APPLICATION OF SLAB ANALYSIS METHODS TO RIGID PAVEMENT PROBLEMS

by

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PREFACE

Using an example problem this report describes how the practicing design engineer can solve or analyze rigid pavement problems by the discrete-element method of slab analysis.

This is the twenty-sixth in a series of reports that describes the work done in Research Project 3-5-63-56, entitled "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems." The project is divided into two parts, one concerned primarily with bridge structures and the other with pavement slabs, and this is the eighth report in the series that deals directly with pavement slabs.

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ABSTRACT

The discrete-element method of slab analysis provides a unique method for analyzing both complex and common pavement problems. The purpose of this report is to illustrate the application of this tool to a typical rigid pavement design problem. The problem chosen for use herein involves the design of concrete shoulder pavements.

To facilitate the practical use of the SLAB computer program a detailed description of the guide for data input for the computer program is presented. This report also describes all the necessary steps to be taken by a design engineer in the analysis of any typical problem. Included are all the necessary input computations, detailed coding instructions and explanation of the data, interpretation of the output, and possible uses of the output in further design analysis. The example problems are coded and explained card by card for the benefit of the practicing engineer.

KEY WORDS: discrete-element analysis, rigid pavements, concrete shoulders, program SLAB.

SUMMARY

Research showed that the particular effect of providing concrete shoulders on the behavior of the continuously reinforced concrete pavements being studied was a considerable reduction in deflections and stresses. This reduction resulted from removing the load from the pavement edge, since some continuity is provided by the concrete shoulders.

Hence, the construction of portland cement concrete shoulders may be justified by savings from reduced slab pavement thickness, as well as improved performance and low maintenance cost. The presence of the discrete-element method of slab analysis is a valuable tool as applied in this study.

IMPLEMENTATION STATEMENT

This document is a user's guide for the discrete-element slab analysis programs developed in Project 3-5-63-56, "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems." Design engineers can use this guide together with previous theoretical developments, i.e., the computer methods themselves, to analyze both common and unique rigid pavement problems. With it the practicing pavement design engineer can acquaint himself with SLAB analysis methods to the extent necessary to begin analyzing pavement problems directly. The methods will also be assimilated into the pavement system design method for rigid pavements (RPS) which has been developed as a part of Project 123 (Ref 20).

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CHAPTER 1. INTRODUCTION

Background

The discrete-element method of analysis for pavement slabs was developed in the mid-1960's and has been revised and improved several times since (Refs 1, 2, and 3). The method has been proved by tests (Refs 4 and 5) and applied in field studies (Ref 6) and is ready for further application to field problems. Some applications for which the discrete-element method has been used are (1) the investigation of the effect of load placement on pavement analysis and design (Ref 8), (2) the analysis of experimental airfield pavement slabs (Ref 7), and (3) a variety of special problems which have been used to illustrate the reports that have documented the method. These special problems have ranged from simple slabs to very complex structures such as bridge approach slabs. There has also been some limited application of the method to analysis of continuously reinforced concrete pavements (Ref 18).

Objective

The objective of this report is to illustrate how a practicing engineer can use one of the SLAB computer programs to analyze a pavement problem. The design problem used here was obtained from the Texas Highway Department and has been of some concern in determining the economics of concrete shoulders.

Scope

This report illustrates the application of the analysis method to one kind of design problem and discusses the important modeling decisions which must be made in using the method. The report covers selection of the parameters required for development of a discrete-element solution, and does so in such a way that a user can understand it and solve the problem himself. The same approach can then be applied to other field analyses. The problem is coded step by step, and an actual computer solution is included in the appendix. The computer output from the discrete-element analysis is evaluated and interpreted, and the design implications of the problem are suggested.

CHAPTER 2. THE PROBLEM AND APPROACH

Description of the Study

The design study used here to illustrate the discrete-element method of slab analysis involves portland cement concrete pavements with and without concrete shoulders. Since integral shoulders provide partial continuity for the pavement edge and the resulting load stresses and deflections diminish considerably, their use could be very economical. Hence, if shoulders are provided, a lower pavement thickness may be required and the use of shoulders might thus be economically justified over the life of the facility. In this study the resulting stresses and deflections in a continuously reinforced concrete pavement with concrete shoulders are compared to those in a pavement without concrete shoulders. Two slab thicknesses, 7 and 8 inches, are considered since it was anticipated that the thickness will be reduced when concrete shoulders are used. The pavement lies on a cement-stabilized subbase and a highly plastic subgrade. The modulus of subgrade reaction for the pavement was 300 pci/in, but because of the presence of highly expansive soils which have a high probability of creating nonuniform support, it is assumed that the composite subgrade k-value must be reduced to 100 pci/in (Ref 15).

The concrete used in this pavement has the medium to high modulus of elasticity which can be expected for pavements constructed with concrete containing siliceous river gravel aggregates and five sacks of cement per cubic yard, and therefore, a modulus of 4,000,000 psi is used here. The pavement is two lanes, 24 feet, wide (Fig 1). The highway is divided and there is a shoulder on only one side in each direction. The shoulders are 10 feet wide. The joints, sawed to a depth of one-fourth the slab thickness, which is standard jointing practice for longitudinal joints, are considered as cracked sections in this analysis.

Performance studied (Refs 9 and 10) have shown that a desirable crack-spacing in continuously reinforced concrete pavements is about 6 to 8 feet, and this range is simulated in the analysis. The load used is an 18-kip single-axle, which is the maximum legal single-axle load in Texas. It serves

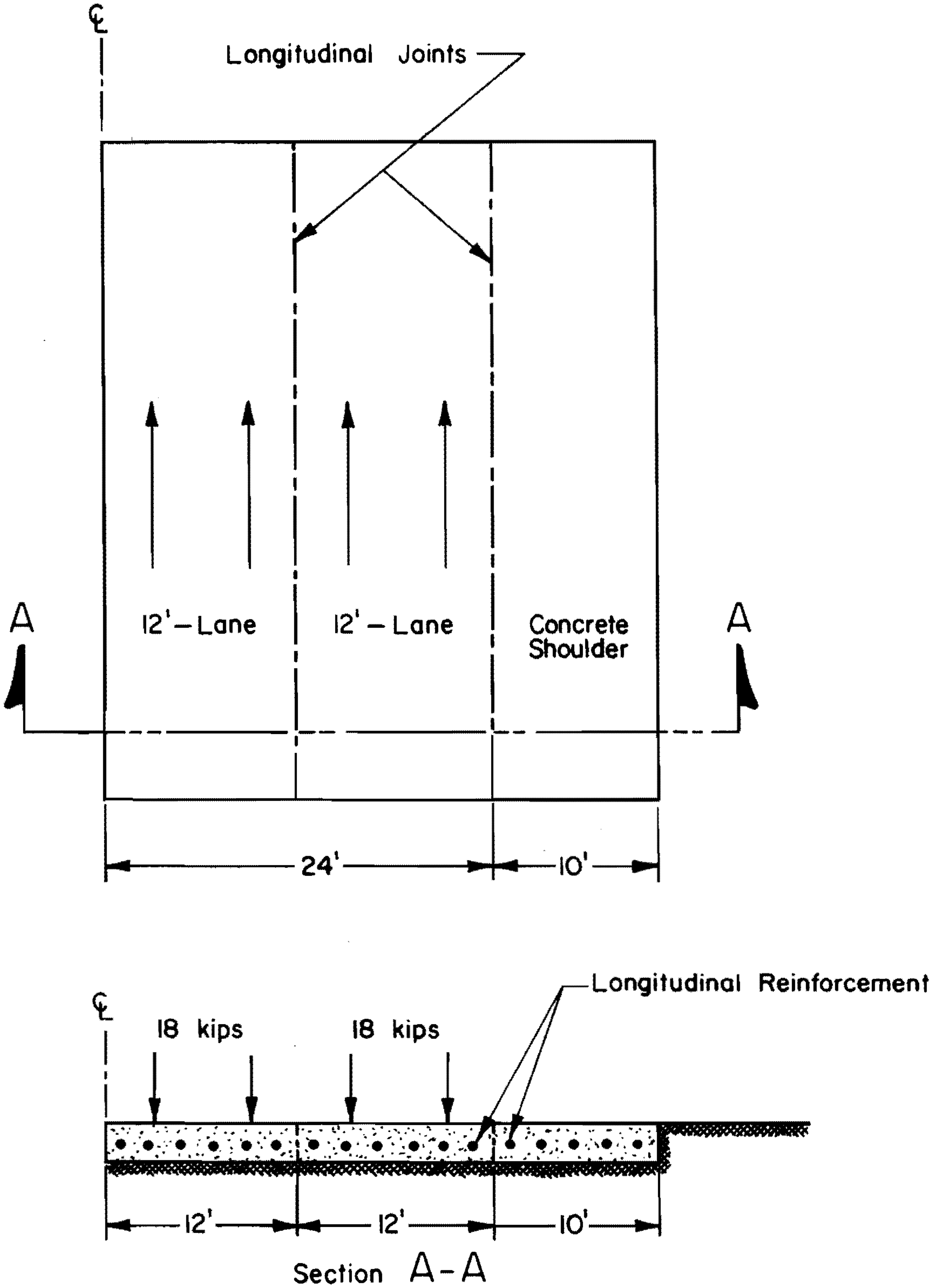


Fig 1. Continuously reinforced concrete pavement with 10 ft-wide concrete shoulders.

to illustrate the maximum expected stresses. Similar comparisons could be made for other loads as desired.

Description of Guide for Data Input

The program used to solve the problems presented in this study is SLAB 49, which is the most recent SLAB analysis method. Details of the procedure for using the data coding form of this SLAB version are given in the guide for data input, Appendix A, which is designed so that copies can be made and used for routine reference,

The first two cards of a problem series are for identification (Fig 2). Any alphanumeric information can be entered, but it is suggested that the date of the run, ther user's name, and units used always be included on these two cards.

The third card gives the problem number and a brief description of the problem. The problem number, which is entered on the first five columns, can contain alphabetical characters if desired. If a blank problem number is encountered, i.e. the first five columns are blank, the program will terminate. Any number of problems can be run at one time.

Table 1 (Fig 2 and Appendix A) is used to input the problem control data and is always comprised of two cards. It includes the keep options, multiple load option, number of cards input for this problem, and other output options including plots.

The first card of Table 1 contains the keep options, with which any data from the preceding problem can be retained by specifying 1 in the appropriate column. Table 2 cannot be added to or modified, but any of the other data tables can be retained and additional data cards can be input up to the combined maximum total of cards for each table. The multiple load option in column 50 of the first Table 1 card is left blank if each successive problem is independent of the preceding problem. If a following problem is for the same pavement-and-grid system, and if only the load pattern and placement, given in Table 7, change, the option of the first problem is specified with +1. This is the "parent" problem, that is the first such problem in a series. The option for each successive loading on problems in the same series is -1, and these problems are called "offspring" problems. When a blank option or another +1 is encountered, that problem is another independent problem or a new problem, and therefore new basic data are to be input.

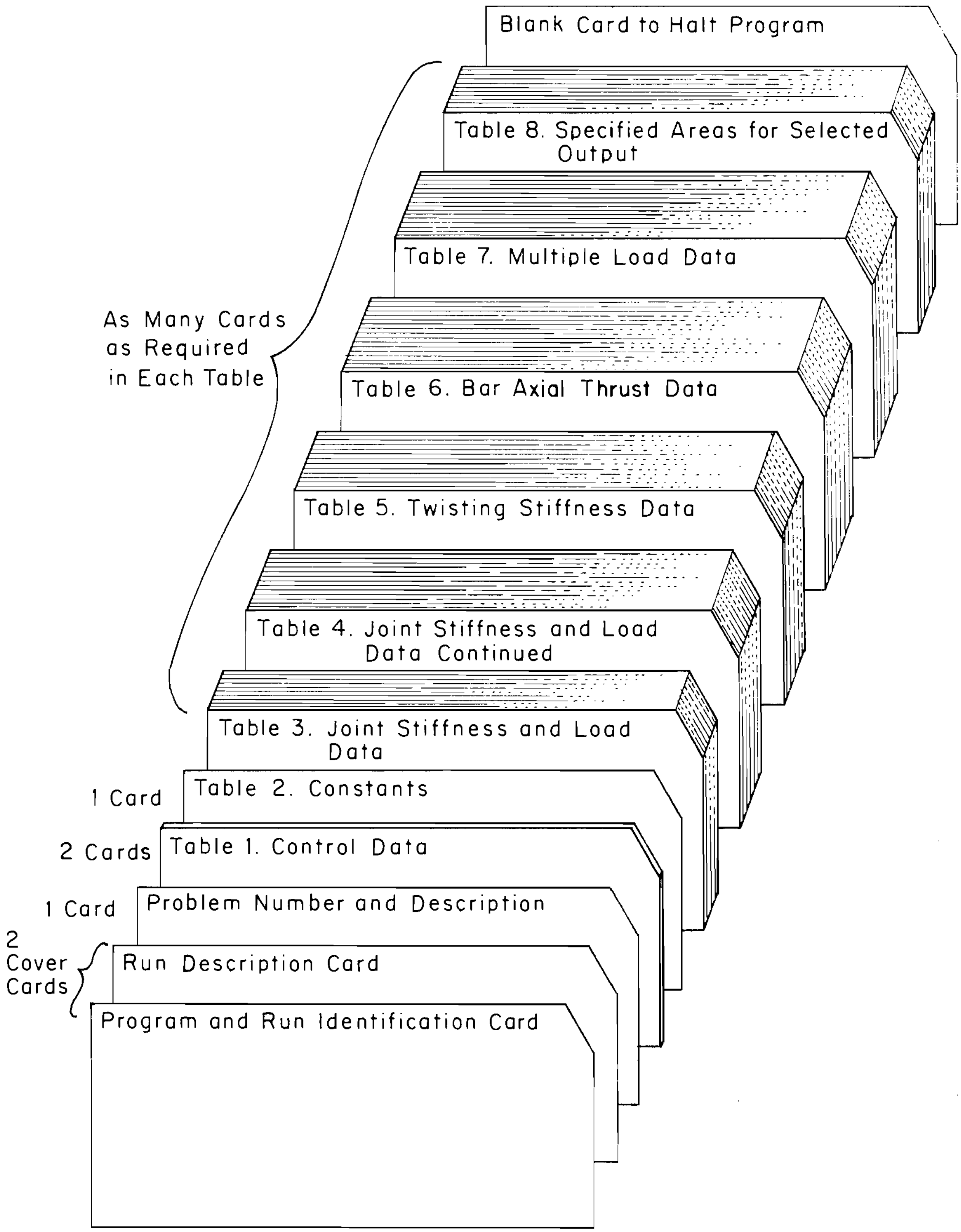


Fig 2. Data assembly.

The second card of Table 1 is for the designation of the number of data cards to be input in this problem for Tables 2 through 9. The user should carefully check the card counts to avoid data errors. A number of common types of data errors are checked for by the input routines, but it is possible to create a false problem if the number of cards specified in Table 1 does not match with the number of available data cards.

The four options in columns 50 through 65 of the second card of Table 1 are for output options (Appendix A). The statics check option can be exercised by entering a 1 in column 50. This is useful for determining if a solution inaccuracy exists, especially for computer systems which have required double precision operations. The statics check is computed internally in the program by reapplication of the governing equations (Ref 17) to the computed values of deflection. Any applied loads and external couples are deducted and the remaining quantity represents the computational error at each joint of the system. The statics check option is normally left blank, in which case the concentrated support reaction at each joint is printed instead. The second output option, in column 55, is exercised by entering a 1 if the user desires that the computed value of principal moment in the slab be converted to an equivalent value of stress. The computed value of stress is correct only for slab areas of uniform thickness with no discontinuities. If this stress option is exercised, an appropriate value of slab thickness must then be input in Table 2. The principal moment is converted to a stress having the same sign by multiplication of the moment by the plate section modulus, which is internally computed from the Table 2 input value of thickness. Axial forces or thrusts if present are not included as part of the stress calculation.

To facilitate and speed up the interpretation of results, the program has the capability of providing, in addition to tabulated results, a graphical presentation or plots of responses such as deflections, moments, or stresses of critical specified stations or areas of the problem. The stations for which the plot is desired are specified in Table 8. The type of plotted output is controlled by the third option, in column 60. If the column is left blank or zero, a printer plot is obtained along with tabulated output designated by Table 8. If 1 is entered, no tabulated output is printed for the areas specified in Table 8, but the plots of those areas are on microfilm, assuming the microfilm is available on the particular computer system. If 2 is entered, then a printer and microfilm plots are obtained. If the option is set equal to 3, only a line plot on paper is obtained for the Table 8 areas and no tabulation is printed. The fourth option, in column 65, is exercised by entering a 1 to create a pseudo-three-dimensional plotted display of all the computed deflections of the entire slab or grid. This is illustrated in Appendix C, where a three-dimensional plot is shown for the example problem studied.

Table 2 is used to specify the constants for the problem and contains only one card. These constants are the number of increments in the x and y directions, the increment lengths in both directions and Poisson's ratio. For efficient solution of the program, it is recommended that the user orients the problem analyzed so that the number of increments in the y-direction is equal to or greater than the number of x-increments. Table 2 must be kept for offspring problems since the constants must be the same as in the parent problem. The thickness of a slab or plate can also be entered in Table 2. The thickness must be entered if the stress option in Table 1 is exercised. The thickness is appropriate only for slabs of a constant thickness. At a specified discontinuity in the slab, such as a crack or joint which might be modeled by means of a reduced bending stiffness (Ref 18), the output value of stress at that location may be misleading. A better estimate of stress at a discontinuity may be obtained by inspecting the variation in computed stress at several stations adjacent to the discontinuity.

Table 3 is for joint stiffness and load data. The number of cards present in this table is as specified in Table 1. Card counts should be carefully checked. It is recommended that a listing of the data cards be checked by the user prior to submission of the program for a run.

The technique required to distribute the stiffness over the slab area is covered in detail in Appendix A. The load input in this table is usually the dead load of the slab, but live loads can be coded here. If the analysis consists of multiple problems for which only the live load is changing, the load is coded in Table 7. The spring values represent the subgrade support.

In the analysis of composite slabs, such as a highway bridge consisting of a concrete deck resting on a system of longitudinal beams (Ref 17), beam bending stiffness is needed in the analysis. However, in most pavement slab analysis beam bending stiffness is not required.

Table 4 is for input of rotational restrains and applied moments, which are input as concentrated effects in either the x or y direction. For most pavement problems this table is not used.

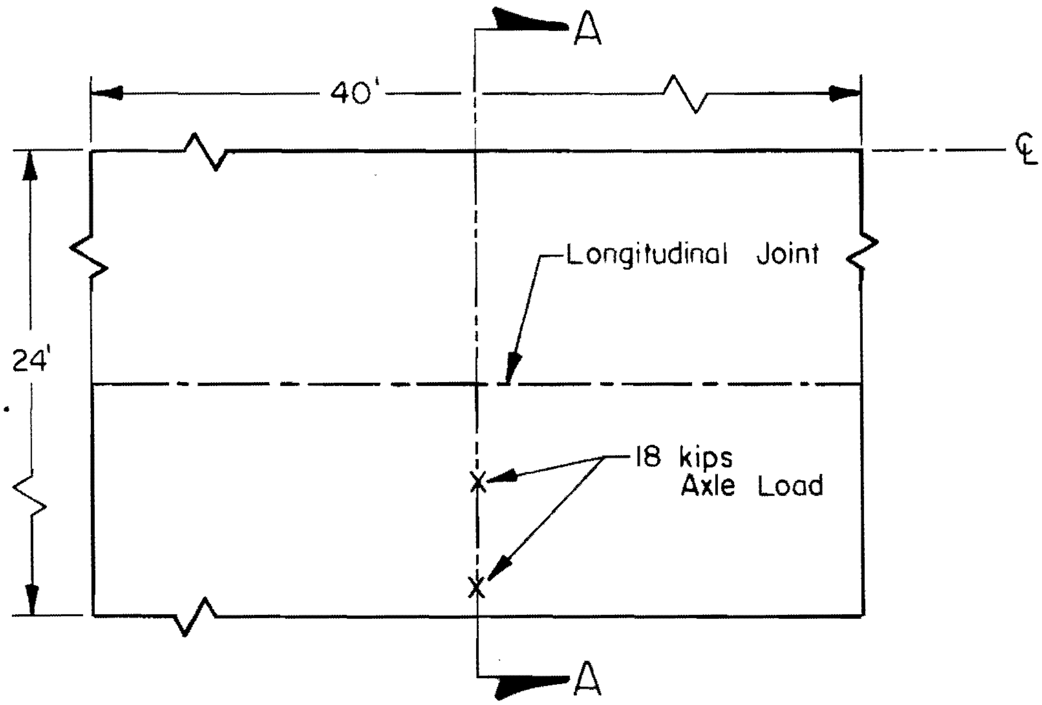
Table 5 is for input of the twisting stiffness associated with the slab or plate. Since this represents stiffness between joints it is not input in the same table as the bending stiffness constants. Normally this table contains only one card.

Table 6 provides for the input of axial forces or thrusts in either the slab or the supporting grid-beam network. All the axial loads are concentrated values, and therefore any distributed axial thrusts in slabs must be concentrated over the appropriate increment width. While it is worth noting that the effect of slab or beam axial thrusts is the same within the program, a provision for inputting them separately is made so that they are easier to visualize and also to allow the independent solution of either grid-beam assemblages or slabs (Ref 17).

Table 7 is used for convenience only for input of loads which change position or magnitude for two or more problems on the same structure. Loads in Table 7 could have been input in Table 3 also, and the data field for the load values is the same for both tables. For offspring problems, i.e., when the multiple load option is -1, the loads must be input in Table 7, and loads or stiffnesses input in Table 3 are retained. For normal problems or parent problems, i.e., when the multiple load option is 0 or +1, loads can be input in either table.

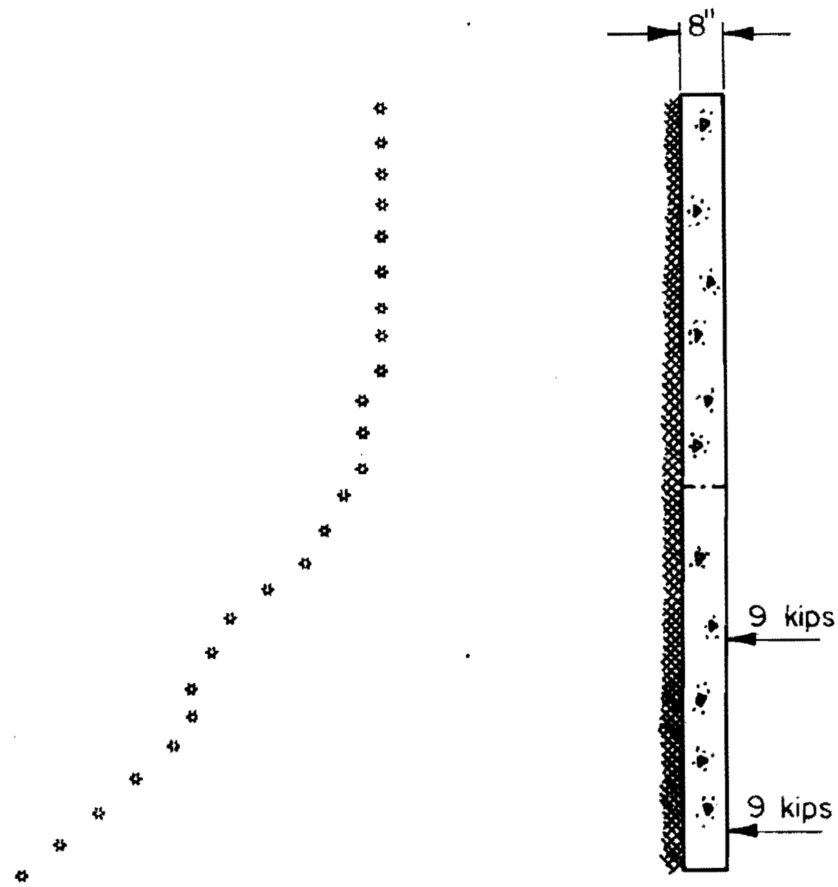
Table 8 is used to define the lines or areas of selected tabulated and plotted output for deflection, bending moments in the x and y directions, and either the maximum principal moment or stress, depending on the stress option in Table 1. This allows for concise printout for a specific location, such as near wheel loads and support points. The number of cards is specified in Table 1 and can include 10 cards. Each card can include 300 points; for instance, coordinates from 11,11 through 20,40 or from 0,0 through 11,24 could be specified. If a larger area is required, another card covering the adjacent area can be added.

The major advantage of Table 8 is that a crude printer plot display can be obtained for each area specified if the option in Table 1 is 0 or 2. This is illustrated in Fig 3, in which a deflection profile along section A-A in the pavement slab is shown. Similar useful plots can be obtained for stresses or moments along a line or over a local area to be studied. Table 8 can be omitted, since all selected output values appear in the complete printout



(a) Plan view of CRCP

X	Y	DEFLECTION
0	20	9.978E-05
1	20	9.369E-05
2	20	8.499E-05
3	20	6.947E-05
4	20	4.111E-05
5	20	-8.305E-06
6	20	-6.955E-05
7	20	-2.162E-04
8	20	-4.047E-04
9	20	-6.739E-04
10	20	-1.044E-03
11	20	-1.535E-03
12	20	-2.158E-03
13	20	-3.713E-03
14	20	-5.453E-03
15	20	-7.392E-03
16	20	-9.466E-03
17	20	-1.140E-02
18	20	-1.208E-02
19	20	-1.280E-02
20	20	-1.401E-02
21	20	-1.590E-02
22	20	-1.848E-02
23	20	-2.155E-02
24	20	-2.397E-02



(b) Deflection profile along section A-A.

Fig 3. Slab deflection profile to illustrate the use of the printed plot display.

of results, but caution should be used; if all or part of the complete printout of results is suppressed in Table 9, as discussed below, a significant amount of computer time will be used but no results will be printed out. Hence, the user should be careful in selecting the plotted output and areas desired. The type of printer or line plotted output depends on the plot control option in Table 1, as discussed above.

Table 9 allows the user to select the sections of the complete output to be printed. This is sometimes desirable for a problem series in which local areas of the structure are under study for various positions of loads, supports, discontinuities, etc. Table 9 is omitted if a zero is input in column 40 of the second card of Table 1. In this case, i.e., if Table 9 is omitted, the complete output is printed. A partial output is printed when the sections to be printed are specified within the y stations or bounds designated on the Table 9 cards. Up to 10 different y bounded sections can be printed. The sections may overlap; the doubly defined areas are printed only once. Caution is again advised, to assure that output which might be of interest is not suppressed. The areas of interest should be included between the specified y stations that define the bound to be printed.

General Data Input Comments

It is wise to obtain a listing of the data input for verification of correctness prior to program submission, especially for large and time-consuming problems with complex data input.

All data in Tables 3, 4, 5, 6, and 7 are algebraically accumulated for storage as needed and, therefore, values may be added or subtracted regardless of other values input or held from previous problems.

For offspring problems, only Tables 1 and 7 are required, but Tables 8 and 9 may be specified if different output areas are desired. When solving an offspring problem, the user must hold Tables 2, 3, 4, 5, and 6, adding no cards to them. The multiple-loading solution technique (Ref 17) offers a considerable computer time advantage for a problem series in which only the load magnitude and position change. If the user adds any data to that in Tables 3 through 6, the problem must be considered another parent or independent problem.

Data Errors

All data are checked internally by the program for compatibility with the geometry of the specified slab and consistency of coordinate input. If errors are found they are counted in each table and the problem is terminated with a message showing the number of data errors. Typical errors are (1) misusing the multiple-load option, e.g., inputting a -1 to follow a 0 in the preceding problem, in which case information that is required in the offspring problem will not be stored from the preceding problem: if an offspring problem to follow, the multiple load option in the parent problem should be +1; (2) having the number of increments in the x-direction exceed those in the y-direction, which would give an inefficient and time-consuming computer solutions; (3) specifying a negative or zero increment length; (4) inputting a negative Poisson's ratio or thickness; (5) making the "through" x or y coordinate in a data specification numerically less than the "from" coordinate (see Appendix A); (6) specifying data outside the geometric limits of the slab; (7) specifying a zero x or y coordinate for a twisting stiffness; (8) using a zero x coordinate for x-bar axial force or a zero y coordinate for y-bar force; (9) specifying a number of increments greater than the dimensioned storage with which the program can operate; and (10) misusing the selected output option.

Computation and Selection of Input Parameters

The following problems have been prepared:

Problem 101, without concrete shoulders and a slab thickness of 8 inches;

Problem 201, with concrete shoulders and a slab thickness of 8 inches;

Problem 301, without concrete shoulders and a slab thickness of 7 inches; and

Problem 401, with concrete shoulders and a slab thickness of 7f inches.

The necessary input parameters are developed for these problems.

Slab Plan Dimensions. In the application of the discrete-element method to the rigid pavement problems, the user must determine the appropriate plan dimensions of the slab. For the problems analyzed herein, the continuously reinforced concrete pavement is 24 feet wide. Since in this pavement type no expansion or contraction joints are provided, as much length from the slab as possible should be considered to simulate the continuity effect. Experience in the field and with the SLAB computer programs (Ref 18) shows that for an 18,000-pound axle load, a length extending 15 to 20 feet on each side of the loaded area with free edges, i.e., no boundary restraints, is adequate. In the problems studied in this report, a total length of 40 feet is used. Figure 4 shows the pavement without shoulders (Problems 101 and 301), and Fig 5 shows the pavement with a 10-foot wide shoulder (Problems 201 and 401).

Increment Lengths. The slab to be analyzed is divided into a selected number of equal increments in both the x and y-directions. To get an efficient solution, if the problem is rectangular the y-dimension should be the longer dimension, i.e., the number of increments in the x-direction should not be more than the number of increments in the y-direction. The increments in any one direction must all be of the same size. The greater the number of increments, the more computer time is needed. It was shown in Ref 2 that usable increment lengths for pavements are 12, 18, and 24 inches. A smaller increment length, i.e., 6 inches, can be used but is not really necessary. Therefore, for the problem presented here, a 12-inch increment length was selected for both the x and y-directions. As mentioned before, Problems 101 and 301 are 24 by 40 feet in size, and hence the number of increments in the x and y directions is 24 and 40 respectively. Because of the 10-foot shoulder in Problems 201 and 401, the number of x-increment is 34, but the number of y-increments is again 40.

Computation of Slab Bending Stiffness D_x and D_y. The bending stiffness of the slab is computed by the formula

$$D = \frac{Et^3}{12(1-\nu^2)} \tag{2.1}$$

where

D = the bending stiffness per unit width, $\frac{\text{lb-in}^2}{\text{in}}$;

E = the modulus of elasticity, psi;

ν = Poisson's ratio; and

t = slab thickness, inches.

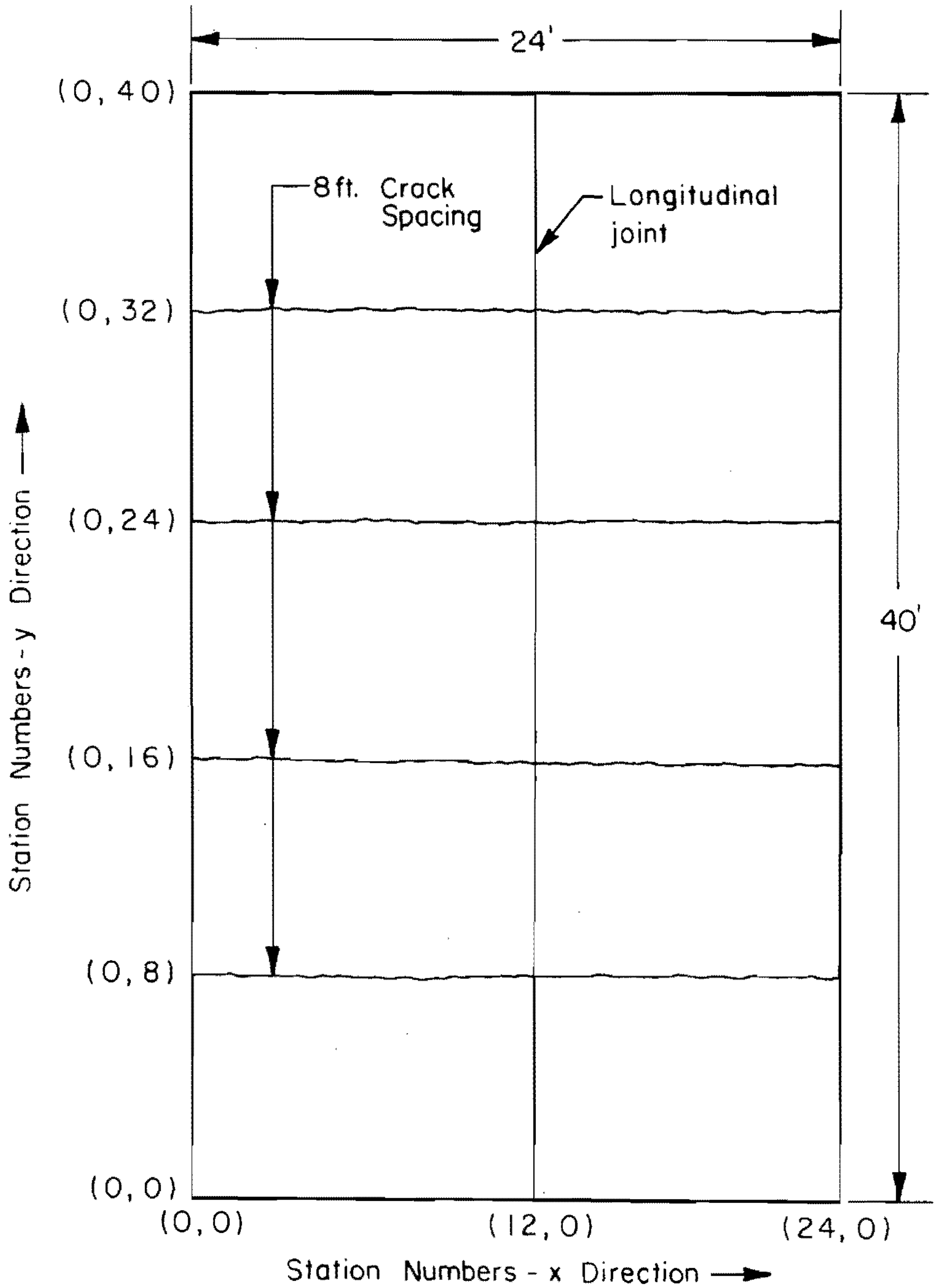


Fig 4. Slab plan layout with cracks and longitudinal joint (Problems 101 and 301).

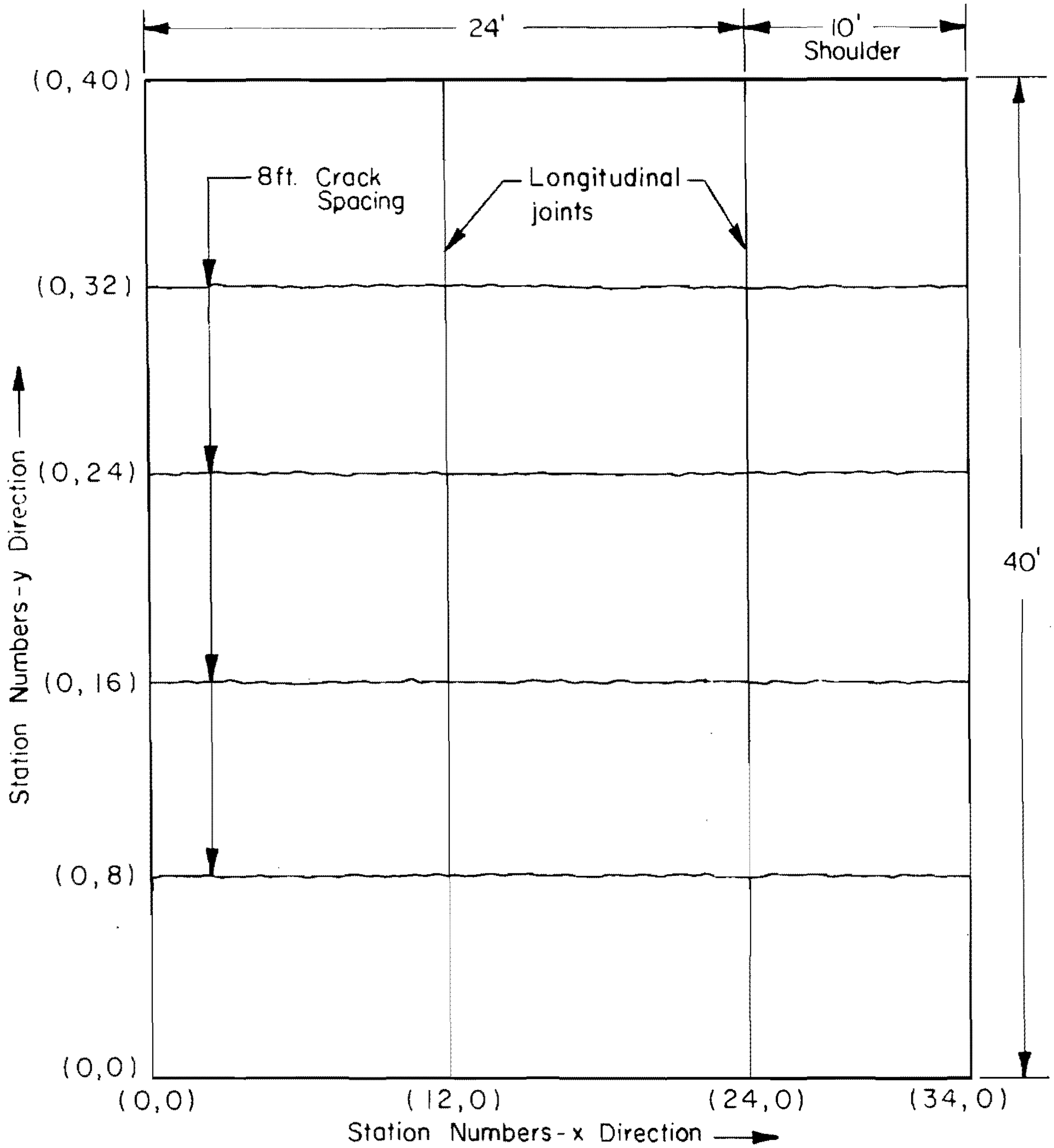


Fig 5. Slab plan layout with cracks, longitudinal joints, and concrete shoulders (Problems 201 and 401).

Longitudinal Joints and Transverse Cracks. The bending resistance of structural members is considerably influenced by the presence of discontinuities, such as joints and cracks. These discontinuities can be effectively modeled by a reduction in the bending stiffness (Ref 18).

In this study, the longitudinal joints are considered as cracked sections. A 0.5 percent reinforcement is assumed to be present in the pavement, as well as in the concrete shoulders. Hence, the amount of stiffness reduction applied at the transverse cracks and longitudinal joints was 90 percent (Ref 18) of the original stiffness value.

It should be noted that since the longitudinal joints are running in the y-direction (Figs 4 and 5), the x-direction stiffness D_x is reduced at the appropriate stations (Appendix B). Transverse volume-change cracks which occur randomly in continuously reinforced concrete pavement are simulated by a reduction of the y-direction stiffness D_y at each crack location. A reasonable and desirable crack spacing is 8 feet, which is used in the problems herein. In a given problem the actual crack spacing can be simulated. The computed values of stiffness to be reduced for the joint and crack simulation are shown in Table 1.

Foundation Support. The modulus of subgrade reaction used in this study is for a real example problem, in which a modulus value of 100 psi/in is taken to simulate a medium strength subgrade. The foundation support springs which are needed as input data are computed by the equation

$$S = h_x \cdot h_y \cdot k \qquad (2.2)$$

where

h_x = x-direction increment length, inches;

h_y = y-direction increment length, inches; and

k = the modulus of subgrade reaction, psi/in.

Using Eq 2.2 and the increment lengths chosen, the support spring S is computed as shown in Table 1.

Torsional Stiffness. The torsional stiffness or twisting stiffness is the last parameter necessary to code the problem. The twisting stiffness per unit width C is calculated by the equation

TABLE 1. SLAB INPUT COMPUTATIONS

Problem Number	Thickness, t	Bending Stiffness D , $\frac{\text{lb-in}^2}{\text{in.}}$			Support Spring S , lb/in		Twisting Stiffness C ,
	in.	D	D/4	$0.9\ \frac{D}{2}$	S	S/4	$\frac{\text{lb-in}^2}{\text{in/rad}}$
101	8	1.778×10^8	4.445×10^7	8.000×10^7	14,400	3600	1.422×10^8
201	8	1.778×10^8	4.445×10^7	8.000×10^7	14,400	3600	1.422×10^8
301	7	1.191×10^8	2.978×10^7	5.360×10^7	14,400	3600	9.528×10^7
401	7	1.191×10^8	2.978×10^7	5.360×10^7	14,400	3600	9.528×10^7

for all problems;

modulus of elasticity $E = 4.0 \times 10^6$ psi

Poisson's ratio $\nu = 0.20$

$$C = \frac{Et^3}{12(1+\nu)} \tag{2.3}$$

where all variables are as defined previously.

Using Eq 2.3 the computed values of the torsional stiffnesses for the selected problems are shown in Table 1.

These foregoing computations provide all the information required to fill the coding forms for Problems 101, 201, 301, and 401. The next step is a step-by-step coding of these problems as presented in tabulated form.

Coding of Problems

Due to the change in the stiffness and or geometric properties of the problems used herein, each of the problems was run independently. The data deck for each of the four solutions is coded in detail. All of the coded data are presented in Appendix B. As an illustration, the coding of Problem 101 is presented in the text. The cards which are coded for Problem 101 are shown in Table 2. The numbers to the left of column 1 on the code sheet are identification numbers to use in relating the coded cards and the written text.

Cards 1 and 2 are identification cards which simply identify the run which was made for this analysis:

1	ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
2	PROJECT 56 SLAB APPLICATIONS--HARVEY J. TREYBIG

This information could have appeared anywhere on these two cards. It was spaced as it is for appearance.

The third card identifies the problem:

3	101	24 X 40 FT CRCP WITHOUT CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS

Columns 3, 4, and 5 contain the problem number, 101. Columns 11 through 80 are provided for a description of the problem, and any desirable information can be entered.

Table 1. The fourth and fifth cards in the data deck constitute Table 1, the control data. Each problem has two cards for the control Data:

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
4										1						
5	1	14	0	1	0	2	3	0			1	0	1			

TABLE 2. CODED DATA INPUT - EXAMPLE PROBLEM 201

IDENTIFICATION PROBLEM 101 CODED BY HJT; AAA DATE PAGE 1 OF 1

```
 1            ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
 2                 PROJECT 56 APPLICATIONS---HARVEY J. TREYBIG
 3    101     24 X 40 FT CRCP WITHOUT CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS
 4
 5      1   14    0    1    0    2    3    0              1    0    1
 6     24   40           1.200E+01 1.200E+01 2.000E-01 8.000E+01
 7      0    0   24   40 4.445E+07 4.445E+07                               3.600E+03
 8      0    1   24   39 4.445E+07 4.445E+07                               3.600E+03
 9      1    0   23   40 4.445E+07 4.445E+07                               3.600E+03
10      1    1   23   39 4.445E+07 4.445E+07                               3.600E+03
11     12    0   12   40-8.000E+07
12     12    1   12   39-8.000E+07
13      0    8   24    8          -8.000E+07
14      1    8   23    8          -8.000E+07
15      0   16   24   16          -8.000E+07
16      1   16   23   16          -8.000E+07
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IDENTIFICATION CODED BY DATE PAGE OF

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17      0   24   24   24          -8.000E+07
18      1   24   23   24          -8.000E+07
19      0   32   24   32          -8.000E+07
20      1   32   23   32          -8.000E+07
21      1    1   24   40 1.422E+08
22     17   20   17   20                                        -9.000E+03
23     23   20   23   20                                        -9.000E+03
24      0   20   24   20    1    1    1    1
25     17    0   17   40    1    1    1    1
26     23    0   23   40    1    1    1    1
```

Since this is a parent problem, columns 1 to 40 of card 4 are left blank, and +1 is entered in column 50. Columns 1 to 40 of card 5 are usually coded while the rest of the problem is coded. A 1 is coded in column 55 of card 5 to obtain principal stresses instead of principal moments; this requires that a thickness is to be entered in Table 2. Column 60 of the same card has a zero in it since printer plots are desired of the areas specified in Table 9 and there is a 1 in column 65 to obtain a three-dimensional plot of deflections of the entire slab or grid (Appendix C).

Table 2. Card 6 is Table 2 or the constants required for the problem:

6	24	40			1.200E+01	1.200E+01	2.000E-01	8.000E+00

In card 6, columns 4 and 5 contain the number of increments in the x-direction, 24, and columns 9 and 10 contain the number of increments in the y-direction, 40. Columns 22 through 30 contain the increment length in the x-direction, 1.200E+01. Increment length in the y-direction, also 1.200E+01, is coded in columns 32 through 40. Poisson's ratio, 2.000E-01, is coded in columns 42 through 50. Since the printout of principal stress is desired for this problem the thickness of the slab, 8.000E+00, is coded in columns 52 through 60. Only one card is coded for Table 2; therefore, in column 5 of card 5 (Table 1), a 1 is coded as the number of cards in Table 2.

Table 3. Joint stiffness and load data are contained in Table 3. According to the guide for data input the stiffness and load data are distributed over

	5	10	15	20	30	40	50	60	70	80
7	0	0	24	40	4.445E+07	4.445E+07				3.600E+03
8	0	1	24	39	4.445E+07	4.445E+07				3.600E+03
9	1	0	23	40	4.445E+07	4.445E+07				3.600E+03
10	1	1	23	39	4.445E+07	4.445E+07				3.600E+03
11	12	0	12	40	-8.000E+07					
12	12	1	12	39	-8.000E+07					
13	0	8	24	8		-8.000E+07				
14	1	8	23	8		-8.000E+07				
15	0	16	24	16		-8.000E+07				
16	1	16	23	16		-8.000E+07				
17	0	24	24	24		-8.000E+07				
18	1	24	23	24		-8.000E+07				
19	0	32	23	32		-8.000E+07				
20	1	32	23	32		-8.000E+07				

the selected area by coding the "from" and "through" coordinates and the appropriate stiffness and load data as shown in cards 7 through 20 for problem 101.

In preparing the data for a SLAB solution it is necessary to input for distributed values of stiffness and/or subgrade support half-values at mesh points on the edge of the slab and quarter values at the corners since each mesh point represents the area within one-half increment length on all four sides. Because of these characteristics, the stiffness data are usually coded, i.e., distributed, in quarter-values. For problem 101

$$D/4 = D_x/4 = D_y/4 = 4.445E+07$$

as shown in the coding. Also coded with the stiffness is the subgrade support, which is distributed in quarter-values of 3.600E+03 for this problem.

The best analysis available was used to simulate the longitudinal joint and transverse cracks in CRCP. The longitudinal joint was simulated by reducing the original stiffness, i.e., coding a negative stiffness at those stations which geometrically simulate the longitudinal joint. It has been found that discontinuities in CRCP can be modeled in the discrete-element SLAB analysis by a percent reduction in the appropriate bending stiffness, depending on the percentage reinforcement (Ref 18). A 90 percent reduction is applied here, which corresponds to a percentage reinforcement of about 0.5 percent. Coding the stiffness reduction requires two cards for each crack or joint because of the half-values of stiffness along the edges. Cards 11 and 12 are for the longitudinal joint for which the x-direction bending stiffness D_x is reduced by 90 percent:

$$-D_x(\text{joint}) = (0.900)\left(\frac{D}{2}\right) = 0.900\left(\frac{(1.778)10^8}{2}\right)$$

$$-D_x(\text{joint}) = (8.000)(10^7) \quad \text{(see Table 1)} \qquad (2.4)$$

Similarly, for a selected transverse crack spacing the y-direction stiffness is also reduced by 90 percent. Cards 13 through 20 input the negative stiffness D_y to simulate an 8-foot crack spacing. The last step in the coding of Table 3 is to count the number of cards and record it in columns 9 and 10 of card 5, in Table 1.

Table 4. Table 4 is an additional table for coding stiffness and load data. For this problem there were no cards in this table, and therefore a zero is entered in column 15 of card 5, in Table 1.

Table 5. Twisting stiffness data are coded in Table 5. The twisting stiffness is coded with relation to the mesh, which is made up by four joints (see Appendix A). The mesh is numbered according to the joint number at the upper right corner. For this problem card 21 reflects the twisting stiffness, 1.422E+08 (Table 2):

21	1	1	24	40	1.422E+08

The number of cards in Table 5 is recorded on card 5, column 20, in Table 1.

Table 6. Bar axial thrusts are coded in Table 6. This table is not used for this problem since no axial loads are involved; therefore, a zero is entered in column 25 of card 5, in Table 1.

Table 7. Table 7 contains what is referred to as multiple-load data. The loads used in this problem are coded in this table, but they could have been coded in Table 3 instead. It is desirable to use Table 7 if there is a possibility of solving a successive problem where only the load position, configuration, or magnitude changes. Cards 22 and 23 contain the two loads used:

22	17	20	17	20	-9.000E+03
23	23	20	23	20	-9.000E+03

The negative sign is used because the sign convention regards "up" as positive. These two cards complete Table 7 and a 2 is entered in column 30 of card 5 in Table 1.

Table 8. The cards which indicate the areas of the slab for which special output is requested are in Table 8. For this problem graphical output was obtained for deflection, x-direction moment, y-direction moment, and principal stress. These parameters are plotted along lines through each of the two loads in each of the orthogonal x and y-coordinate directions. Cards 24, 25, and 26 contain the stations for which the graphs are desired and the coding for the desired plots:

24	0	20	24	20	1	1	1	1
25	17	0	17	40	1	1	1	1
26	23	0	23	40	1	1	1	1

A 3 is entered in column 35 of card 5 in Table 1, as the number of cards in Table 8.

Table 9. This table is omitted, i.e., a zero is coded in column 40 of card 5, in Table 1, since a complete output is desired in this case.

The problem is completed by checking to make sure that the number of cards in each table is properly recorded in Table 1. Also, as mentioned previously, in column 60 of the control data a zero is entered to signify the plot option which is desired. By coding a zero, printer plots are obtained.

Coding for Problem 201

The following is an explanation of the detailed coding of problem 201. The entire coded problem 201 is shown as Table 3. Not all cards in Table 3 are discussed in the text, as was true for problem 101. The cards are numbered in Table 3 and should be referred to there. The first two cards identify the run, and the third card identifies the problem.

Table 1. Cards 4 and 5 are the control data table and are coded as the balance of the problem is completed.

Table 2. The constants for the problem are on the sixth card and include the number of increments in each direction, the increment lengths in these directions, Poisson's ratio, and slab thickness. There is only one card in this table; therefore a 1 is coded in column 5 of card 5 in Table 1.

Table 3. Cards numbered 7 through 22 are included in this stiffness and load data table. Cards 7 through 10 distribute the slab stiffness and support over the slab area using the technique described in conjunction with the coding of problem 101. This problem has two longitudinal joints and they are simulated by 90 percent reductions in the x-direction bending stiffness, on cards 11 through 14. Again, the technique used is as described previously with problem 101.

The pattern of transverse volume change cracks in the slab is the same in this problem as in problem 101. The cracks are coded to cross the pavement shoulder. Cards 15 through 22 represent these cracks by 90 percent reductions in the y-direction bending stiffness. The technique for the crack simulation coding is again as described in problem 101.

The total number of cards in this table is 16, which is reflected in columns 9 and 10 of card 5, in Table 1.

TABLE 3. CODED DATA INPUT - EXAMPLE PROBLEM 201

IDENTIFICATION PROBLEM 201 CODED BY HJT;AAA DATE PAGE 1 OF 1

```
          ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
               PROJECT 56 SLAB APPLICATIONS--HARVEY J. TREYBIG
  201     34 X 40 FT CRCP WITH CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS
                                                 1
    1   16    0    1    0    2    3    0              1    2
   34   40           1.200E+01 1.200E+01 2.000E-01 8.000E+00
    0    0   34   40 4.445E+07 4.445E+07                               3.600E+03
    0    1   34   39 4.445E+07 4.445E+07                               3.600E+03
    1    0   33   40 4.445E+07 4.445E+07                               3.600E+03
    1    1   33   39 4.445E+07 4.445E+07                               3.600E+03
   12    0   12   40-8.000E+07
   12    1   12   39-8.000E+07
   24    0   24   40-8.000E+07
   24    1   24   39-8.000E+07
    0    8   34    8          -8.000E+07
    1    8   33    8          -8.000E+07
```

IDENTIFICATION CODED BY DATE PAGE OF

```
    0   16   34   16          -8.000E+07
    1   16   33   16          -8.000E+07
    0   24   34   24          -8.000E+07
    1   24   33   24          -8.000E+07
    0   32   34   32          -8.000E+07
    1   32   33   32          -8.000E+07
    1    1   34   40 1.422E+08
   17   20   17   20                                        -9.000E+03
   23   20   23   20                                        -9.000E+03
    0   20   34   20    1    1    1    1
   17    0   17   40    1    1    1    1
   23    0   23   40    1    1    1    1
```

Table 4. Table 4 is an additional table for coding stiffness and load data. For this problem there were no cards in this table; therefore, a zero is entered in column 15 of Table 1.

Table 5. The twisting stiffness for this problem is coded on one card, number 23. The technique for coding the twisting stiffness was described in the coding of problem 101.

Table 6. Bar axial thrust data is coded in Table 6. For this problem, as in most pavement applications, this table is not used, and a zero is entered in column 25 of card 5, of the control data.

Table 7. The loads, 9,000 pounds each, are coded on cards 24 and 25. The negative sign is used because the sign convention used regards "up" as positive. A 2 is entered in column 30 of card 5, in Table 1, as the number of cards added for Table 7.

Table 8. For this problem selected output including x and y-direction moments, deflection, and principal stresses is specified for three areas. These areas are defined by lines through each load in each direction, on cards 26 through 28. A 3 is entered in column 35 of card 5, in Table 1.

Table 9. In this problem, Table 9 is suppressed, i.e., a zero is entered in column 40 of card 5, in Table 1; hence a complete output of the problem is obtained.

After the coding is completed, each table is checked to insure that the proper number of cards is listed in the control data. Also, in column 60 of card 5, in control data, a 2 is coded to signify the desired graphical output option. The 2 indicates that printer-plots and microfilm plots will be made.

CHAPTER 3. INTERPRETATION AND ANALYSIS OF PROGRAM OUTPUT

General Description

The input data coded for any problem are automatically reprinted as the first part of the computer output, exactly as utilized by the computer. This is always headed by a line which includes the program title, specific revision, and latest program revision date. Immediately below are the two alphanumeric information data header cards, followed by the problem number and description. Run dates and descriptive alphanumeric information for the problem series header cards and problem number cards are used to avoid confusion and mixups among a large number of problems run simultaneously.

Data for each input table, including those retained from previous problems, are echo printed with explanatory headings exactly as they were used. It is good practice for the user to recheck all data for possible errors prior to interpreting the computed results.

Tabulated Results. The computed results from the solution are printed in y-station groups (Appendix C) in reverse order because of the computation arrangement set up in the program. The output is arranged to give the x and y-joint coordinates, the transverse deflection at each joint (upward deflections are positive), the slab and beam bending moments, the slab twisting moment, the principal slab moment or stress and its direction, and either the concentrated value of support reaction or the statics check. Output values of bending and twisting moments are given on a per unit width basis. Bending moments and stress are positive for compression in the top of the beams or slab. The x-bending moments act in the x-direction and the y-bending moments in the y-direction.

In the analysis of composite slabs, such as a highway bridge consisting of a concrete deck resting on a system of longitudinal beams (Ref 17), beam bending stiffness is needed. In most pavement slab analysis, however, beam bending stiffness is not required. The output for the slabs is automatically given in a reduced form if the input data did not include any beam stiffnesses (Appendix C). The reverse is true if no slab stiffness data were input. The output is arranged so that the x and y beam moments are printed directly below each value of slab moment when both slab and beam data are present.

Twisting Moments. The per unit width x-twisting moments are tabulated and are exactly equal to the y-twisting moments with opposite signs. The x-twisting moments act in the x-direction and rotate around the y-axis. Even though the input values of twisting stiffnesses were specified for each mesh, the output values of twisting moment are the average of four adjacent mesh areas and are given at the stations. The user is cautioned that the output values of twisting moment along the edges or other discontinuities of a slab or plate reflect the average and may be one-quarter, or one-half, since the twisting moments correspond to the twisting stiffness present along the edges. The output values of largest principal moment or stress at edges are also affected by this averaging.

Principal Moments or Stresses. A Mohr's circle analysis is made at each joint, using the orthogonal slab bending moments and twisting moments to yield the larger numeric value (positive or negative) of principal moment per unit width and the angle from the x-axis of the coordinate system to the acting direction of this larger value. Counterclockwise angles are positive. The principal moment values are converted to the larger numerical value of principal stress if the stress option is specified in Table 1 and a thickness is provided in Table 2. A positive stress indicates tension in the bottom of the slab, which follows the same sign convention as the bending moments. The stress option is properly used only for slabs or plates of constant thickness. A direct conversion can be made for principal stress from the principal moment for plates of variable stiffness and thickness. The output value of stress does not include any in-plane forces that may be present. The user must also consider axial forces (tension or compression) input in Table 6 when interpreting stress results. This can be done by computing the x and y stresses from the corresponding x and y bending moments and superimposing on these stresses the effect of inplane stress due to the axial force. A Mohr circle analysis would then be needed if the maximum principal stress is desired. It is worth noting that the effect of axial force is already included in the overall stiffness matrix of the structure.

Reactions. The last column of output lists the support reactions at each station if the statics check option in Table 1 is blank. The support reaction is the concentrated value of resistance to displacement offered by any support springs that are present. A subgrade modulus spring will reflect the concentrated value of pressure under the slab. If the spring is specified with a large value to represent a rigid support, the value printed is the rigid support reaction.

A statics check is printed instead of support reaction if the Column 50 statics check option in Table 1 is exercised. This statics check is the summation of all the computed shears, twisting moment forces, restraint and applied moment forces, subgrade reaction, and applied external load at each joint. The value printed represents the amount of error at that joint which is inherent in the computer solution. This option has no practical application, but if it is suspected that there are computer inaccuracies which are being generated by roundoff, truncation, or errors, this option will help to determine their magnitude.

As a check on the back-substitution process in the computer solution, and as a check on the total load input to the grid-slab structure, a final result is printed at the end of the detailed output. This is the algebraic sum of all the reaction values and should be equal to the sum of all the applied loads. This check should always be inspected by the user to verify that the desired load system was specified and that the problem was properly solved. Another value, the maximum statics check error, together with the station at which it occured is printed following this value. This value is always printed, whether the statics check option in Table 1 is exercised or not, and can act as an immediate flag to the user if some error has occurred in the computer. The error would normally be expected to be less than about 10 orders of magnitude smaller than the largest load applied.

Profile Output. After the detailed output, areas of selected profile output designated by Table 8 are printed. No tabulated values will be printed if the plot option in column 60 of Card 5, in Table 1, was 1 or 3. Profile tabulations are obtained if the option was 0 or 2. These tabulations are printed in consecutive groups associated with the largest number of increments designated in the Table 8 rectangular area. For instance, if the area desired is from 10,16 to 12,20 then there would be three station x-groups, each with five values. If the area is square, the groups would be for consecutive y values. If the area is square, the groups would be for consecutive y values, which is the same arrangement as the normal output discussed previously.

Adjacent to the coordinates is the numerical value of the deflection, moment, or stress. Printed to the right of the output values is a series of asterisks whose placement relative to one another is based on the numerical values. Thus, a crude plot of the output values is obtained. The user is cautioned not to misinterpret apparent changes in plot curvature which might be due to very slight numerical changes.

The printer plots have been found to be especially valuable because the user obtains them with the rest of his printed output; time is not spent unnecessarily waiting for line plotter output or in hand plotting. The printer plots are also useful in understanding slab behavior for areas adjacent to concentrated wheel loads and supports. Deflection areas are printed and plotted adjacent to each other with a set of common coordinates if both x and y-moments desired were in the same area. The final selected profile output is for the principal moments or stresses, again depending on the Table 1 option. It is worth noting that along slab lines, the direction of principal moment or stress at each station might be varying. The plots are valuable, however, in pointing out maximum values which might be overlooked when inspecting a mass of numbers in the normal detailed output.

Other plot options such as microfilm, paper, or three-dimensional plots can be made if the appropriate plotter routines and hardware are available on the computer in use. The subroutines which generate the three dimensional plots have been written using standard routines available for Calcomp plot systems. Each plot is arranged to fit within a 7-inch by 10-inch paper area.

The final printed output is the computer time used for the problem and the total accumulated time for the problem series. The user should record run times for parent and offspring problems for each problem size run on his computer system to estimate run times required for future problems. For small problems, the offspring times will be from 20 to 50 percent of the parent problem times. Fortunately, the offspring problem time decreases to a very small proportion of the parent problem time as the problem size becomes large. A time as low as 4 percent is possible.

Analysis of the Output

Figure 6 shows the layout of the problem without concrete shoulders. The nine input tables and printed output for problem 101 are included in Appendix C.

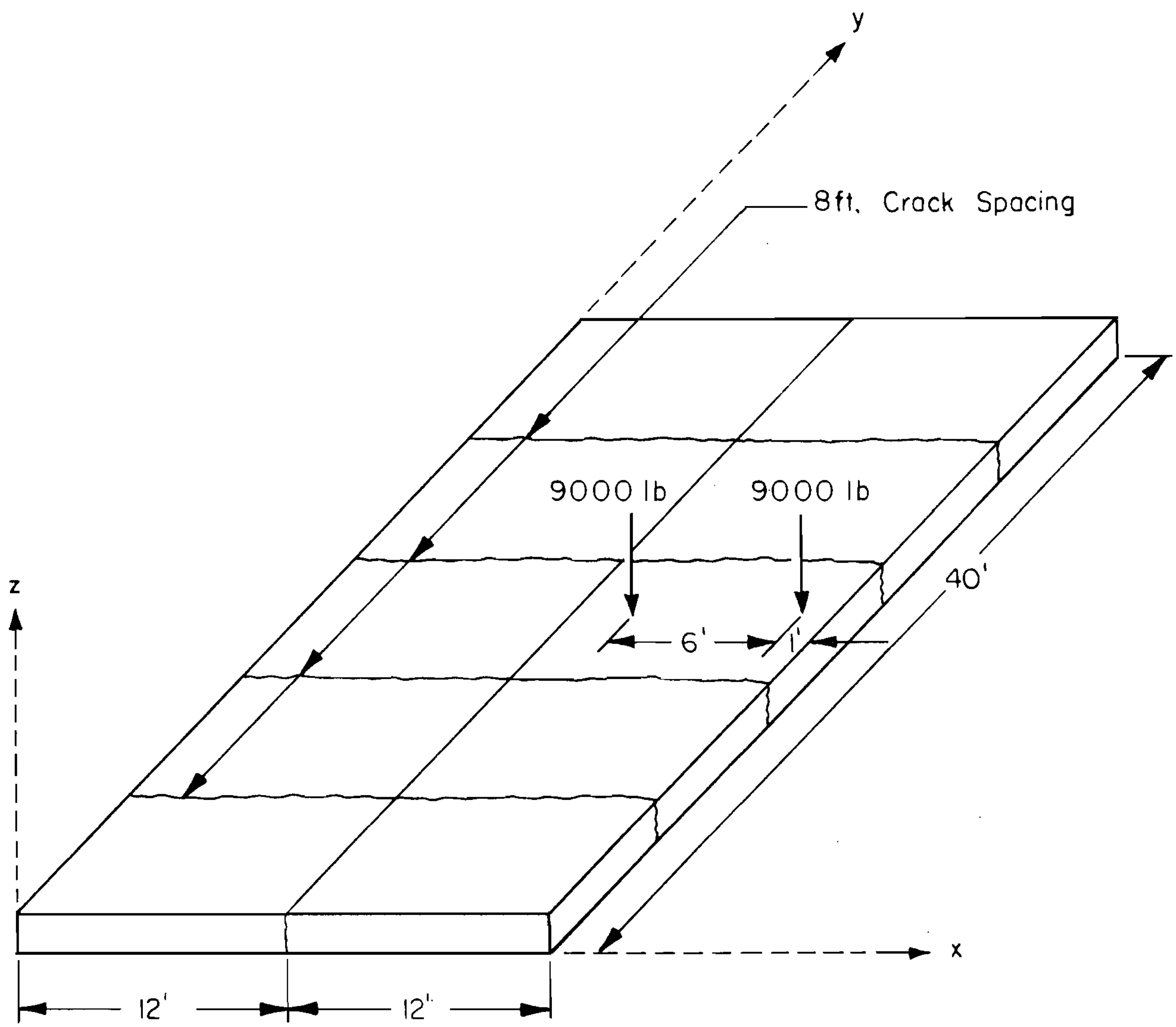

Fig 6. Problem layout with axes orientation.

By scanning the output, the user can determine the magnitudes of the maximum deflection and the maximum principal moment or stress, as well as their locations. More easily, he can determine these maximums from the selected output specified in Table 8 of the input data. This is illustrated in example Problem 101, where the selected output consists of deflections and moments across the two concentrated loads (Fig 6) in the transverse and longitudinal directions (Appendix C). The user usually has some idea of where the maximums will occur and thereby specifies the selected output to include these areas.

Problems 201, 301, and 401 were also solved. Though the entire printed output is not included herein, in the following sections are an analysis and comparison of the results with Problem 101.

Analysis of Deflections. For the continuously reinforced pavement examples without shoulders, the 18-kip axle was placed 1 foot from the edge of the slab. This same loading position was also used with shoulders. Figure 7 shows the deflection profile across the slab under this 18-kip axle loads. Also shown in this figure is a profile of deflection of the slab when the pavement includes a continuously reinforced concrete shoulder of the same thickness as the pavement. There is a significant difference in deflection profile as well as the maximum deflection value. Even though the outermost load of the 18-kip axle is 1 foot from the edge of the pavement, which is a very critical loading condition, the maximum deflection is about twice that of the pavement with shoulders. The maximum deflection for the pavement without shoulders is 0.0239 inch, and the maximum deflection for the pavement with shoulders is 0.0114 inch. These two maximums do not occur on the same geometric location. For the pavement without shoulders, the maximum deflection is at the edge as expected. The maximum deflection of the pavement with shoulders is underneath one of the loads.

Similarly, the 7-inch pavement is analyzed in terms of deflection. Figure 8 shows the deflection profiles across the center of the slab for the 7-inch continuously reinforced pavement with and without concrete shoulders. The maximum deflection of the pavement without shoulders was 0.0276 inch at the edge. The maximum deflection of the 7-inch pavement with shoulders was 0.0134 inch under one of the two loads, 23 feet from the centerline (Fig 8).

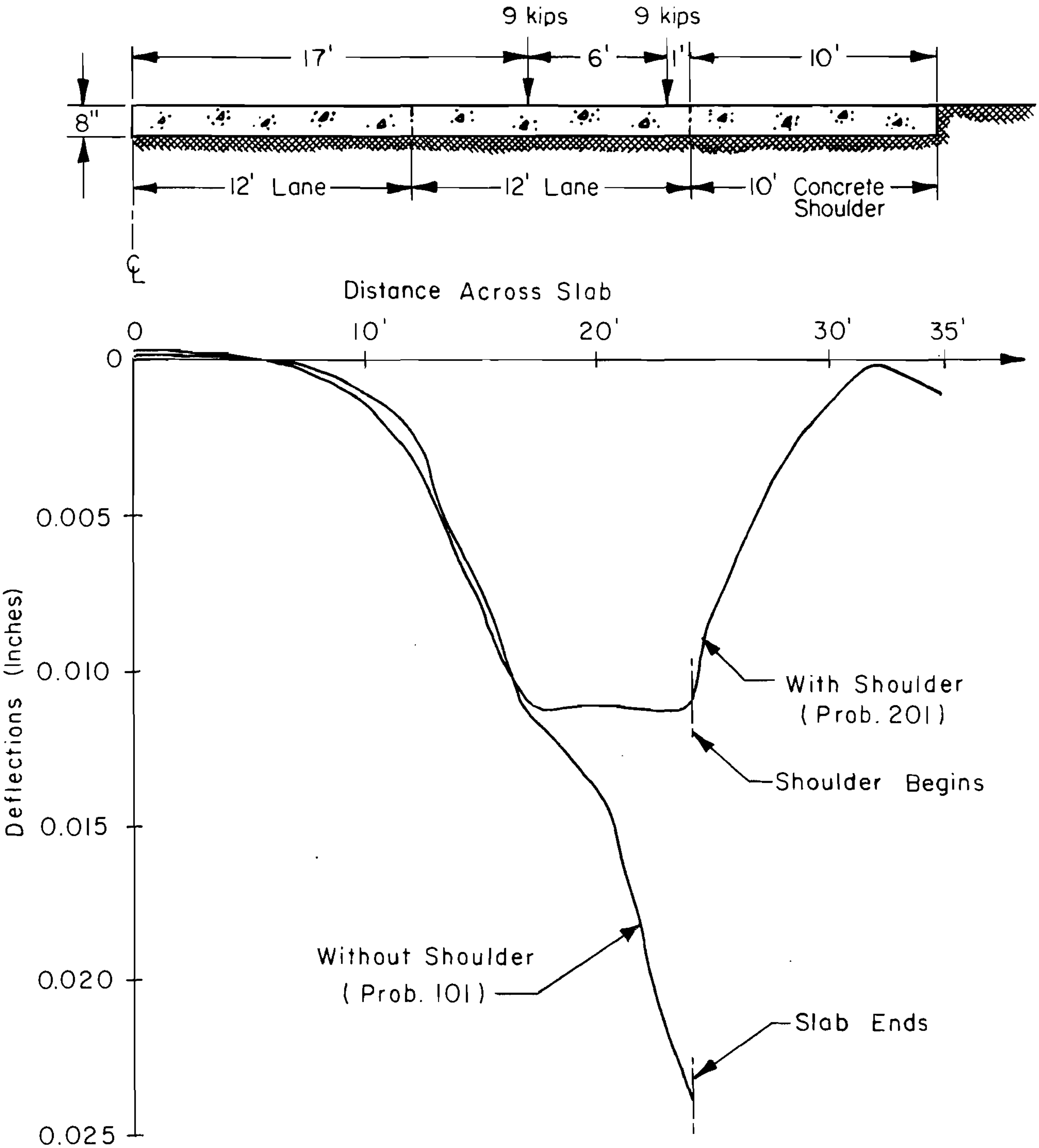

Fig 7. Transverse section and deflection profile for 8-inch CRCP, with and without concrete shoulders.

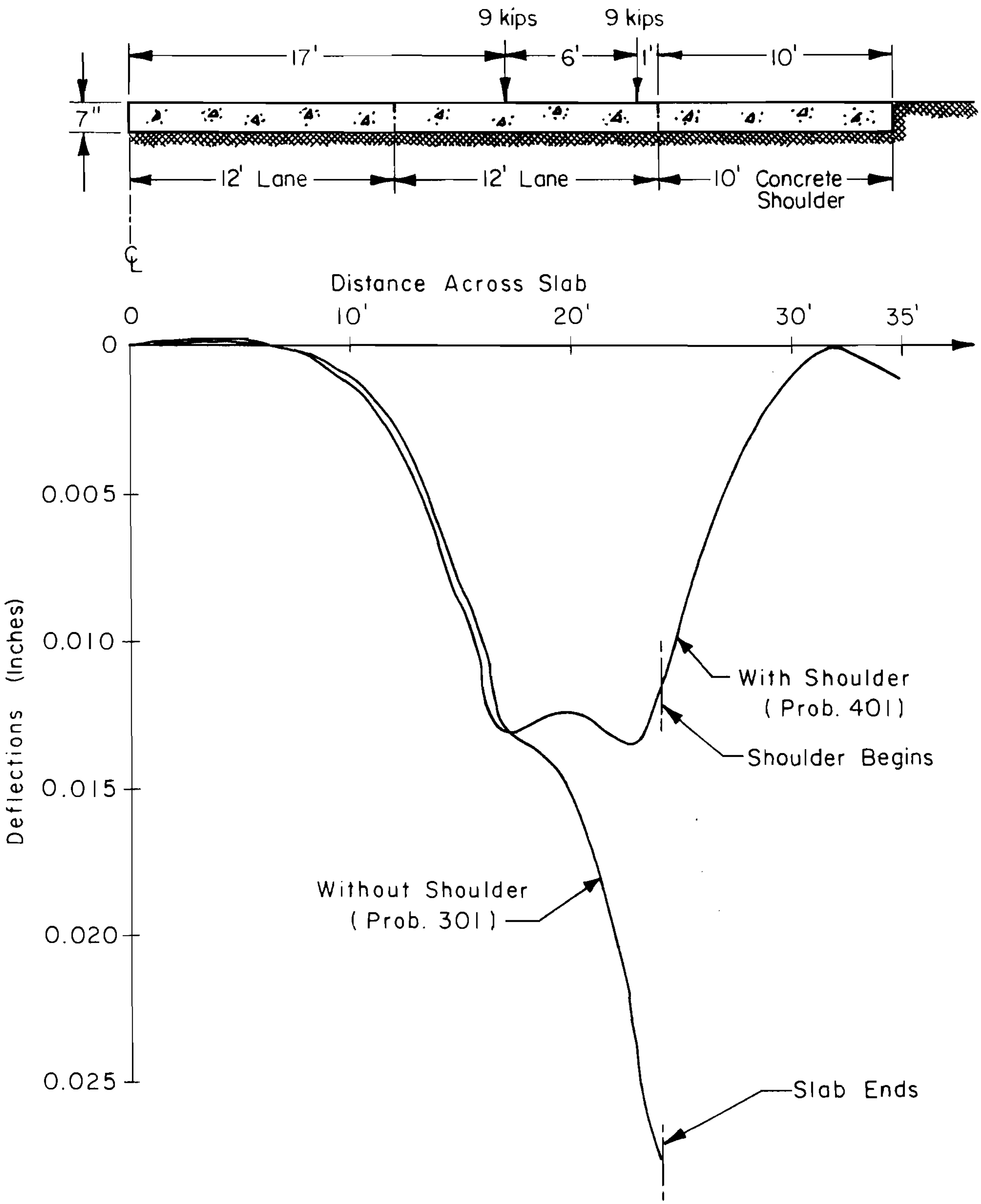

Fig 8. Transverse section and deflection profile for 7-inch CRCP, with and without concrete shoulders.

The deflections of the 7-inch pavement and the 8-inch pavement without shoulders differ about 0.004 inch, whereas the difference in deflection of the 7 and 8-inch pavements with concrete shoulders is only 0.002 inch. This implies that the effect of the increase in pavement thickness decreases if concrete shoulders are provided. The percentage change, however, is about the same.

This analysis shows the critical conditions in terms of deflections. The deflections which are predicted for the pavement without shoulders are reasonable and experience has shown that deflections of this order of magnitude are realistic for pavements with subgrade k-values of about 100 psi/in (Refs 6, 9, and 10).

Analysis of Stresses. The SLAB computer program computes the bending moments and subsequently the stresses at each coordinate in the slab geometry. The selected output of principal stresses is used to compare the pavements.

Figure 9 shows a comparison of the 8-inch continuously reinforced pavement with and without concrete shoulders. The data plotted are the maximum principal stress along a line across the slab, through the two loads. The peaks in the curves represent the load positions. The maximum stress predicted for the pavement without shoulders was 329 psi. The maximum stress for the pavement with concrete shoulders was 244 psi. The maximum stress in the pavement without shoulders is about 35 percent greater than in the pavement with concrete shoulders. These maximums are located under the load nearest to the pavement edge.

Similarly, the computer output yields the stresses in the 7-inch pavement. Figure 10 shows a profile of predicted stresses in the pavement along a line through the 18-kip axle load. For the 7-inch pavement with shoulders, the maximum predicted stress is 305 psi. For the pavement without shoulders, the maximum predicted stress is 406 psi, which is about 33 percent greater than the pavement with concrete shoulders.

The foregoing is a brief analysis of the maximum stress and deflection, which is important to pavement designers. The analysis method provides much more analysis results than are usually available to the practicing engineer. If desired, the deflection and stress values could be plotted at all coordinates on the slab and contours of the deflections and stress could be plotted for a given load condition. This would probably be important in analyzing special conditions such as the analysis of the complex bridge approach slab or a

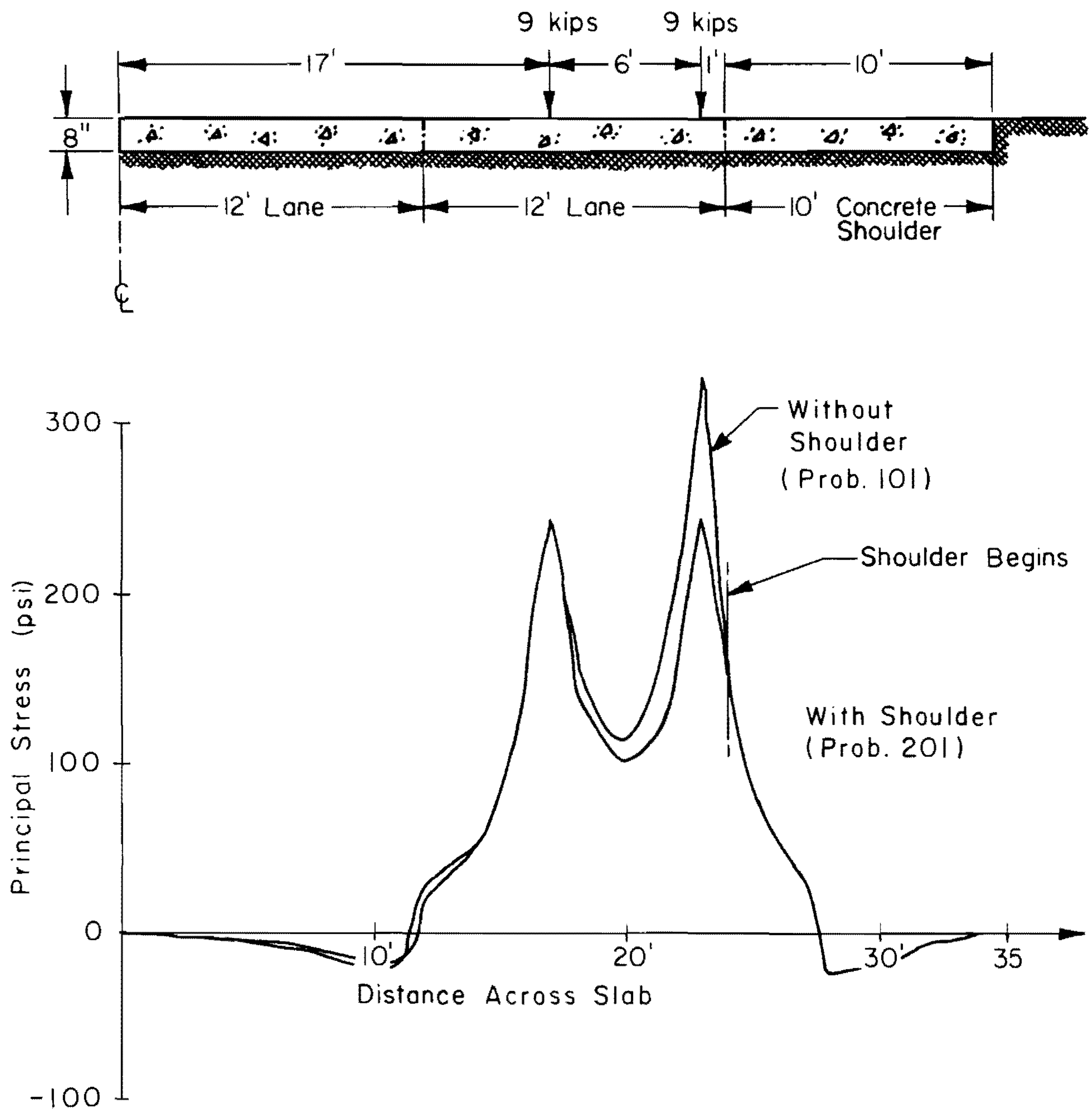

Fig 9. Transverse section and stress profile for 8-inch CRCP, with and without concrete shoulders.

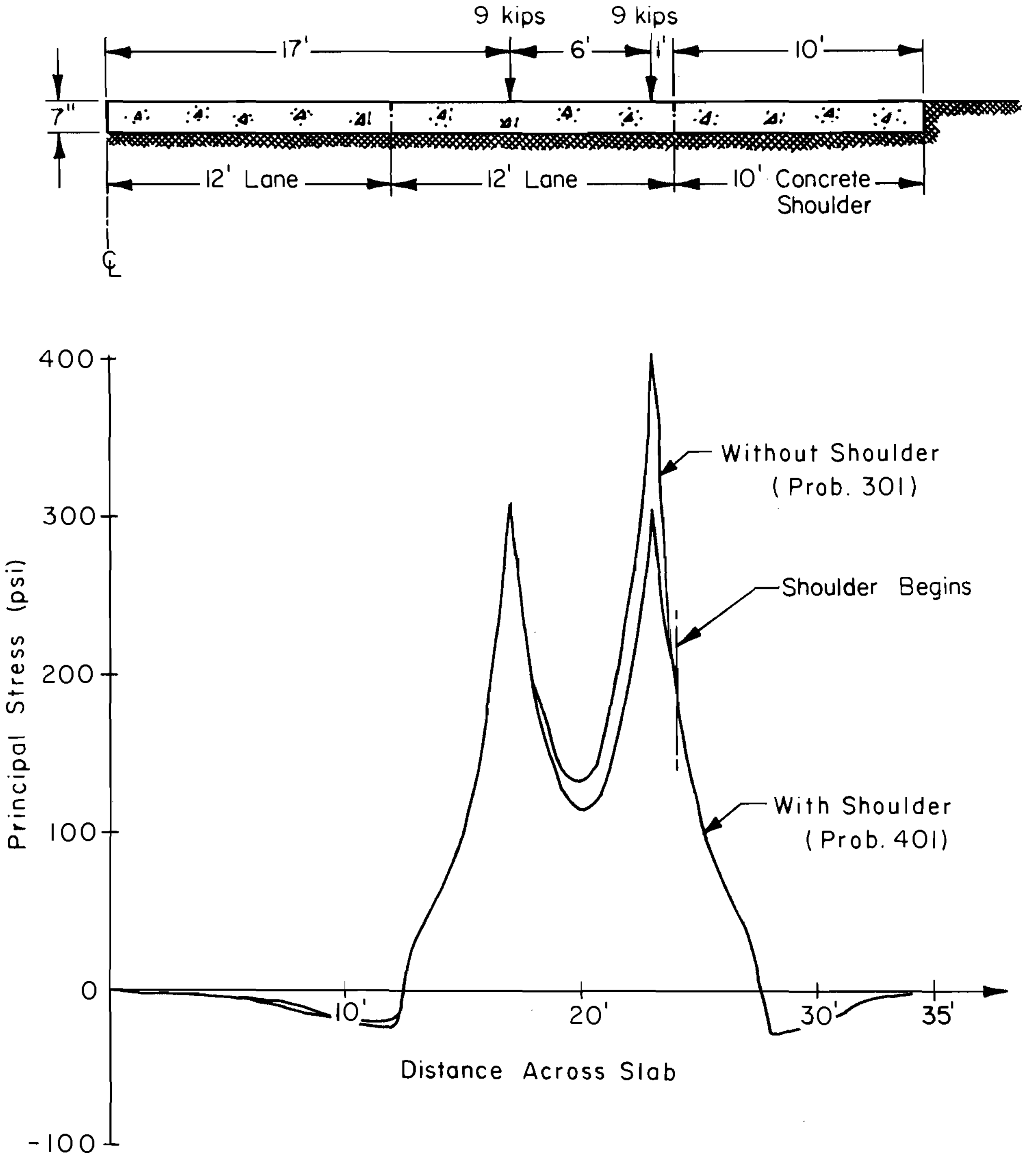

Fig 10. Transverse section and stress profile for 7-inch CRCP with and without concrete shoulders.

hydraulic inlet, but for a section of pavement this may not be necessary. Therefore, for this analysis, the contours are not plotted for either the deflections or the maximum principal stress.

CHAPTER 4. STRESS ANALYSIS OF PAVEMENT WITH CONCRETE SHOULDERS

Current rigid pavement design procedures which have been used to develop rigid pavement design standards used in recent years by the Texas Highway Department are for a static load case. These design standards are based on Westergaard's analysis of plain slabs. Recent revisions in a valuable design procedures have made available an empirical technique for selecting pavement thickness. This load design is based on the extended AASHO Interim Guide rigid pavement design equation as modified by Hudson and McCullough (Ref 11) and as evaluated by Treybig (Ref 12). It has since been used to select pavement thicknesses for different performance periods for continuously reinforced concrete pavement.

A basic relationship from the AASHO Road Test which related the number of applications of a given level of stress in a pavement of a given concrete flexural strength can be utilized to predict the number of load applications (Ref 19). If the stress in the pavement, strength of the concrete, and the terminal serviceability index are known, the number of stress applications or pavement life can be computed. For a terminal serviceability index of 2.5 the relation of stress, concrete strength, and load repetitions is as follows:

$$\log W = 5.789 + 3.42 \log \left(\frac{S_c}{\sigma}\right) \tag{4.1}$$

where

W = the number of applications of the stress σ ,

S_c = the 28-day flexural strength of the concrete, and

σ = the predicted stress in the concrete due to external loading.

Currently, the Texas Highway Department standard specifications include a 7-day concrete strength minimum of 575 psi (Ref 13), center point loading on a 6-inch by 6-inch by 24-inch concrete beam. To change this 7-day strength to 28-day strength (Ref 14):

$$S_{c(28\ day)} = 1.23\ S_{c(7\ day)} \tag{4.2}$$

$$S_{c(28)} = 1.23 \times 575 = 707\ \text{psi}$$

The next step is to change this strength from center-point to third-point loading to correspond to Road Test data:

$$S_{c(28\text{-day, 3rd point})} = 0.90\ S_{c(28\text{-day, center point})} \tag{4.3}$$

$$S_{c(28\text{-day, 3rd point})} = 0.90 \times 707 = 636\ \text{psi}$$

For further computations a round value of 640 psi is used.

Use of Eq 4.1 is made to calculate the number of stress applications or pavement life for the four problems analyzed. As shown in Table 4 the effect of the shoulders on pavement life is quite significant. For both pavement thicknesses studied, the number of stress applications with concrete shoulders is almost three times that without shoulders. This is due partly, to the continuity provided by the shoulders, which reduces the effect of an edge loading. Besides increasing the number of load applications, concrete shoulders provide a better performance and lower maintenance cost.

The true lateral distribution of wheel loads with respect to the pavement edge has been idealized in this analysis by placing the dual wheel 1 foot from the pavement edge. A more extensive analysis would include slab solutions for various load positions and the distribution of wheel loads with respect to load position would be applied. However, this was not done here because it is beyond the scope of this report.

TABLE 4. TABULATED VALUES OF PAVEMENT LIFE (from Eq 4.1)

Thickness, in.	Shoulder	σ, psi	log W	W
8	asphalt	329	6.788	6.0×10^6
	concrete	244	7.222	16.7×10^6
7	asphalt	406	6.463	2.9×10^6
	concrete	305	6.891	7.8×10^6

CHAPTER 5. SUMMARY

The discrete-element slab analysis, provides a unique method of analyzing both complex and common pavement design problems. The application made herein illustrates the application of this new and valuable analysis tool to a problem which cannot otherwise be easily analyzed by highway engineers. All the necessary computations, decisions, and data evaluation procedures involved in using this SLAB method for this problem have been covered in very close detail, including filling-out the coding forms for the problems involved in the comparative analysis.

For the concrete shoulders example and the design conditions assumed herein, the 7-inch continuously reinforced concrete pavement with a continuously reinforced concrete shoulder of the same thickness should have a service life equal to or greater than an 8-inch continuously reinforced concrete pavement on the same foundation without concrete shoulders. Therefore, when continuously reinforced concrete shoulders are considered, if the economics of the improved performance and reduced maintenance of the concrete shoulder along with the saving of one inch of concrete in the slab thickness, can justify it, the construction of the Portland Cement Concrete shoulder would be a good investment for the Highway Department.

The primary purpose of this report is not solely to discuss the merits of concrete shoulders. It is more directly to illustrate in a practical way the use and application of the SLAB programs to problems of design and analysis facing practicing engineers. The coding methods illustrated and the data evaluation techniques used are equally applicable to a wide variety of other problems.

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APPENDIX A

GUIDE FOR DATA INPUT

IDENTIFICATION OF RUN (2 cards per run)

Enter descriptive alphanumeric information - - date of run, user's name,

and the chosen units should always be included

IDENTIFICATION OF PROBLEM (1 card each problem; program stops if PROB NUM is left blank)

PROB NUM	Alphanumeric problem description
5	11

TABLE 1. CONTROL DATA (2 cards for each problem)

Enter "1" to KEEP prior TABLE

2	3	4	5	6	7	8	9		Multiple Load Option	
										+1 for Parent Problems -1 for Offspring Problems
5	10	15	20	25	30	35	40		46 50	

Number of cards added for TABLE

2	3	4	5	6	7	8	9		Enter "1" for Statics Check	Enter "1" for Principal Stress	Plot Options Profiles	Plot Options 3-D
*											**	***
5	10	15	20	25	30	35	40		46 50	55	60	65

* Number of cards added must be zero if preceeding table is kept or if this is an offspring problem.

** Profile plots are for areas specified by Table 8. If option is zero or blank, printer plot is made; if 1, microfilm; if 2, printer and microfilm; if 3, paper.

*** Enter 1 to obtain exaggerated isometric (three-dimensional paper plot) display of deflections.

TABLE 2. CONSTANTS (One card, none if Table 2 of preceding problem is kept)

Num X	Incr Y		Increment Length in X-Direction h_x	Increment Length in Y-Direction h_y	Poisson's Ratio ν	Slab Thickness t	
5	10		21 — 30	40	50	60	

TABLE 3. JOINT BENDING STIFFNESSES, LOADS, AND SUPPORTS (Maximum of 300 cards including those kept)

From X	From Y	Through X	Through Y	Slab Bending Stiffness D^x	Slab Bending Stiffness D^y	Beam Bending Stiffness F^x	Beam Bending Stiffness F^y	Load Q	Spring S
5	10	15	20	30	40	50	60	70	80

TABLE 4. JOINT RESTRAINTS AND APPLIED MOMENTS (Maximum of 50 cards including those kept)

From X	From Y	Through X	Through Y		Rotational Restraint R^x	Rotational Restraint R^y	Applied Moment T^x	Applied Moment T^y
5	10	15	20		41 — 50	60	70	80

TABLE 5. MESH TWISTING STIFFNESSES (Maximum of 100 cards including those kept)

From X	From Y	Through X	Through Y	Twisting Stiffness C^t	
5	10	15	20	30	

TABLE 6. BAR AXIAL THRUSTS (Maximum of 50 cards including those kept)

From X	From Y	Through X	Through Y		Slab Axial Thrust P^x	Slab Axial Thrust P^y	Beam Axial Thrust $\bar{P}^x$	Beam Axial Thrust $\bar{P}^y$
5	10	15	20		41 — 50	60	70	80

TABLE 7. MULTIPLE LOADS (Maximum of 100 cards including those kept)

From X	From Y	Through X	Through Y		Load Q
5	10	15	20		61–70

TABLE 8. PROFILE OUTPUT AREAS (Maximum of 10 cards, including those kept)

From X	From Y	Through X	Through Y	Defl	X-Mom	Y-Mom	Princ Mom or Stress
					*	*	
5	10	15	20	25	30	35	40

* Enter 1 for slab moments,
2 for beam moments

TABLE 9. PRINTED OUTPUT LIMITS (Maximum of 10 cards including those kept)

From Y	Through Y
6–10	16–20

If this table is omitted, all results will be printed. Each Y-bounded area specified includes the complete X-width.

TERMINATION OF RUN (one blank PROB NUM card)

5		Alphanumeric information may be punched here if desired, e.g., END OF DATA

GENERAL PROGRAM NOTES

The data cards must be assembled in proper order for the program to run.

A consistent system of units must be used for all input data, for example, kips and feet.

All 2 to 5-space words are understood to be right-justified integers or whole decimal numbers. . . $\boxed{+\ 4\ 3\ 2\ 1}$

All 10-space words are floating-point decimal numbers . . . . $\boxed{+\ 4\ .\ 3\ 2\ 1\ E\ +\ 0\ 3}$

Any number of problems may be run together.

TABLE 1. CONTROL DATA

If the KEEP option for Table 2 is set equal to 1, there must be no card input for that table.

For Tables 3 through 9, any data from prior problems may be retained in card image storage by the KEEP options. The number of cards input for each table is independent of the KEEP options, except that the cumulative total of cards cannot exceed the specified amount for each table.

Card counts for Tables 3 through 9 should be carefully rechecked after coding is completed.

The multiple-load option is exercised for problem series in which only the load positions and magnitudes will vary. This is done by input of new loads in Table 7. Tables 2 through 6 must be held and no cards may be added to them. The first problem in a series is the Parent and is specified by entering +1; successive loadings are the Offspring and are specified by entering -1. If the option is left blank or zero, the problem is complete within itself. Tables 8 and 9 may be used as desired for all problems.

The options for Statics Check or Principal Stress may be exercised by entering 1. If the Principal Stress is to be used, then a slab or plate thickness must be available in Table 2. The option is useful only if the real slab is of uniform thickness with no discontinuities. The output value of principal stress has the same sign as the principal moment from which it is computed.

Two types of plots are available. The first option if left blank or set equal to zero causes the printer to create profile plots along with tabulated values; if the option is equal to 1, the plot is made on microfilm with no tabulation; if the option is set equal to 2, the combination of 0 and 1 is obtained; if the option is set equal to 3, only paper plots are made. The profiles are in areas specified by Table 8. The second type of plot creates a pseudo three-dimensional paper plot of the entire set of deflection

TABLE 2. CONSTANTS

Variables:	h_x, h_y	ν	t
Typical Input Units:	in.	none	in.

This table is omitted for Offspring problems

Poisson's ratio will be taken as zero unless specified (always positive). It is not needed when running grid-beam type problems since no Poisson's effects are considered for the beam elements.

Slab or plate thickness must be entered if the Stress Option in Table 1 is used. The stress is computed directly from the value of principal moment and has the same sign.

TABLES 3 and 4. JOINT BENDING STIFFNESSES, LOADS, SUPPORTS, RESTRAINTS, AND APPLIED MOMENTS DATA

Variables:	D^x, D^y	F^x, F^y	Q	S	R^x, R^y	T^x, T^y
Typical Input Units:	$\frac{\text{lb-in}^2}{\text{in.}}$	lb-in^2	lb	$\frac{\text{lb}}{\text{in.}}$	$\frac{\text{in-lb}}{\text{rad}}$	in-lb

Unit stiffness values D^x and D^y for a slab or plate and concentrated stiffness values F^x and F^y for beams are input at all joints. The values are reduced proportionately for edges.

Customary relationships for isotropic slabs or plates and beams of known cross section are given here for reference:

$$D^x = D^y = \frac{Et^3}{12(1-\nu^2)} \qquad C^t = \frac{Et^3}{12(1+\nu)} \qquad F = EI$$

E is the modulus of elasticity t , the plate or slab thickness, ν is Poisson's ratio, and I is the total beam cross section moment of inertia including composite effects if present.

Load values Q and support springs S for any joint are determined by multiplying the unit load or unit support value by the appropriate area of the real slab assigned to that joint. Hinged supports are provided by using large S values. Concentrated loads that occur between joints can be apportioned geometrically to adjacent joints.

All data are described with a coordinate system which is related to the X and Y-station numbers. To distribute data over a rectangular area, the lower left hand and the upper right hand coordinates must be specified. Figure A2 illustrates a sample data input.

To specify data at a single location, the same coordinates must be specified for both the From and Through coordinates.

The Through coordinates must always be equal to or numerically greater than the From coordinates.

The user may input values on the edges of the slab and the corners to represent the proportionate area desired, as illustrated in Fig A2.

There are no restrictions on the order of cards. The values input are algebraically accumulated at each coordinate.

TABLE 5. MESH TWISTING STIFFNESSES

Variable: C^t

Typical Input Unit: $\frac{\text{lb-in}^2}{\text{in/rad}}$

Unit twisting stiffness C^t is defined for the mesh of the plate or slab surrounded by four rigid bars and four joints. The mesh is numbered according to the joint number at the upper right corner of the mesh as shown in Fig A1.

The same general notes as listed for Tables 3 and 4 are applicable.

TABLE 6. BAR AXIAL THRUSTS

Variables:	P^x, P^y	$\overline{P}^x$, $\overline{P}^y$
Typical Input Units:	lb	lb

All data in this table are concentrated. Distributed data must be summed over the width of the increment involved. Proportionate values can be used along edges.

All tension (+) or compression (-) values P^x are specified for each X-bar in the X-direction. Since it is a bar force, no coordinate should be used which would specify a P^x value in a bar outside the real plate or slab. The bars are numbered according to the joint number at the increasing station end of the bar, as shown in Fig A1. P^y values are specified in the Y-direction.

The same general notes as listed for Tables 3 and 4 are applicable.

TABLE 7. MULTIPLE LOADS

Variable: Q

Typical Input Unit: lb

When a problem is such that only the load changes from problem to problem, it is appropriate to enter it in this table and hold all other stiffness, load, and geometrical data of Tables 2, 3, 4, 5, and 6 from the previous problem, thus creating an Offspring problem. Any loads entered or held in Table 3 are added to the loads of Table 7.

The multiple-loading options are specified in Table 1. The greatest amount of computer time is needed for the first problem in a multiple-loading problem series and subsequent problems are then solved in a fraction of the solution time.

TABLE 8. PROFILE OUTPUT AREAS

Each card may encompass up to a maximum of 300 points. For larger areas, additional cards may be used to the limit of 10, including those kept from previous problems.

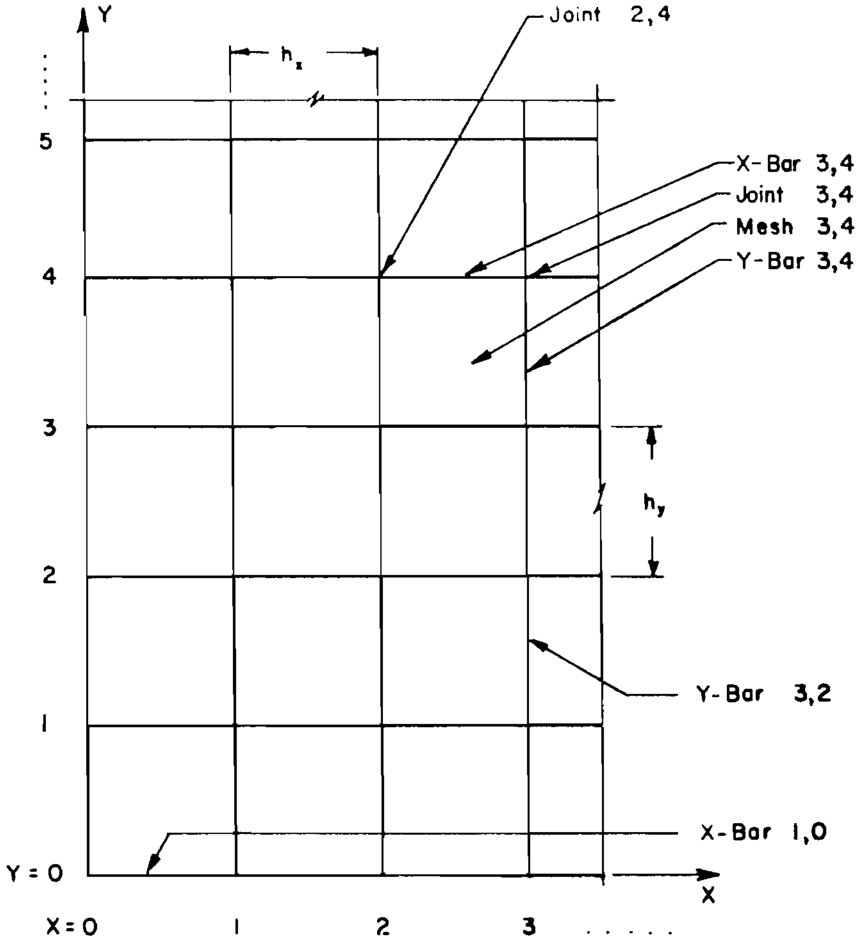
If profile plot options in Table 1 were set to 1 or 3, no tabulated output of Table 8 areas is printed. A blank or 2 option will cause tabulated and printer display of the selected profiles.

Any one or all four types of profile output may be selected by entering a 1 for those desired. Beam moments may be chosen by entering a 2. One limitation for the moment options is that all areas entered or kept from the previous problem must be either for slab or beam X and Y-moments. A mixture of slab and beam profile output within a problem is disallowed.

TABLE 9. PRINTED OUTPUT LIMITS

If this table is omitted, the complete printout of results is obtained. Partial output may be obtained by specifying the sections to be printed within the Y-bounded limits designated on each card. Up to 10 Y-bounded sections may be printed.

Y-bounded areas may overlap or be contiguous.



Joint Data : D^x, D^y, F^x, F^y, Q, S, R^x, R^y, T^x, T^y

(D^x and D^y are per unit width, all others are concentrated values)

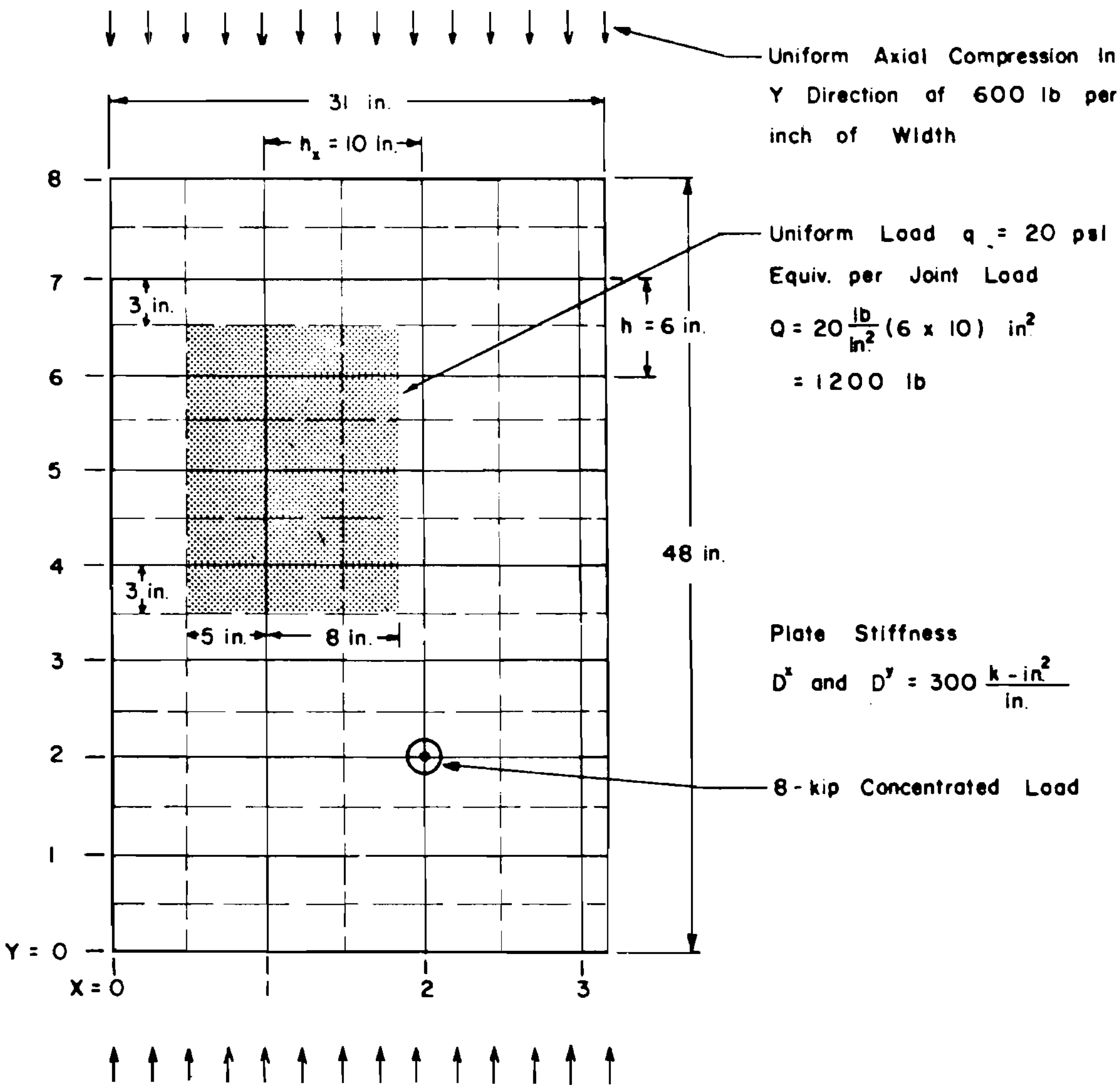
Mesh Data : C^t

(C^t is per unit width)

Bar Data : P^x, P^y, $\bar{P}^x$, $\bar{P}^y$

(all values are concentrated)

Fig A1. Data coordinate numbering system.



From X	From Y	Through X	Through Y	D^x and D^y	Q	P^y
0	0	2	8	7.500E+04		
0	1	2	7	7.500E+04		
1	1	2	7	1.500E+05		
3	0	3	8	9.000E+04		
3	1	3	7	9.000E+04		
1	4	1	6		-1.200E+03	
2	4	2	6		-3.600E+02	
2	2	2	2		-8.000E+03	
0	1	0	8			-3.000E+03
1	1	2	8			-6.000E+03
3	1	3	8			-3.600E+03

data incomplete for this sample

Fig A2. Sample data input.

APPENDIX B

CODING OF ILLUSTRATIVE PROBLEMS

IDENTIFICATION Problems For Applications Report CODED BY HJT, AAA DATE 23 JULY 1970 PAGE 1 OF 7

```
          ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
               PROJECT 56 SLAB APPLICATIONS---HARVEY J. TREYBIG
  101     24 X 40 FT CRCP WITHOUT CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS
                                                 1
    1   14    0    1    0    2    3    0              1    0    1
   24   40           1.200E+01 1.200E+01 2.000E-01 8.000E+00
    0    0   24   40 4.445E+07 4.445E+07                               3.600E+03
    0    1   24   39 4.445E+07 4.445E+07                               3.600E+03
    1    0   23   40 4.445E+07 4.445E+07                               3.600E+03
    1    1   23   39 4.445E+07 4.445E+07                               3.600E+03
   12    0   12   40-8.000E+07
   12    1   12   39-8.000E+07
    0    8   24    8          -8.000E+07
    1    8   23    8          -8.000E+07
    0   16   24   16          -8.000E+07
    1   16   23   16          -8.000E+07
```

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5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
0	24	24	24				-8.000E+07								
1	24	23	24				-8.000E+07								
0	32	24	32				-8.000E+07								
1	32	23	32				-8.000E+07								
1	1	24	40		1.422E+08										
17	20	17	20										-9.000E+03		
23	20	23	20										-9.000E+03		
0	20	24	20	1	1	1	1								
17	0	17	40	1	1	1	1								
23	0	23	40	1	1	1	1								
201		34 X 40 FT CRCP WITH CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS													
1	16	0	1	0	2	3	0			1	2				
34	40				1.200E+01		1.200E+01		2.000E-01		8.000E+00				
0	0	34	40		4.445E+07										3.600E+03
0	1	34	39		4.445E+07										3.600E+03

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1–5	6–10	11–15	16–20	21–30	31–40	41–50	51–60	61–70	71–80
1	0	33	40	4.445E+07	4.445E+07				3.600E+03
1	1	33	39	4.445E+07	4.445E+07				3.600E+03
12	0	12	40	-8.000E+07					
12	1	12	39	-8.000E+07					
24	0	24	40	-8.000E+07					
24	1	24	39	-8.000E+07					
0	8	34	8		-8.000E+07				
1	8	33	8		-8.000E+07				
0	16	34	16		-8.000E+07				
1	16	33	16		-8.000E+07				
0	24	34	24		-8.000E+07				
1	24	33	24		-8.000E+07				
0	32	34	32		-8.000E+07				
1	32	33	32		-8.000E+07				
1	1	34	40	1.422E+08					
17	20	17	20					-9.000E+03	

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1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–70	71–80
23	20	23	20									-9.000E+03	
0	20	34	20	1	1	1	1						
17	0	23	40	1	1	1	1						
23	0	23	40	1	1	1	1						
301		24 X 40 FT CRCP WITHOUT CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS											
									1				
1	14	0	1	0	2	3	0			1	2		
24	40			1.200E+01		1.200E+01		2.000E-01		7.000E+00			
0	0	24	40	2.978E+07		2.978E+07							3.600E+03
0	1	24	39	2.978E+07		2.978E+07							3.600E+03
1	0	23	40	2.978E+07		2.978E+07							3.600E+03
1	1	23	39	2.978E+07		2.978E+07							3.600E+03
12	0	12	40	-5.360E+07									
12	1	12	39	-5.360E+07									
0	8	24	8			-5.360E+07							
1	8	23	8			-5.360E+07							

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0	16	24	16			-5.360E+07									
1	16	23	16			-5.360E+07									
0	24	24	24			-5.360E+07									
1	24	23	24			-5.360E+07									
0	32	24	32			-5.360E+07									
1	32	23	32			-5.360E+07									
1	1	24	40	9.528E+07											
17	20	17	20									-9.000E+03			
23	20	23	20									-9.000E+03			
0	20	24	20	1	1	1	1								
17	0	17	40	1	1	1	1								
23	0	23	40	1	1	1	1								
401		34 X 40 FT CRCP WITH CONCRETE SHOULDERS, 18 KIP LOAD BETWEEN CRACKS													
									1						
1	16	0	1	0	2	3	0			1	0				
34	40			1.200E+01		1.200E+01		2.000E-01		7.000E+00					

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1–5	6–10	11–15	16–20	21–30	31–40	71–80
0	0	34	40	2.978E+07	2.978E+07	3.600E+03
0	1	34	39	2.978E+07	2.978E+07	3.600E+03
1	0	33	40	2.978E+07	2.978E+07	3.600E+03
1	1	33	39	2.978E+07	2.978E+07	3.600E+03
12	0	12	40	-5.360E+07		
12	1	12	39	-5.360E+07		
24	0	24	40	-5.360E+07		
24	1	24	39	-5.360E+07		
0	8	34	8		-5.360E+07	
1	8	33	8		-5.360E+07	
0	16	34	16		-5.360E+07	
1	16	33	16		-5.360E+07	
0	24	34	24		-5.360E+07	
1	24	33	24		-5.360E+07	
0	32	34	32		-5.360E+07	
1	32	33	32		-5.360E+07	

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1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–60	61–70	71–80
1	1	34	40	9.528E+07						
17	20	17	20						-9.000E+03	
23	20	23	20						-9.000E+03	
0	20	34	20	1	1	1	1			
17	0	17	40	1	1	1	1			
23	0	23	40	1	1	1	1			

APPENDIX C

COMPUTER OUTPUT PROBLEM 101

PROGRAM SLAB 49 -DEVELOPMENT DECK- MATLOCK,PANAK, ENDRES REV DATE 13 JUL 71

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                             *
*   THIS PROGRAM IS BEING USED AT YOUR OWN RISK.              *
*   CHANGES MAY OCCUR AFTER THE ABOVE REVISION DATE.          *
*   PLEASE REPORT DIFFICULTIES TO THE ABOVE PEOPLE            *
*   AT THE CENTER FOR HIGHWAY RESEARCH, UT AT AUSTIN.         *
*                                                             *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
PROJECT 56 SLAB APPLICATIONS---HARVEY J. TREYBIG

PROB
1.1 24*40 FT CRCP WITHOUT CONCRETE SHOULDERS + 18KIP LOAD BETWEEN CRACKS

TABLE 1. CONTROL DATA

	TABLE NUMBER 2	3	4	5	6	7	8	9
KEEP FROM PRECEDING PROBLEM (1=YES)	-0	-0	-0	-0	-0	-0	-0	-0
NUM CARDS INPUT THIS PROBLEM	1	14	0	1	0	2	3	0

MULTIPLE LOAD OPTION	1
STATICS CHECK OPTION	-0
PRIN STRESS OPTION	1
PROFILE PLOT OPTION	0
3-D PLOT OPTION	1

TABLE 2. CONSTANTS

NUMBER OF INCREMENTS IN X DIRECTION	24
NUMBER OF INCREMENTS IN Y DIRECTION	40
INCREMENT LENGTH IN X DIRECTION	1.200E+01
INCREMENT LENGTH IN Y DIRECTION	1.200E+01
POISSONS RATIO	2.000E-01
SLAB THICKNESS	8.000E+00

TABLE 3. JOINT STIFFNESS AND LOAD DATA

FROM JOINT	THRU JOINT	DX	DY	FX	FY	Q	S
0 0	24 40	4.445E+07	4.445E+07	-0.	-0.	-0.	3.600E+03
0 1	24 39	4.445E+07	4.445E+07	-0.	-0.	-0.	3.600E+03
1 0	23 40	4.445E+07	4.445E+07	-0.	-0.	-0.	3.600E+03
1 1	23 39	4.445E+07	4.445E+07	-0.	-0.	-0.	3.600E+03
12 0	12 40	-8.000E+07	-0.	-0.	-0.	-0.	-0.
12 1	12 39	-8.000E+07	-0.	-0.	-0.	-0.	-0.
0 8	24 8	-0.	-8.000E+07	-0.	-0.	-0.	-0.
1 8	23 8	-0.	-8.000E+07	-0.	-0.	-0.	-0.
0 16	24 16	-0.	-8.000E+07	-0.	-0.	-0.	-0.
1 16	23 16	-0.	-8.000E+07	-0.	-0.	-0.	-0.
0 24	24 24	-0.	-8.000E+07	-0.	-0.	-0.	-0.
1 24	23 24	-0.	-8.000E+07	-0.	-0.	-0.	-0.
0 32	24 32	-0.	-8.000E+07	-0.	-0.	-0.	-0.
1 32	23 32	-0.	-8.000E+07	-0.	-0.	-0.	-0.

TABLE 4. JOINT STIFFNESS AND LOAD DATA CONTD

FROM JOINT	THRU JOINT	RX	RY	TX	TY

NONE

TABLE 5. MESH STIFFNESS DATA

FROM MESH	THRU MESH	C
1 1	24 40	1.422E+08

TABLE 6. BAR STIFFNESS DATA

FROM BAR	THRU BAR	PX	PY	RBX	RBY

NONE

TABLE 7. MULTIPLE LOAD DATA

FROM JOINT	THRU JOINT	QM
17 20	17 20	-9.000E+03
23 20	23 20	-9.000E+03

TABLE 8. PROFILE OUTPUT AREAS

FROM JOINT	THRU JOINT	DEFL (1=YES)	X MOMENT (1=SLAB,2=BEAM)	Y MOMENT	PRIN MOM OR STRESS (1=YES)
0 20	24 20	1	1	1	1
17 0	17 40	1	1	1	1
23 0	23 40	1	1	1	1

TABLE 9. PRINTED OUTPUT LIMITS

FROM Y STA	THRU Y STA

NONE

PROGRAM SLAB 49 -DEVELOPMENT DECK- MATLOCK,PANAK, ENDRES REV DATE 13 JUL 71

THIS PROGRAM IS BEING USED AT YOUR OWN RISK.
CHANGES MAY OCCUR AFTER THE ABOVE REVISION DATE.
PLEASE REPORT DIFFICULTIES TO THE ABOVE PEOPLE
AT THE CENTER FOR HIGHWAY RESEARCH, UT AT AUSTIN.

ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
PROJECT 56 SLAB APPLICATIONS---HARVEY J. TREYBIC

PROB (CONTD)
101 24*40 FT CRCP WITHOUT CONCRETE SHOULDERS , 18KIP LOAD BETWEEN CRACKS

RESULTS

SLAB X MOMENT AND X TWISTING MOMENT ACT IN THE X DIRECTION (ABOUT Y AXIS)
Y TWISTING MOMENT = -X TWISTING MOMENT, COUNTERCLOCKWISE BETA ANGLES ARE
POSITIVE FROM THE X AXIS TO THE DIRECTION OF THE LARGEST PRINCIPAL STRESS
SLAB MOMENTS ARE PER UNIT WIDTH

X	Y	DEFL	SLAB X MOMENT	SLAB Y MOMENT	SLAB X TWISTING MOMENT	LARGEST PRINCIPAL SLAB STRESS	BETA X TO LARGEST STRESS	SUPPORT REACTION
0	40	-9.597E-05	3.400E-12	4.793E-12	-1.963E-01	1.841E-02	-45.0	3.455E-01
1	40	-9.314E-05	-8.118E-01	3.267E-12	-6.211E-01	-1.076E-01	28.4	6.706E-01
2	40	-9.167E-05	-1.033E+00	4.498E-12	-1.009E+00	-1.547E-01	31.4	6.600E-0
3	40	-9.195E-05	-9.610E-01	6.372E-12	-1.392E+00	-1.831E-01	35.5	6.6
4	40	-9.385E-05	-7.207E-01	4.658E-12	-1.766E+00	-2.028E-01	39	
5	40	-9.697E-05	-3.944E-01	6.265E-12	-2.128E+00	-2.188E		
6	40	-1.008E-04	-4.618E-02	5.515E-12	-2.467E+00			
7	40	-1.046E-04	2.695E-01	4.337E-12	-2.77			
8	40	-1.080E-04	5.054E-01	4.605E-1				
9	40	-1.106E-04	6.226E-01					.262E-02
10	40	-1.121E-04	5.957E				.6	1.152E+00
11	40	-1.126E-04				00	-7.9	2.901E+00
12	40					.250E+00	-8.3	5.506E+00
13					E+01	-1.012E+01	-8.8	9.226E+00
				01	3.410E+01	-1.170E+01	-9.4	1.434E+01
				1E+02	4.596E+01	1.241E+01	79.8	2.109E+01
			02	1.933E+02	8.392E+01	2.017E+01	75.4	2.965E+01
			1.306E+02	3.038E+02	1.324E+02	3.197E+01	74.3	5.111E+01
		1E-03	-8.669E+01	4.603E+02	1.771E+02	4.806E+01	73.5	7.489E+01
	21	-7.003E-03	7.704E+01	6.602E+02	2.412E+02	7.004E+01	70.2	1.008E+02
16	21	-8.852E-03	4.487E+02	8.686E+02	2.922E+02	9.548E+01	62.8	1.275E+02
17	21	-1.047E-02	1.028E+03	9.560E+02	8.036E+01	1.012E+02	33.0	1.507E+02
18	21	-1.138E-02	2.766E+02	1.014E+03	-1.205E+02	9.689E+01	-81.0	1.639E+02
19	21	-1.223E-02	-2.355E+02	9.783E+02	-3.451E+01	9.181E+01	-88.4	1.761E+02
20	21	-1.344E-02	-4.658E+02	1.003E+03	9.416E+01	9.463E+01	86.3	1.935E+02
21	21	-1.522E-02	-4.358E+02	1.144E+03	2.397E+02	1.106E+02	81.6	2.191E+02
22	21	-1.755E-02	-9.155E+01	1.377E+03	3.810E+02	1.378E+02	76.3	2.527E+02
23	21	-2.020E-02	5.649E+02	1.573E+03	2.859E+02	1.545E+02	75.2	2.908E+02
24	21	-2.263E-02	1.364E-10	9.026E+02	1.133E+02	8.593E+01	83.0	1.629E+02
0	20	9.978E-05	4.499E-12	-3.810E-01	1.606E-12	-3.572E-02	-90.0	-7.184E-01
1	20	9.369E-05	-3.081E+00	6.048E-02	2.462E-12	-2.889E-01	-.0	-1.349E+00
2	20	8.499E-05	-7.900E+00	8.823E-01	5.889E-12	-7.406E-01	-.0	-1.224E+00
3	20	6.947E-05	-1.482E+01	2.015E+00	8.405E-12	-1.389E+00	-.0	-1.000E+00
4	20	4.111E-05	-2.419E+01	3.875E+00	9.934E-12	-2.268E+00	-.0	-5.920E-01
5	20	-8.305E-06	-3.632E+01	7.056E+00	1.295E-11	-3.405E+00	-.0	1.196E-01
6	20	-8.955E-05	-5.133E+01	1.242E+01	9.850E-12	-4.813E+00	-.0	1.290E+00
7	20	-2.162E-04	-6.905E+01	2.124E+01	1.199E-11	-6.473E+00	-.0	3.113E+00
8	20	-4.047E-04	-8.866E+01	3.530E+01	2.141E-11	-8.312E+00	-.0	5.828E+00
9	20	-6.739E-04	-1.083E+02	5.717E+01	1.713E-11	-1.015E+01	-.0	9.705E+00
10	20	-1.044E-03	-1.243E+02	9.043E+01	3.255E-11	-1.165E+01	-.0	1.504E+01
11	20	-1.535E-03	-1.295E+02	1.399E+02	3.426E-11	1.311E+01	90.0	2.210E+01
12	20	-2.158E-03	-1.103E+02	2.205E+02	4.111E-11	2.068E+01	90.0	3.107E+01
13	20	-3.713E-03	-1.485E+02	3.580E+02	-4.111E-11	3.356E+01	-90.0	5.346E+01
14	20	-5.453E-03	-1.204E+02	5.747E+02	-2.056E-11	5.388E+01	-90.0	7.853E+01
15	20	-7.392E-03	2.649E+01	9.284E+02	1.507E-10	8.704E+01	90.0	1.064E+02
16	20	-9.466E-03	4.690E+02	1.550E+03	-1.370E-11	1.453E+02	-90.0	1.363E+02
17	20	-1.140E-02	2.023E+03	2.625E+03	-1.096E-10	2.461E+02	-90.0	1.642E+02
18	20	-1.208E-02	2.849E+02	1.718E+03	-6.852E-11	1.611E+02	-90.0	1.740E+02
19	20	-1.280E-02	-3.128E+02	1.305E+03	-2.467E-10	1.223E+02	-90.0	1.844E+02
20	20	-1.401E-02	-5.490E+02	1.248E+03	-2.193E-10	1.170E+02	-90.0	2.018E+02
21	20	-1.590E-02	-5.339E+02	1.507E+03	-2.741E-10	1.413E+02	-90.0	2.289E+02
22	20	-1.848E-02	-1.329E+02	2.184E+03	-4.385E-10	2.048E+02	-90.0	2.662E+02
23	20	-2.155E-02	1.474E+03	3.509E+03	-4.659E-10	3.289E+02	-90.0	3.103E+02
24	20	-2.397E-02	-1.655E-10	1.587E+03	-3.015E-10	1.488E+02	-90.0	1.726E+02
0	19	9.946E-05	4.016E-12	-3.982E-01	-5.774E-01	-7.593E-02	54.5	-7.161E-01
1	19	9.397E-05	-2.927E+00	-3.426E-02	-1.301E+00	-3.212E-01	21.0	-1.353E+00
2	19	8.603E-05	-7.569E+00	7.113E-01	-1.735E+00	-7.423E-01	11.4	-1.239E+00
3	19	7.157E-05	-1.427E+01	1.727E+00	-2.518E+00	-1.374E+00	8.7	-1.031E+00
4	19	4.479E-05	-2.335E+01	3.396E+00	-3.757E+00	-2.238E+00	7.8	-6.450E-01
5	19	-2.265E-06	-3.509E+01	6.258E+00	-5.609E+00	-3.360E+00	7.6	3.262E-02
6	19	-7.998E-05	-4.961E+01	1.110E+01	-8.296E+00	-4.755E+00	7.6	1.152E+00
7	19	-2.014E-04	-6.667E+01	1.905E+01	-1.211E+01	-6.408E+00	7.9	2.901E+00
8	19	-3.823E-04	-8.547E+01	3.171E+01	-1.740E+01	-8.250E+00	8.3	5.506E+00
9	19	-6.407E-04	-1.042E+02	5.132E+01	-2.460E+01	-1.012E+01	8.8	9.226E+00
10	19	-9.956E-04	-1.192E+02	8.085E+01	-3.410E+01	-1.170E+01	9.4	1.434E+01
11	19	-1.465E-03	-1.239E+02	1.241E+02	-4.596E+01	1.241E+01	-79.8	2.109E+01
12	19	-2.059E-03	-1.064E+02	1.933E+02	-8.392E+01	2.017E+01	-75.4	2.965E+01
13	19	-3.549E-03	-1.306E+02	3.038E+02	-1.324E+02	3.197E+01	-74.3	5.111E+01
14	19	-5.201E-03	-8.669E+01	4.603E+02	-1.771E+02	4.806E+01	-73.5	7.489E+01
15	19	-7.003E-03	7.704E+01	6.602E+02	-2.412E+02	7.004E+01	-70.2	1.008E+02
16	19	-8.852E-03	4.487E+02	8.686E+02	-2.922E+02	9.548E+01	-62.8	1.275E+02
17	19	-1.047E-02	1.028E+03	9.560E+02	-8.036E+01	1.012E+02	-33.0	1.507E+02
18	19	-1.138E-02	2.766E+02	1.014E+03	1.205E+02	9.689E+01	81.0	1.639E+02
19	19	-1.223E-02	-2.355E+02	9.783E+02	3.451E+01	9.181E+01	88.4	1.761E+02
20	19	-1.344E-02	-4.658E+02	1.003E+03	-9.416E+01	9.463E+01	-86.3	1.935E+02
21	19	-1.522E-02	-4.358E+02	1.144E+03	-2.397E+02	1.106E+02	-81.6	2.191E+02
22	19	-1.755E-02	-9.155E+01	1.377E+03	-3.810E+02	1.378E+02	-76.3	2.527E+02
23	19	-2.020E-02	5.649E+02	1.573E+03	-2.859E+02	1.545E+02	-75.2	2.908E+02
24	19	-2.263E-02	3.702E-10	9.026E+02	-1.133E+02	8.593E+01	-83.0	1.629E+02
0	18	9.847E-05	-7.501E-13	-4.498E-01	-1.081E+00	-1.246E-01	50.9	-7.090E-01
1	18	9.472E-05	-2.482E+00	-3.108E-01	-2.439E+00	-3.812E-01	33.0	-1.364E+00
2	18	8.894E-05	-6.620E+00	2.209E-01	-3.255E+00	-7.427E-01	21.8	-1.281E+00
3	18	7.754E-05	-1.269E+01	9.146E-01	-4.714E+00	-1.328E+00	17.4	-1.117E+00
4	18	5.527E-05	-2.096E+01	2.055E+00	-7.008E+00	-2.149E+00	15.7	-7.959E-01
5	18	1.498E-05	-3.162E+01	4.042E+00	-1.042E+01	-3.229E+00	15.1	-2.156E-01
6	18	-5.268E-05	-4.473E+01	7.445E+00	-1.534E+01	-4.585E+00	15.2	7.586E-01
7	18	-1.593E-04	-5.999E+01	1.307E+01	-2.228E+01	-6.210E+00	15.7	2.294E+00
8	18	-3.188E-04	-7.658E+01	2.200E+01	-3.176E+01	-8.056E+00	16.4	4.590E+00
9	18	-5.466E-04	-9.277E+01	3.568E+01	-4.449E+01	-1.000E+01	17.4	7.871E+00
10	18	-6.586E-04	-1.054E+02	5.586E+01	-6.094E+01	-1.180E+01	18.5	1.236E+01

11	18	-1.269E-03	-1.094E+02	8.449E+01	-8.091E+01	-1.300E+01	19.9	1.827E+01
12	18	-1.786E-03	-9.645E+01	1.287E+02	-1.436E+02	1.861E+01	-64.0	2.572E+01
13	18	-3.107E-03	-9.984E+01	1.918E+02	-2.171E+02	2.883E+01	-61.9	4.474E+01
14	18	-4.545E-03	-4.900E+01	2.685E+02	-2.659E+02	3.933E+01	-60.4	6.545E+01
15	18	-6.070E-03	8.406E+01	3.402E+02	-3.121E+02	5.151E+01	-56.2	8.740E+01
16	18	-7.581E-03	3.044E+02	3.783E+02	-3.043E+02	6.074E+01	-48.5	1.092E+02
17	18	-8.899E-03	4.860E+02	3.731E+02	-1.436E+02	5.473E+01	-34.3	1.281E+02
18	18	-9.870E-03	1.583E+02	4.723E+02	1.232E+00	4.428E+01	89.8	1.421E+02
19	18	-1.079E-02	-1.760E+02	5.384E+02	-3.914E+01	5.067E+01	-86.9	1.553E+02
20	18	-1.194E-02	-3.537E+02	5.861E+02	-1.640E+02	5.756E+01	-80.4	1.720E+02
21	18	-1.350E-02	-3.368E+02	6.360E+02	-3.108E+02	6.814E+01	-73.7	1.944E+02
22	18	-1.544E-02	-1.280E+02	6.741E+02	-4.185E+02	7.994E+01	-66.9	2.224E+02
23	18	-1.761E-02	1.452E+02	6.832E+02	-3.888E+02	8.315E+01	-62.3	2.536E+02
24	18	-1.977E-02	2.192E-10	3.915E+02	-1.960E+02	4.432E+01	-67.5	1.423E+02
0	17	9.671E-05	8.674E-12	-5.363E-01	-1.447E+00	-1.631E-01	50.2	-6.963E-01
1	17	9.563E-05	-1.796E+00	-7.522E-01	-3.277E+00	-4.305E-01	40.5	-1.37[illegible]
2	17	9.316E-05	-5.176E+00	-5.321E-01	-4.385E+00	-7.328E-01	31.[illegible]	
3	17	8.641E-05	-1.031E+01	-2.946E-01	-6.334E+00	-1.254E+00		
4	17	7.102E-05	-1.736E+01	1.076E-01	-9.364E+00	-2.[illegible]		
5	17	4.096E-05	-2.644E+01	8.776E-01	-1.383E[illegible]			
6	17	-1.155E-05	-3.750E+01	2.296E+00	[illegible]			
7	17	-9.607E-05	-5.020E+01	4.7[illegible]				
8	17	-2.238E-04	-6.375E+01					[illegible]E-01
9	17	-4.067E-04	-7.[illegible]					6.600E-01
10	17	-6.568E[illegible]					-35.5	6.621E-01
11	17	[illegible]				[illegible]E-01	-39.2	6.757E-01
12					[illegible]00	-2.188E-01	-42.4	6.982E-01
					[illegible]467E+00	-2.334E-01	-44.7	7.254E-01
				[illegible]E-12	2.771E+00	2.727E-01	43.6	7.532E-01
				2.196E-12	3.023E+00	3.081E-01	42.6	7.777E-01
			[illegible]E-01	3.025E-12	3.202E+00	3.308E-01	42.2	7.961E-01
		[illegible]E-04	5.957E-01	2.624E-12	3.284E+00	3.371E-01	42.4	8.069E-01
		[illegible]126E-04	4.175E-01	3.748E-12	3.247E+00	3.246E-01	43.2	8.105E-01
	0	-1.124E-04	8.334E-02	3.505E-12	3.010E+00	2.861E-01	44.6	8.090E-01
13	0	-1.108E-04	2.880E-01	3.427E-12	2.693E+00	2.664E-01	43.5	7.978E-01
14	0	-1.088E-04	3.125E-01	2.624E-12	2.421E+00	2.421E-01	43.2	7.830E-01
15	0	-1.062E-04	1.457E-01	2.624E-12	2.118E+00	2.055E-01	44.0	7.645E-01
16	0	-1.034E-04	-2.057E-01	2.142E-12	1.772E+00	-1.760E-01	-43.3	7.442E-01
17	0	-1.009E-04	-6.975E-01	2.302E-12	1.378E+00	-1.659E-01	-37.9	7.264E-01
18	0	-9.959E-05	-1.253E+00	1.608E-12	9.447E-01	-1.650E-01	-28.2	7.170E-01
19	0	-1.004E-04	-1.772E+00	2.034E-12	4.969E-01	-1.783E-01	-14.6	7.229E-01
20	0	-1.042E-04	-2.145E+00	2.462E-12	7.545E-02	-2.013E-01	-2.0	7.503E-01
21	0	-1.116E-04	-2.262E+00	3.427E-12	-2.666E-01	-2.150E-01	6.6	8.038E-01
22	0	-1.229E-04	-2.027E+00	3.105E-12	-4.722E-01	-1.998E-01	12.5	8.847E-01
23	0	-1.375E-04	-1.341E+00	3.428E-12	-4.959E-01	-1.410E-01	18.2	9.903E-01
24	0	-1.545E-04	2.088E-12	1.446E-12	-2.410E-01	2.259E-02	-45.0	5.561E-01

STATICS CHECK. SUMMATION OF REACTIONS = 1.800E+04

MAXIMUM STATICS CHECK ERROR AT STA 17 19 = 1.244E-08

PROGRAM SLAB 49 -DEVELOPMENT DECK- MATLOCK,PANAK, ENDRES REV DATE 13 JUL 71

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ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
PROJECT 56 SLAB APPLICATIONS___HARVEY J. TREYBIG

PROB (CONTD)
101 24*40 FT CRCP WITHOUT CONCRETE SHOULDERS , 18KIP LOAD BETWEEN CRACKS

PROFILE OUTPUT AREAS
X MOMENTS ACT IN X DIRECTION (ABOUT Y AXIS)
THE PLOTTED RESULTS INDICATE THE RELATIVE VALUE EACH HAS WITHIN THAT LIST

DEFLECTIONS BETWEEN (0 , 20) AND (24 , 20)

X	Y	DEFLECTION
0	20	9.978E-05
1	20	9.369E-05
2	20	8.499E-05
3	20	6.947E-05
4	20	4.111E-05
5	20	-8.305E-06
6	20	-6.955E-05
7	20	-2.162E-04
8	20	-4.047E-04
9	20	-6.739E-04
10	20	-1.044E-03
11	20	-1.535E-03
12	20	-2.158E-03
13	20	-3.713E-03
14	20	-5.453E-03
15	20	-7.392E-03
16	20	-9.466E-03
17	20	-1.140E-02
18	20	-1.208E-02
19	20	-1.280E-02
20	20	-1.401E-02
21	20	-1.590E-02
22	20	-1.848E-02
23	20	-2.155E-02
24	20	-2.397E-02

DEFLECTIONS BETWEEN (17 , 0) AND (17 , 40)

X	Y	DEFLECTION
17	0	-1.009E-04
17	1	-7.697E-06
17	2	8.787E-05
17	3	1.882E-04
17	4	2.950E-04
17	5	4.079E-04
17	6	5.238E-04
17	7	6.350E-04
17	8	7.282E-04
17	9	4.180E-04
17	10	4.005E-05
17	11	-4.395E-04
17	12	-1.055E-03
17	13	-1.838E-03
17	14	-2.805E-03
17	15	-3.957E-03
17	16	-5.258E-03
17	17	-7.096E-03
17	18	-8.899E-03
17	19	-1.047E-02
17	20	-1.140E-02
17	21	-1.047E-02
17	22	-8.899E-03
17	23	-7.096E-03
17	24	-5.258E-03
17	25	-3.957E-03
17	26	-2.805E-03
17	27	-1.838E-03
17	28	-1.055E-03
17	29	-4.395E-04
17	30	4.005E-05
17	31	4.180E-04
17	32	7.282E-04
17	33	6.350E-04
17	34	5.238E-04
17	35	4.079E-04
17	36	2.950E-04
17	37	1.882E-04
17	38	8.787E-05
17	39	-7.697E-06
17	40	-1.009E-04

DEFLECTIONS BETWEEN (23 , 0) AND (23 , 40)

X	Y	DEFLECTION
23	0	-1.375E-04
23	1	-4.203E-05
23	2	5.413E-05
23	3	1.514E-04
23	4	2.493E-04
23	5	3.446E-04
23	6	4.302E-04
23	7	4.939E-04
23	8	5.169E-04
23	9	-1.417E-04
23	10	-9.284E-04
23	11	-1.908E-03
23	12	-3.142E-03
23	13	-4.681E-03
23	14	-6.553E-03
23	15	-8.744E-03
23	16	-1.118E-02
23	17	-1.447E-02
23	18	-1.761E-02
23	19	-2.020E-02
23	20	-2.155E-02
23	21	-2.020E-02
23	22	-1.761E-02
23	23	-1.447E-02
23	24	-1.118E-02
23	25	-8.744E-03
23	26	-6.553E-03
23	27	-4.681E-03
23	28	-3.142E-03
23	29	-1.908E-03
23	30	-9.284E-04
23	31	-1.417E-04
23	32	5.169E-04
23	33	4.939E-04
23	34	4.302E-04
23	35	3.446E-04
23	36	2.493E-04
23	37	1.514E-04
23	38	5.413E-05
23	39	-4.203E-05
23	40	-1.375E-04

SLAB X AND SLAB Y MOMENT BETWEEN (0 , 20) AND (24 , 20)

X	Y	SLAB X MOM	SLAB Y MOM
0	20	4.499E-12	-3.810E-01
1	20	-3.081E+00	6.048E-02
2	20	-7.900E+00	8.823E-01
3	20	-1.482E+01	2.015E+00
4	20	-2.419E+01	3.875E+00
5	20	-3.632E+01	7.056E+00
6	20	-5.133E+01	1.242E+01
7	20	-6.905E+01	2.124E+01
8	20	-8.866E+01	3.530E+01
9	20	-1.083E+02	5.717E+01
10	20	-1.243E+02	9.043E+01
11	20	-1.295E+02	1.399E+02
12	20	-1.103E+02	2.205E+02
13	20	-1.485E+02	3.580E+02
14	20	-1.204E+02	5.747E+02
15	20	2.649E+01	9.284E+02
16	20	4.690E+02	1.550E+03
17	20	2.023E+03	2.625E+03
18	20	2.849E+02	1.718E+03
19	20	-3.128E+02	1.305E+03
20	20	-5.490E+02	1.248E+03
21	20	-5.339E+02	1.507E+03
22	20	-1.329E+02	2.184E+03
23	20	1.474E+03	3.609E+03
24	20	-1.655E-10	1.587E+03

SLAB X AND SLAB Y MOMENT BETWEEN (17 , 0) AND (17 , 40)

X	Y	SLAB X MOM	SLAB Y MOM
17	0	-6.975E-01	2.302E-12
17	1	-1.897E+00	2.439E+00
17	2	-2.389E+00	5.180E+00
17	3	-3.195E+00	6.957E+00
17	4	-4.637E+00	6.418E+00
17	5	-7.031E+00	2.084E+00
17	6	-1.068E+01	-7.658E+00
17	7	-1.585E+01	-2.451E+01
17	8	-2.323E+01	-5.014E+01
17	9	-3.132E+01	-8.643E+01
17	10	-4.056E+01	-1.286E+02
17	11	-4.885E+01	-1.714E+02
17	12	-5.391E+01	-2.081E+02
17	13	-5.226E+01	-2.300E+02
17	14	-3.862E+01	-2.255E+02
17	15	-4.888E+00	-1.788E+02
17	16	6.374E+01	-6.481E+01
17	17	2.095E+02	8.409E+01
17	18	4.860E+02	3.731E+02
17	19	1.028E+03	9.560E+02
17	20	2.023E+03	2.625E+03
17	21	1.028E+03	9.560E+02
17	22	4.860E+02	3.731E+02
17	23	2.095E+02	8.409E+01
17	24	6.374E+01	-6.481E+01
17	25	-4.888E+00	-1.788E+02
17	26	-3.862E+01	-2.255E+02
17	27	-5.226E+01	-2.300E+02
17	28	-5.391E+01	-2.081E+02
17	29	-4.885E+01	-1.714E+02
17	30	-4.056E+01	-1.286E+02
17	31	-3.132E+01	-8.643E+01
17	32	-2.323E+01	-5.014E+01
17	33	-1.585E+01	-2.451E+01
17	34	-1.068E+01	-7.658E+00
17	35	-7.031E+00	2.084E+00
17	36	-4.637E+00	6.418E+00
17	37	-3.195E+00	6.957E+00
17	38	-2.389E+00	5.180E+00
17	39	-1.897E+00	2.439E+00
17	40	-6.975E-01	1.821E-12

SLAB X AND SLAB Y MOMENT BETWEEN (23 , 0) AND (23 , 40)

X	Y	SLAB X MOM	SLAB Y MOM
23	0	-1.341E+00	3.428E-12
23	1	-2.580E+00	2.506E-01
23	2	-2.795E+00	7.966E-01
23	3	-3.430E+00	-3.225E-02
23	4	-4.675E+00	-3.977E+00
23	5	-6.831E+00	-1.279E+01
23	6	-1.039E+01	-2.815E+01
23	7	-1.625E+01	-5.150E+01
23	8	-2.633E+01	-8.443E+01
23	9	-3.122E+01	-1.581E+02
23	10	-4.050E+01	-2.367E+02
23	11	-5.232E+01	-3.123E+02
23	12	-6.556E+01	-3.748E+02
23	13	-7.896E+01	-4.097E+02
23	14	-9.053E+01	-3.968E+02
23	15	-9.662E+01	-3.083E+02
23	16	-9.262E+01	-1.072E+02
23	17	-2.366E+01	1.747E+02
23	18	1.452E+02	6.832E+02
23	19	5.649E+02	1.573E+03
23	20	1.474E+03	3.509E+03
23	21	5.649E+02	1.573E+03
23	22	1.452E+02	6.832E+02
23	23	-2.366E+01	1.747E+02
23	24	-9.262E+01	-1.072E+02
23	25	-9.662E+01	-3.083E+02
23	26	-9.053E+01	-3.968E+02
23	27	-7.896E+01	-4.097E+02
23	28	-6.556E+01	-3.748E+02
23	29	-5.232E+01	-3.123E+02
23	30	-4.050E+01	-2.367E+02
23	31	-3.122E+01	-1.581E+02
23	32	-2.633E+01	-8.443E+01
23	33	-1.625E+01	-5.150E+01
23	34	-1.039E+01	-2.815E+01
23	35	-6.831E+00	-1.279E+01
23	36	-4.675E+00	-3.977E+00
23	37	-3.430E+00	-3.225E-02
23	38	-2.795E+00	7.966E-01
23	39	-2.580E+00	2.506E-01
23	40	-1.341E+00	1.501E-12

PRINCIPAL STRESS BETWEEN (0 , 20) AND (24 , 20)

X	Y	PRIN STRESS
0	20	-3.572E-02
1	20	-2.889E-01
2	20	-7.406E-01
3	20	-1.389E+00
4	20	-2.268E+00
5	20	-3.405E+00
6	20	-4.813E+00
7	20	-6.473E+00
8	20	-8.312E+00
9	20	-1.015E+01
10	20	-1.165E+01
11	20	1.311E+01
12	20	2.068E+01
13	20	3.356E+01
14	20	5.388E+01
15	20	8.704E+01
16	20	1.453E+02
17	20	2.461E+02
18	20	1.611E+02
19	20	1.223E+02
20	20	1.170E+02
21	20	1.413E+02
22	20	2.048E+02
23	20	3.289E+02
24	20	1.488E+02

PRINCIPAL STRESS BETWEEN (17 , 0) AND (17 , 40)

X ,	Y	PRIN STRESS
17	0	-1.659E-01
17	1	3.704E-01
17	2	5.977E-01
17	3	7.523E-01
17	4	6.989E-01
17	5	-7.604E-01
17	6	-1.138E+00
17	7	-2.306E+00
17	8	-6.150E+00
17	9	-1.128E+01
17	10	-1.528E+01
17	11	-1.969E+01
17	12	-2.383E+01
17	13	-2.686E+01
17	14	-2.762E+01
17	15	-2.455E+01
17	16	-1.732E+01
17	17	3.179E+01
17	18	5.473E+01
17	19	1.012E+02
17	20	2.461E+02
17	21	1.012E+02
17	22	5.473E+01
17	23	3.179E+01
17	24	-1.732E+01
17	25	-2.455E+01
17	26	-2.762E+01
17	27	-2.686E+01
17	28	-2.383E+01
17	29	-1.969E+01
17	30	-1.528E+01
17	31	-1.128E+01
17	32	-6.150E+00
17	33	-2.306E+00
17	34	-1.138E+00
17	35	-7.604E-01
17	36	6.989E-01
17	37	7.523E-01
17	38	5.977E-01
17	39	3.704E-01
17	40	-1.659E-01

PRINCIPAL STRESS BETWEEN (23 , 0) AND (23 , 40)

X ,	Y	PRIN STRESS
23	0	-1.410E-01
23	1	-3.180E-01
23	2	-4.267E-01
23	3	-6.486E-01
23	4	-1.099E+00
23	5	-1.973E+00
23	6	-3.489E+00
23	7	-5.808E+00
23	8	-9.884E+00
23	9	-1.732E+01
23	10	-2.502E+01
23	11	-3.297E+01
23	12	-4.028E+01
23	13	-4.588E+01
23	14	-4.841E+01
23	15	-4.629E+01
23	16	-4.127E+01
23	17	4.539E+01
23	18	8.315E+01
23	19	1.545E+02
23	20	3.289E+02
23	21	1.545E+02
23	22	8.315E+01
23	23	4.539E+01
23	24	-4.127E+01
23	25	-4.629E+01
23	26	-4.841E+01
23	27	-4.588E+01
23	28	-4.028E+01
23	29	-3.297E+01
23	30	-2.502E+01
23	31	-1.732E+01
23	32	-9.884E+00
23	33	-5.808E+00
23	34	-3.489E+00
23	35	-1.973E+00
23	36	-1.099E+00
23	37	-6.486E-01
23	38	-4.267E-01
23	39	-3.180E-01
23	40	-1.410E-01

TIME FOR THIS PROBLEM = 1 MINUTES 31.664 SECONDS

ELAPSED TIME = 1 MINUTES 58.321 SECONDS

PROGRAM SLAB 35 -DEVELOPMENT DECK- MATLOCK,PANAK, ENDRES REV DATE 13 JUN 71

THIS PROGRAM IS BEING USED AT YOUR OWN RISK.
CHANGES MAY OCCUR AFTER THE ABOVE REVISION DATE.
PLEASE REPORT DIFFICULTIES TO THE ABOVE PEOPLE
AT THE CENTER FOR HIGHWAY RESEARCH, UT AT AUSTIN.

ANALYSIS OF CONCRETE SHOULDERS ON CONTINUOUSLY REINFORCED PAVEMENT
PROJECT 56 SLAB APPLICATIONS___HARVEY J. TREYBIG

ELAPSED TIME = 1 MINUTES 58.338 SECONDS

KEEP RUN TIME RECORDS FOR FUTURE ESTIMATES OF PARENT AND OFFSPRING RUN TIMES

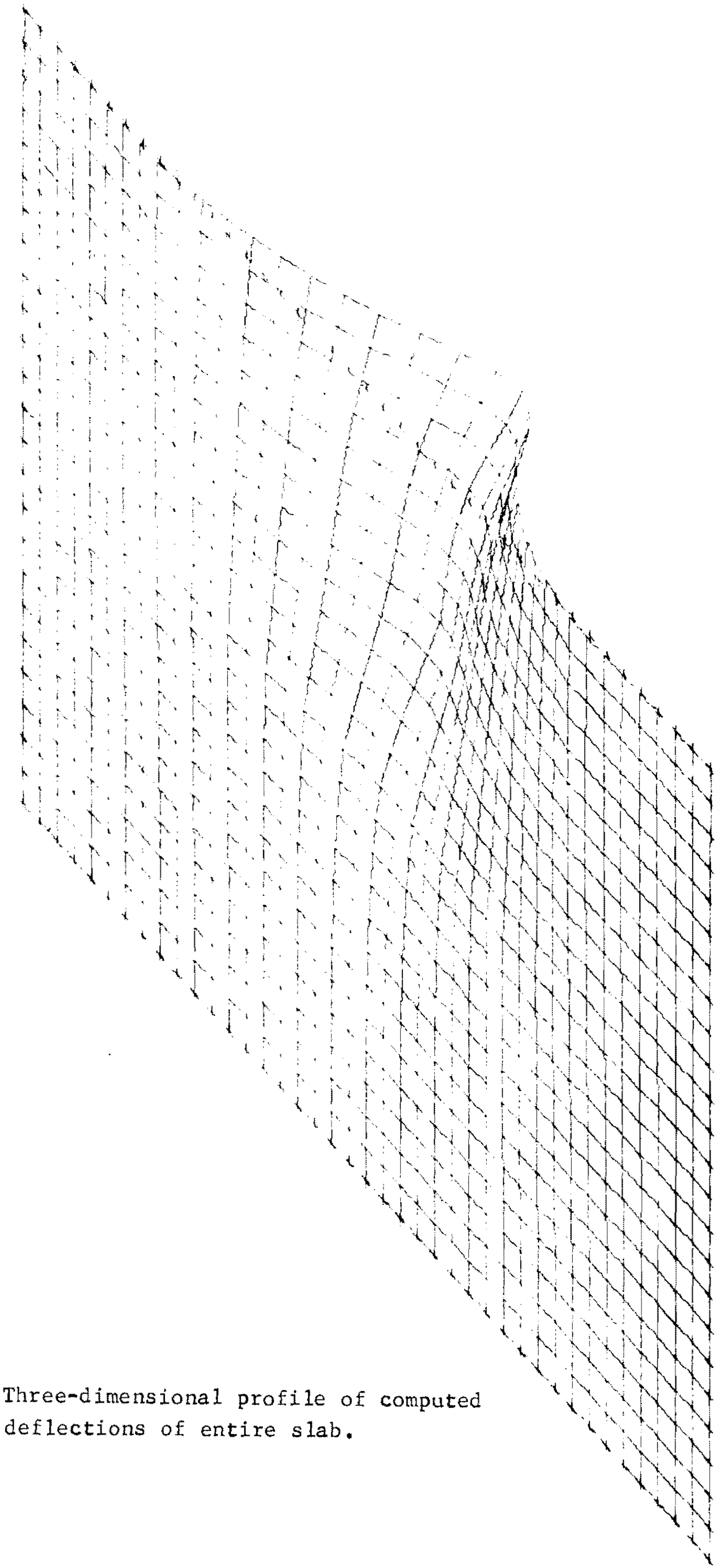

Fig C1. Three-dimensional profile of computed deflections of entire slab.

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