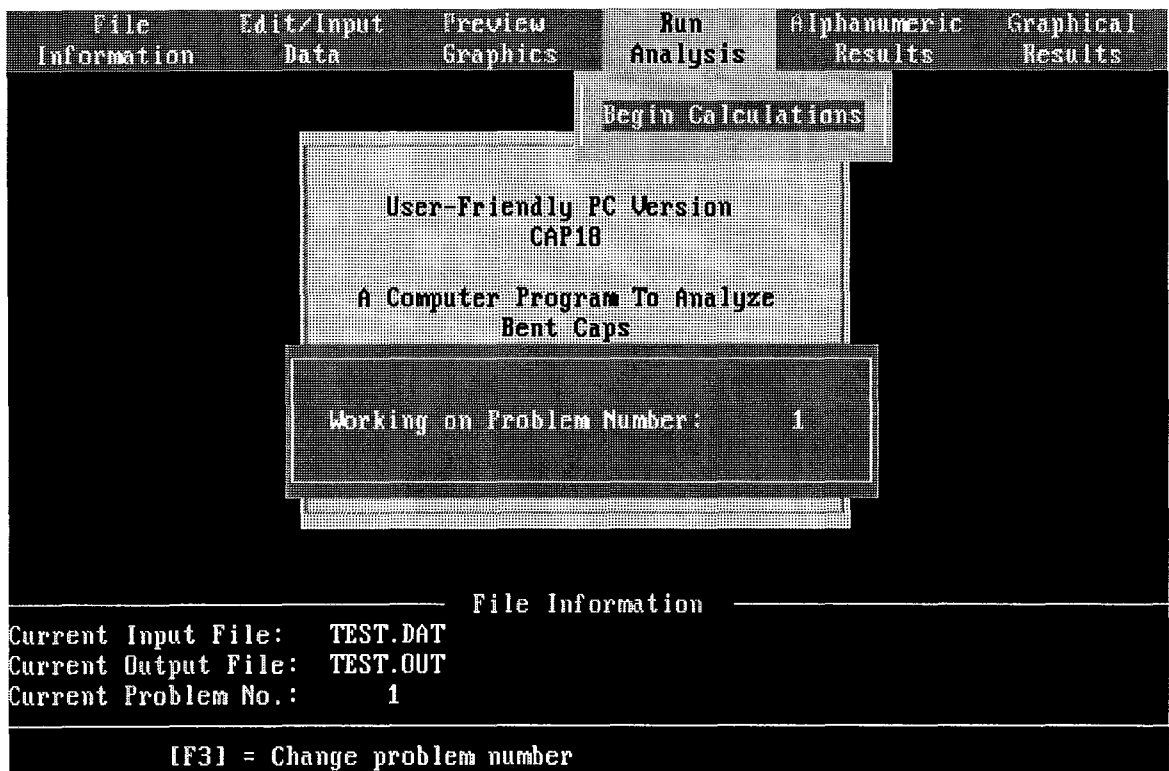
Fig. 23: Screen Display "Run Analysis"

Table 4a Dead Load Results (Working Stress) - This table is shown in Fig. 24. 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 5a1 Multi-lane Loading (Working Stress): Moment - This table is shown in Fig. 25. The same keys are used to move within this table as previously described.

Table 5a2 Multi-lane Loading (Working Stress): Shear - This table is shown in Fig. 26. The same keys are used to move within this table as previously described.

Table 5a3 Multi-lane Loading (Working Stress): Reaction - This table is shown in Fig. 27. The same keys are used to move within this table as previously described.

Table 6a Envelopes of Maximum Value (Working Stress) - This table is shown in Fig. 28. The same keys are used to move within this table as previously described.

Table 7a Maximum Support Reactions (Working Stress) - This table is shown in Fig. 29. The same keys are used to move within this table as previously described.

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Table 4a. Dead Load Results (Working Stress)

Sta.	Dist. X (Ft)	Deflection (Ft)	Moment (K-Ft)	Shear (K)
-1	-.50	.000000	.0	.0
0	.00	.000000	.0	.0
1	.50	.000000	.0	.0
2	1.00	-.002723	.0	.0
3	1.50	-.002489	.0	-.1
4	2.00	-.002255	-.1	-.4
5	2.50	-.002021	-.4	-.9
6	3.00	-.001787	-1.0	-1.3
7	3.50	-.001554	-1.7	-42.2
8	4.00	-.001320	-43.2	-83.1
9	4.50	-.001094	-84.8	-83.6
10	5.00	-.000879	-126.8	-84.1
11	5.50	-.000679	-169.0	-84.7
12	6.00	-.000500	-211.5	-85.3
13	6.50	-.000343	-254.3	-85.9

[Esc] to Exit

Fig. 24: Table 4a - Dead Load Results (Working Stress)

Table 5a1. Multi-Lane Loading Summary (Working Stress): Moment
(*--Represents Critical Number of Lane Loads)

At Sta.	Dead Load Effect	Lane Order	Positive Maximum	Load Lane	At Sta.	Lane Order	Negative Maximum	Load Lane	At Sta.
17	-428.4								
		0	.0			0	-239.5	1	3
		1	.0			1	-239.5	1	3
		2	.0			2	.0		
		3	.0			3	.0		
		0*				0*			
22	-98.4								
		0	130.3	0	20	0	-140.3	1	3
		1	104.5	2	26	1	-140.3	1	3
		2	.0			2	-19.9	3	51
		3	.0			3	.0		
		0*				2*			
37	239.4								
		0	298.5	2	27	0	-79.6	1	3
		1	298.5	2	27	1	-79.6	1	3

[Esc] to Exit

Fig. 25: Table 5a1 - Multi-lane Loading (Working Stress): Moment

Table 5a2. Multi-Lane Loading Summary (Working Stress): Shear
(*--Represents Critical Number of Lane Loads)

At Sta.	Dead Load Effect	Lane Order	Positive Maximum	Load Lane	At Sta.	Lane Order	Negative Maximum	Load Lane	At Sta.
15	-87.1								
		0	.0			0	-47.9	1	3
		1	.0			1	-47.9	1	3
		2	.0			2	.0		
		3	.0			3	.0		
		0*				0*			
19	132.3								
		0	57.2	0	14	0	-8.0	3	51
		1	47.6	1	6	1	-8.0	3	51
		2	41.8	2	26	2	.0		
		3	.0			3	.0		
		2*				0*			
24	48.4								
		0	27.3	0	30	0	-8.0	3	51
		1	27.1	2	28	1	-8.0	3	51

[Esc] to Exit

Fig. 26: Table 5a2 - Multi-lane Loading (Working Stress): Shear

Table 5a3. Multi-Lane Loading Summary (Working Stress): Reaction
(*--Represents Critical Number of Lane Loads)

At Sta.	Dead Load Effect	Lane Order	Positive Maximum	Load Lane	At Sta.	Lane Order	Negative Maximum	Load Lane	At Sta.
17	221.9								
		0	87.6	1	3	0	-8.0	3	51
		1	87.6	1	3	1	-8.0	3	51
		2	41.8	2	26	2	.0		
		3	.0			3	.0		
		2*				0*			
57	221.9								
		0	87.6	3	51	0	-8.0	1	3
		1	87.6	3	51	1	-8.0	1	3
		2	41.8	2	28	2	.0		
		3	.0			3	.0		
		2*				0*			

[Esc] to Exit

Fig. 27: Table 5a3 - Multi-lane Loading (Working Stress): Reaction

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Table 6a. Envelopes of Maximum Values (Working Stress)

Sta.	Dist. X (Ft)	Max. +Moment (Ft-K)	Max. -Moment (Ft-K)	Max. +Shear (K)	Max. -Shear (K)
-1	-.50	.0	.0	.0	.0
0	.00	.0	.0	.0	.0
1	.50	.0	.0	.0	.0
2	1.00	.0	.0	.0	.0
3	1.50	.0	.0	-.1	-.1
4	2.00	-.1	-.1	-.4	-.4
5	2.50	-.4	-.4	-.9	-.9
6	3.00	-1.0	-1.0	-1.3	-1.3
7	3.50	-1.7	-1.7	-42.2	-66.1
8	4.00	-43.2	-67.1	-83.1	-131.0
9	4.50	-84.8	-132.7	-83.6	-131.5
10	5.00	-126.8	-198.6	-84.1	-132.0
11	5.50	-169.0	-264.8	-84.7	-132.6
12	6.00	-211.5	-331.2	-85.3	-133.2
13	6.50	-254.3	-397.9	-85.9	-133.8

[Esc] to Exit

Fig. 28: Table 6a - Envelopes of Maximum Values (Working Stress)

Table 7a. Maximum Support Reactions (Working Stress)

Sta	Dist. X (Ft)	Max. +React. (K)	Max. -React. (K)
17	8.50	351.3	213.9
57	28.50	351.3	213.9

[Esc] to Exit

Fig. 29: Table 7a - Maximum Support Reactions (Working Stress)

Print Output File - This option is used to obtain a printout of numerical results from analysis. After this option is selected, the program displays a menu of print options and 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. Choose the graph desired from the options provided.

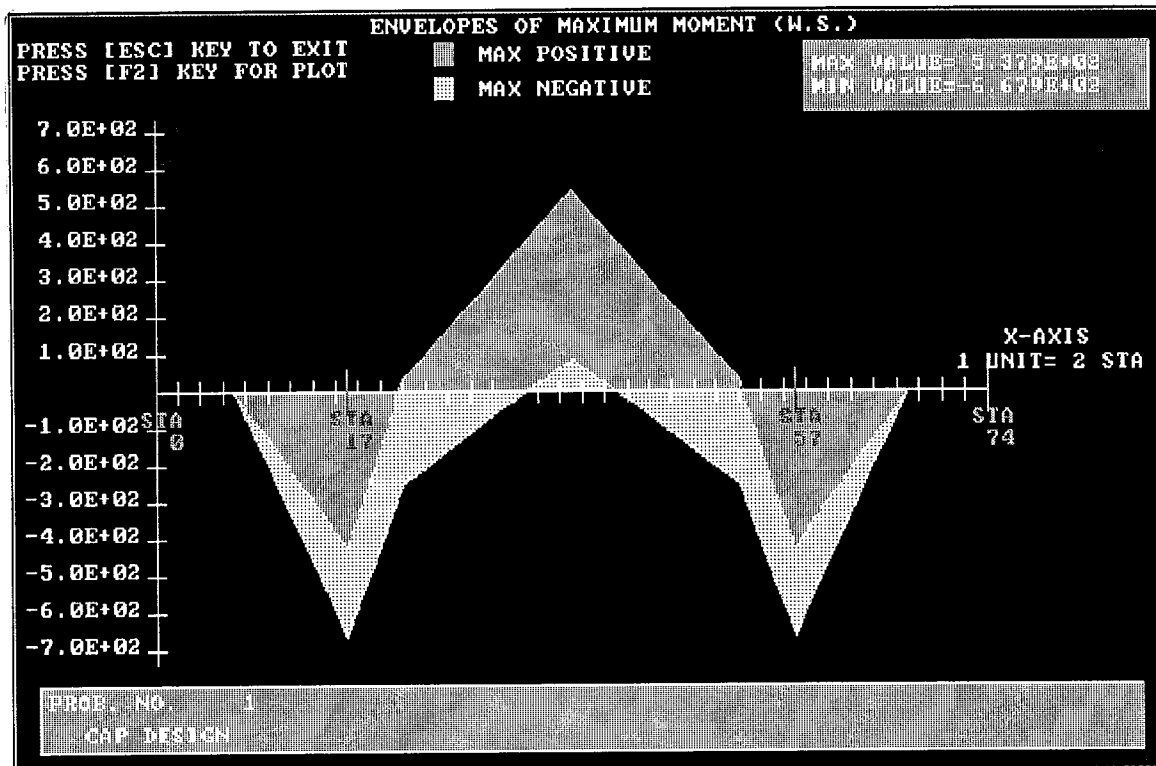**Dead Load Deflection (Working Stress)**

Select this option. The graph displayed on the screen is shown in Fig. 30. Use the [Esc] key to return to the pull-down menu.
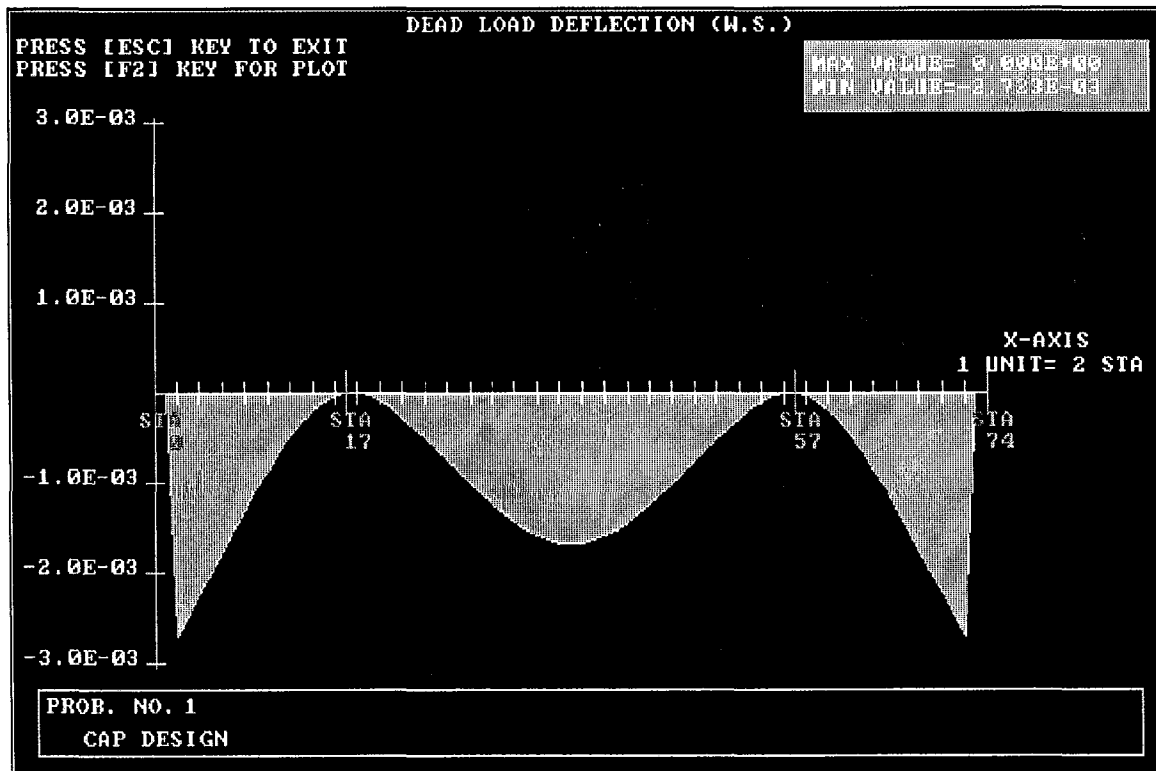
Fig. 30: Graphical Results - Dead Load Deflection (Working Stress)

Envelopes of Maximum Moment (Working Stress)

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

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Fig. 31: Graphical Results - Envelopes of Maximum Moment (Working Stress)

Envelopes of Maximum Shear (Working Stress)

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

Maximum Support Reactions (Working Stress)

Select this option. The graph displayed on the screen is shown in Fig. 33. Use the [Esc] key to return to the pull-down menu.

Envelopes of Maximum Moment (Load Factor)

Select this option. The graph displayed on the screen is shown in Fig. 34. Use the [Esc] key to return to the pull-down menu.

Envelopes of Maximum Shear (Load Factor)

Select this option. The graph displayed on the screen is shown in Fig. 35. Use the [Esc] key to return to the pull-down menu.

Maximum Support Reactions (Load Factor)

Select this option. The graph displayed on the screen is shown in Fig. 36. Use the [Esc] key to return to the pull-down menu.
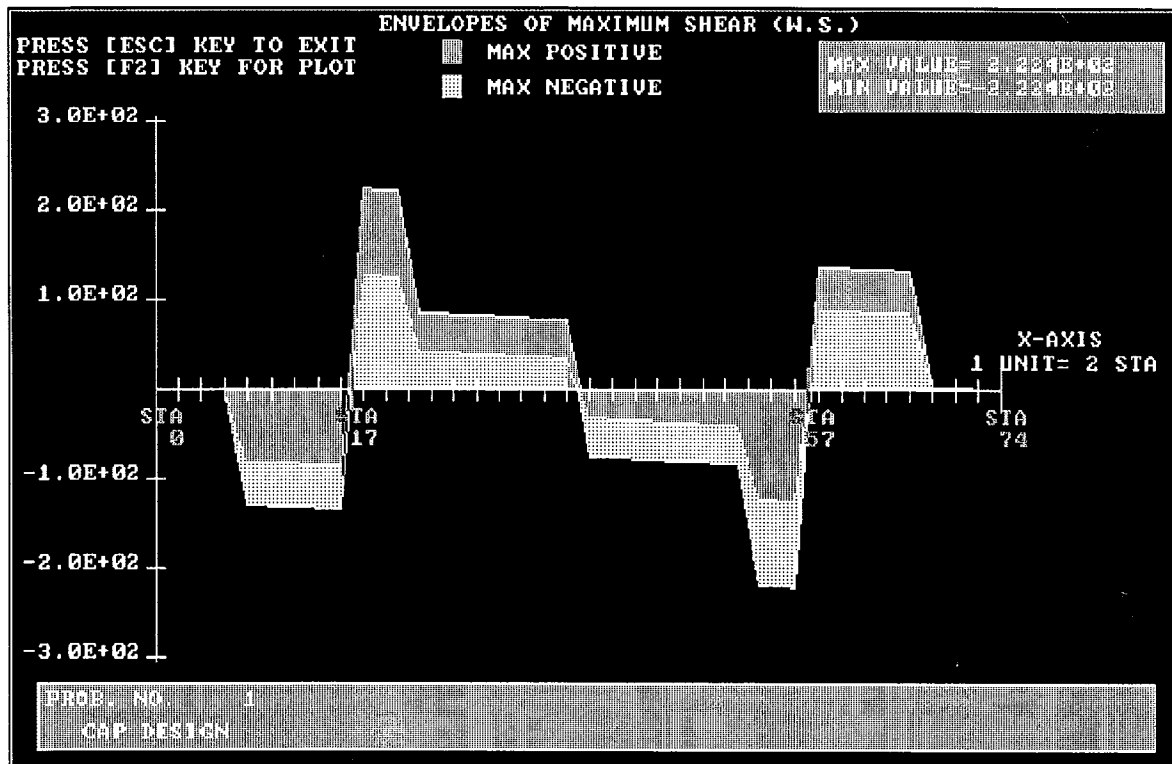
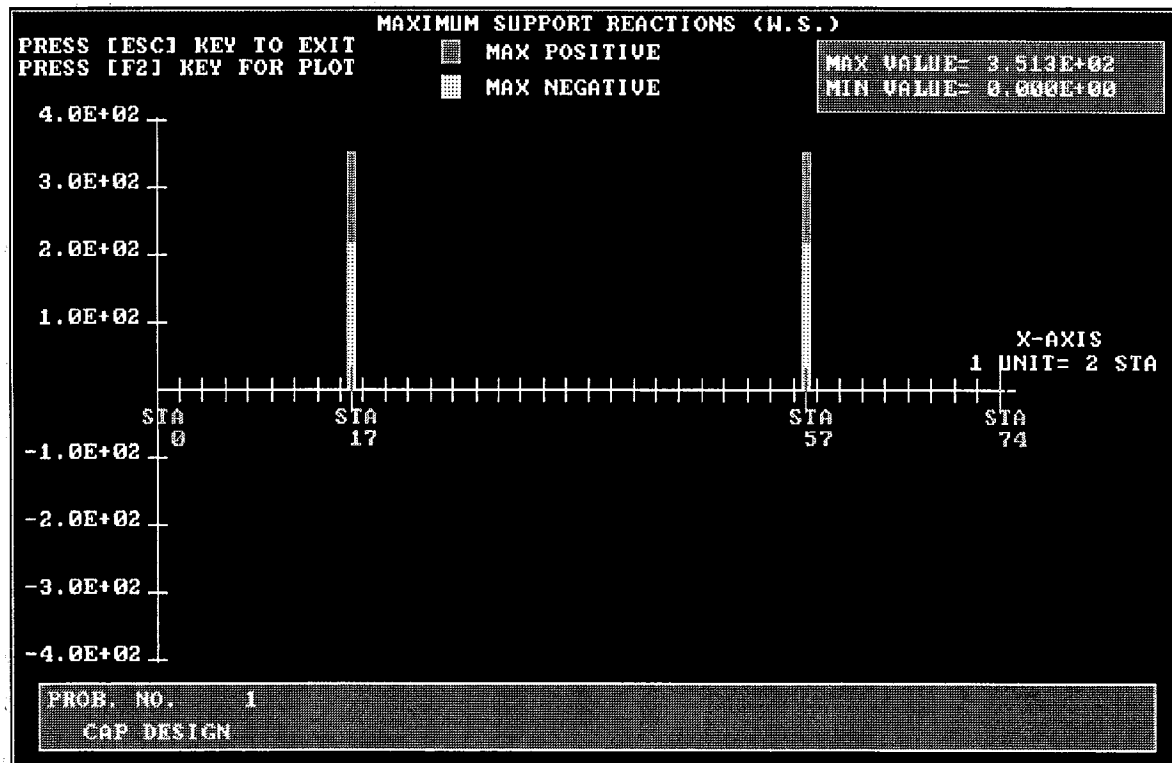**Fig. 32: Graphical Results - Envelopes of Maximum Shear (Working Stress)**

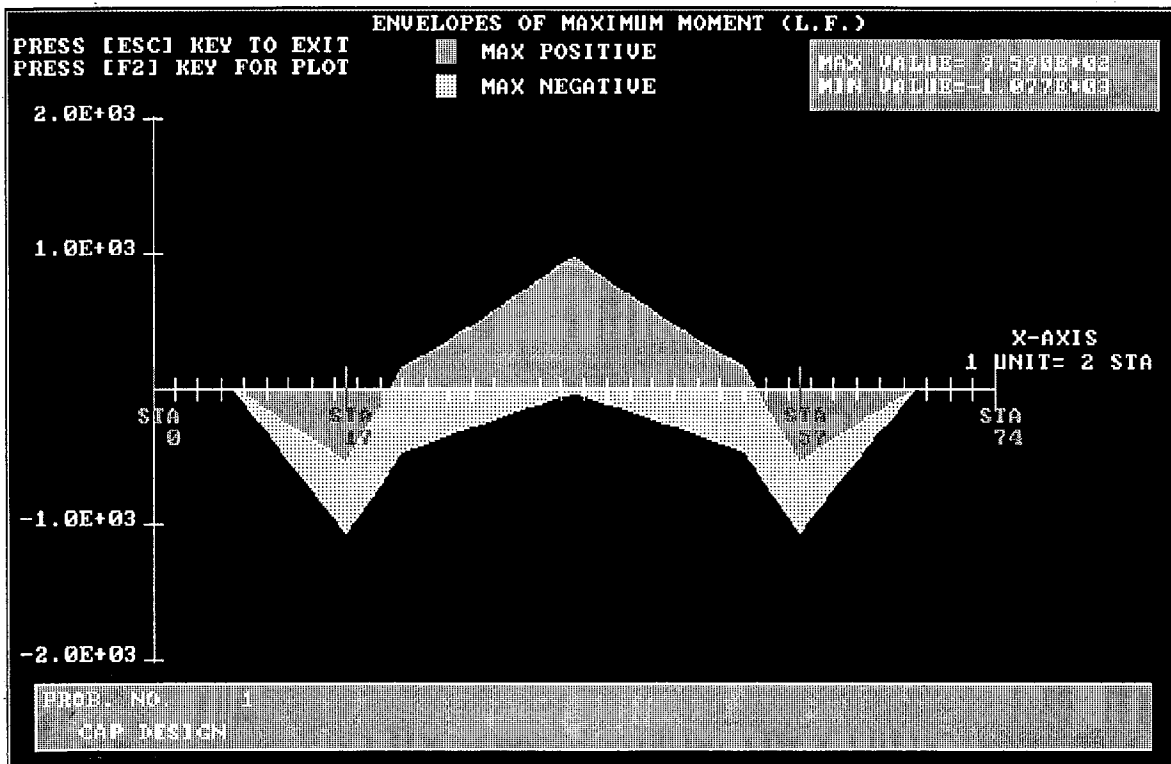**Fig. 33: Graphical Results - Maximum Support Reactions (Working Stress)**

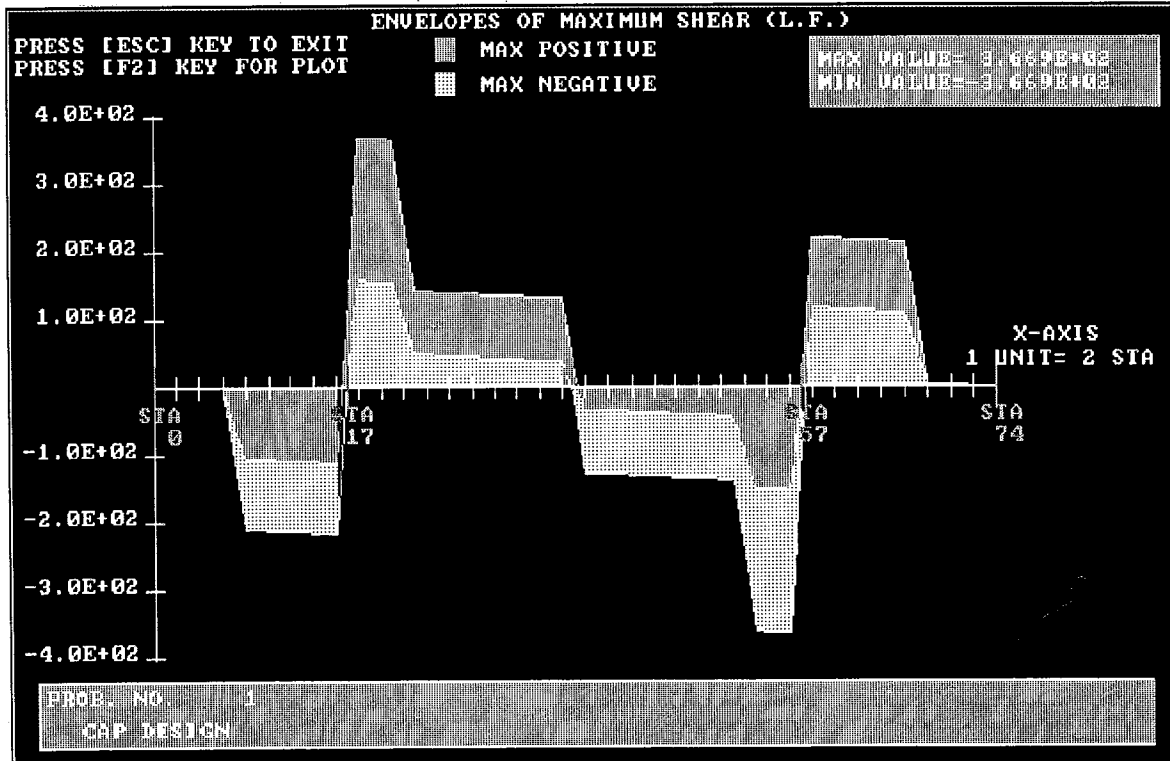**Fig. 34: Graphical Results - Envelopes of Maximum Moment (Load Factor)**

Fig. 35: Graphical Results - Envelopes of Maximum Shear (Load Factor)
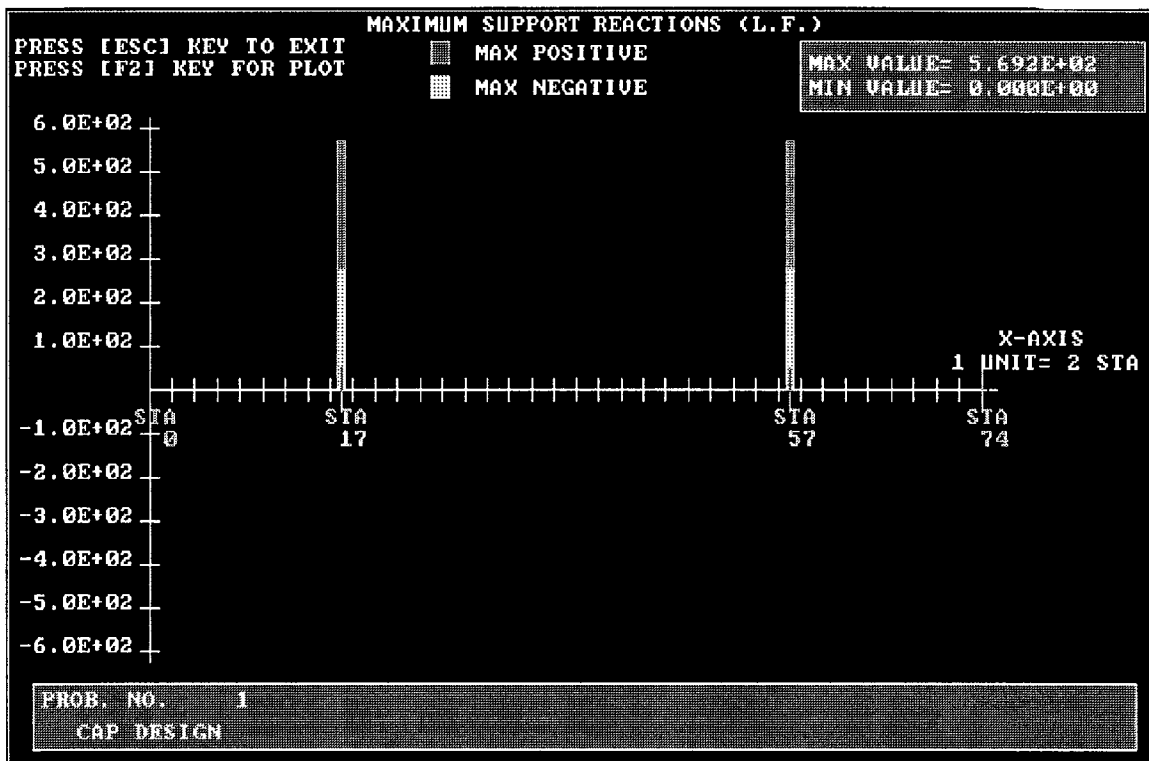
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Fig. 36: Graphical Results - Maximum Support Reactions (Load Factor)

HARDCOPY PLOTS

Hardcopy plots can be obtained once a graph is displayed on the screen. The procedure will be outlined for the Dead Load Deflection graph. The same procedure applies to all types of graphs.

Select this option. The graph will be displayed on the screen as before. Press [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 the following options:

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.

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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 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. 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 a 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 CAP18 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

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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 **CAP18.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 470K 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 CAP18 on a computer with a hard drive, use the DOS COPY command to transfer the executable file from a floppy disk onto 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:CAP18.EXE C:**

REFERENCES

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2. Willis, Leo K., "Bent Cap Program," User Manual, Bridge Division, Texas State Department of Highways and Public Transportation, Austin, January, 1975.

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

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

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