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Computer Program for Bridges on Flexible Bents

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COMPUTER PROGRAM FOR BRIDGES ON FLEXIBLE BENTS

by
C. S. LIN
and
A. C. SCORDELIS

Report to the Sponsors: Division of Highways, Department of Public Works, State of California, and the Bureau of Public Roads, Federal Highway Administration, United States Department of Transportation.

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Department of Civil Engineering
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Structural Mechanics

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COMPUTER PROGRAM FOR BRIDGES ON FLEXIBLE BENTS

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to

the Division of Highways
Department of Public Works
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ABSTRACT

A computer program is presented for the analysis of prismatic folded plate structures with flexible interior diaphragms or supports. The solution is based on a direct stiffness harmonic analysis incorporating a force method taking the interaction forces between the folded plates and diaphragms or support bents as redundants. The structure is considered as an assemblage of rectangular plate elements interconnected at longitudinal joints and simply supported at the two ends. The applied forces are resolved into Fourier series components. A direct stiffness analysis based on classical thin plate bending theory and plane stress elasticity theory is carried out for each harmonic. The interaction forces are determined by satisfying the required compatibility conditions. The final results are obtained by summing the solutions for the known loading and the redundant forces.

KEY WORDS

Computer program, continuous highway bridge, box-girder bridge, T-beam bridge, folded plates, flexible support bent, diaphragm, direct stiffness harmonic analysis, force method, plate bending theory, plane stress elasticity theory.

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1. INTRODUCTION

In California, multi-cell reinforced and prestressed concrete box girder bridges have been widely used both as simple span and continuous structures (Fig. 1). The typical cross-section of a concrete box girder bridge (Fig. 1c) consists of a top and bottom slab connected monolithically by vertical webs to form a cellular or box-like structure. Transverse diaphragms are placed at the end and interior support sections and in some cases, additional interior diaphragms are utilized between supports. Detailed information on research on box girder bridges conducted at the University of California, including listings of computer programs developed, may be found in a series of published research reports [1 - 9].

A computer program (called MUPDI) capable of analyzing open or cellular folded plate structures simply supported at the two ends and having up to four interior rigid diaphragms or supports between the two ends was developed by Lo and Scordelis in 1966 [1, 2]. The program presented in this report extends the original MUPDI program such that up to twelve interior diaphragms or supports may be used, and they need no longer be rigid. Diaphragms may be defined by flexible beams and supports may be defined by two dimensional planar frame bents. Options permit evaluation of internal forces in the bridge and the bent as well as the moment taken by each girder. The program is restricted to the analysis of prismatic structures which may have interior supports, but must be simply supported at the extreme ends. The material properties of each plate element making up the cross section are assumed to be isotropic, homogeneous and linearly elastic.

2. METHOD OF ANALYSIS

2.1 General Remarks

The prismatic folded plate structure is considered as an assemblage of rectangular plate elements interconnected at logitudinal joints and framed into transverse end diaphragms. The end diaphragms are assumed to be infinitely rigid in their own plane, but perfectly flexible normal to their own plane; therefore each individual rectangular plate may be treated as simply supported at the two ends. Such a structure can be efficiently analyzed by the direct stiffness harmonic analysis.

2.2 Solution for a Simply Supported Prismatic Folded Plate Structure

Because of the simple supports at the two ends of the structure, an analysis for applied loads with any arbitrary longitudinal distribution may be performed using a harmonic analysis. The applied forces are first resolved into Fourier series components. An analysis is carried out for all of the loading components of each particular harmonic and then the final results are obtained by summing the results for all of the harmonics used to represent the load. Once the solution technique, which involves extensive computations, has been developed for a single harmonic it can be reused for any harmonic, and thus the approach is ideally suited to the application of a digital computer.

The analysis for each harmonic load has the advantage that such loads will produce displacements of the same variation and vice versa and thus a single characteristic value may be used to describe any force or displacement pattern. For example the displacement pattern:

$$r(x) = r_o \sin \frac{n\pi x}{L}$$

may be described by the single value r_o. This makes it possible to treat an entire longitudinal joint as a single nodal point and to operate with single forces and displacements instead of functions. If the conditions of static equilibrium and geometric compatibility are maintained at a nodal point, they will automatically be satisfied along the entire longitudinal joint.

Each joint or nodal point has four degrees of freedom, it can displace vertically and horizontally in a plane parallel to the end diaphragms; it can move longitudinally parallel to the joint; and it can rotate about an axis parallel to the joint. These directions define a global coordinate system for displacements or forces at the joint (Fig. 2a).

The stresses and displacements in each plate element due to loads normal to the plate (slab action) are determined by classical thin plate bending theory, and those due to loads in the plane of the plate (membrane action) are determined by two dimensional plane stress elasticity theory.

The direct stiffness method has been described in detail in many publications [1,10,11] and thus need only be briefly outlined here by the following steps:

1. Determine the element stiffness matrix for each plate element in the local coordinate system (Fig. 2b).
2. Transform the element stiffness to a global coordinate system (Fig. 2c) and assemble these into the structure stiffness matrix K.

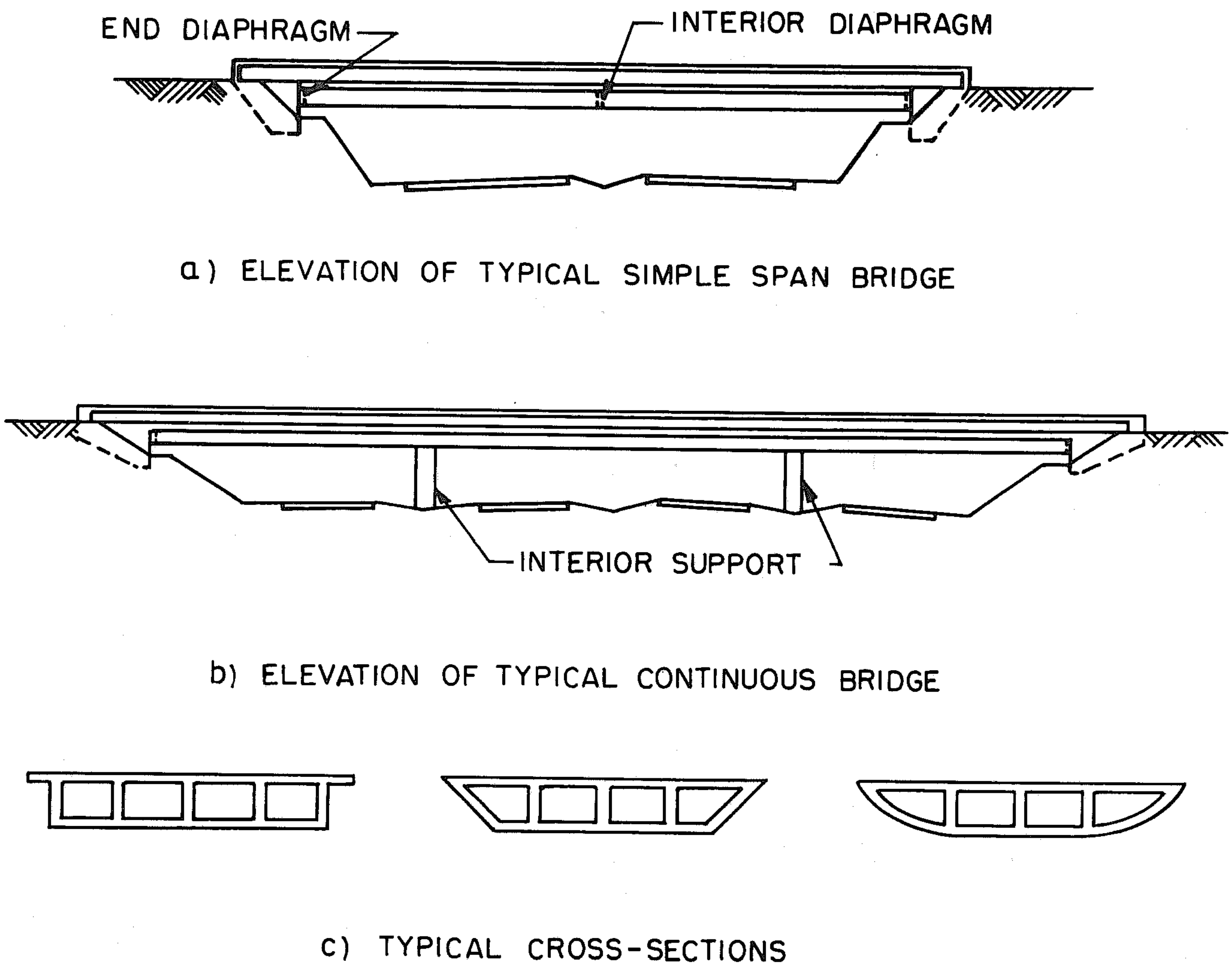


FIG. 1 MULTI-CELL BOX GIRDER BRIDGES

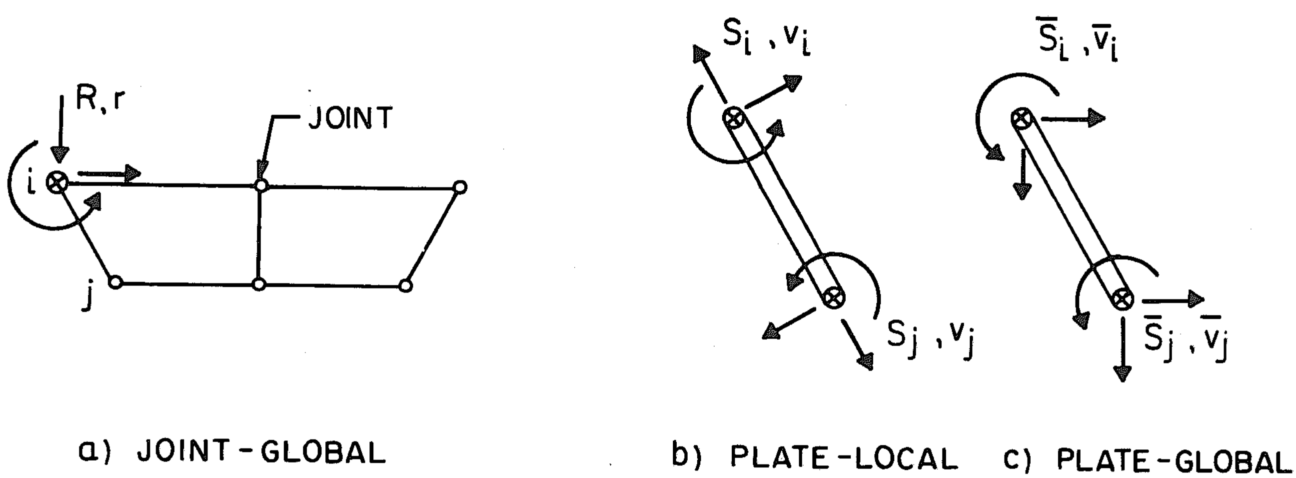


FIG. 2 JOINT AND PLATE EDGE FORCES AND DISPLACEMENTS IN GLOBAL AND LOCAL COORDINATE SYSTEMS

3. Solve the equilibrium equations R = Kr, where R represents the applied loads, for the unknown joint displacements r (Fig. 2a).
4. Determine the plate element internal forces and displacements by expressions relating these quantities to the joint displacements r.

Detailed derivations and necessary formulas for the preceding solution can be found in reference [10].

2.3 Solution for a Prismatic Folded Plate Structure Supported by Flexible Planar Frame Bents

A force method of analysis is used in which the redundants are taken as the interaction forces between the folded plates and the supporting frame bents (Fig. 3). The interaction forces are represented by a set of three joint forces at each longitudinal joint (Fig. 3d), consisting of vertical, horizontal and rotational components in the plane of transverse cross-section.

The analysis is carried out in the following sequence of steps:

1. With the redundants set equal to zero (Fig. 3b), the folded plate structure is analyzed under the given external load by means of the solution described in section 2.2. A displacement vector is found for this case which defines the displacements at the points where the redundants are to act.

$$\left\{ \delta \right\}_o = \begin{Bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_c \end{Bmatrix}_o \qquad (2.1)$$

2. The folded plate structure is then analyzed for unit values of each of the redundant forces X (Fig. 3c), and the corresponding flexibility matrix is formed.

$$\begin{Bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_c \end{Bmatrix}_1 = \begin{bmatrix} F_{11} & F_{12} & \cdots & F_{1c} \\ F_{21} & F_{22} & \cdots & F_{2c} \\ \vdots & \vdots & & \vdots \\ F_{c1} & F_{c2} & \cdots & F_{cc} \end{bmatrix}_1 \begin{Bmatrix} X_1 \\ X_2 \\ \vdots \\ X_c \end{Bmatrix}$$

or simply:

$$\{\delta\}_1 = [F]_1 \; \{X\} \qquad (2.2)$$

3. Each of the planar frame bents is analyzed by the direct stiffness method. The total structure stiffness for the frame bent is formed, then a static condensation is carried out to eliminate the degrees of freedom which do not correspond to the redundant forces. Finally the flexibility matrix of the frame bent corresponding to unit redundant forces is found by inverting the stiffness matrix.

$$\begin{Bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_c \end{Bmatrix}_2 = \begin{bmatrix} F_{11} & F_{12} & \cdots & F_{1c} \\ F_{21} & F_{22} & \cdots & F_{2c} \\ \vdots & \vdots & & \vdots \\ F_{c1} & F_{c2} & & F_{cc} \end{bmatrix}_2 \begin{Bmatrix} X_1 \\ X_2 \\ \vdots \\ X_c \end{Bmatrix}$$

or

$$\{\delta\}_2 = [F]_2 \; \{X\} \qquad (2.3)$$

4. Geometric compatibility requires that

$$\{\delta\}_o + [F]_1 \{X\} + [F]_2 \{X\} = 0$$

or

$$\{\delta\}_o + [F] \{X\} = 0 \tag{2.4}$$

where

$$[F] = [F]_1 + [F]_2$$

The redundants may be found from Eq. (2.4)

$$\{X\} = - [F]^{-1} \{\delta\}_o \tag{2.5}$$

5. The simply supported folded plate structure and the planar frame bent can now be analyzed, subjected to the known loading and the known redundant forces, to determine the final stresses and displacements in the actual structure.

It should be noted that the interior support bents are idealized as two-dimensional planar frames, thus they are assumed to be incapable of carrying loads normal to their own plane. As an illustration, the typical support bent consisting of a transverse girder (diaphragm) and a single column (Fig. 3d) is idealized as a planar frame with some ficticious vertical rigid links connecting the girder elastic axis to the joints of the folded plate system (Fig. 3e). In the execution of the solution, very high values of modulus of elasticity may be used for these ficticious elements to simulate rigid links.

2.4 Solution for a Prismatic Folded Plate Structure with Interior Flexible Diaphragms

Similar to the solution in section 2.3, the interaction forces between the folded plate structure and the diaphragms are taken as

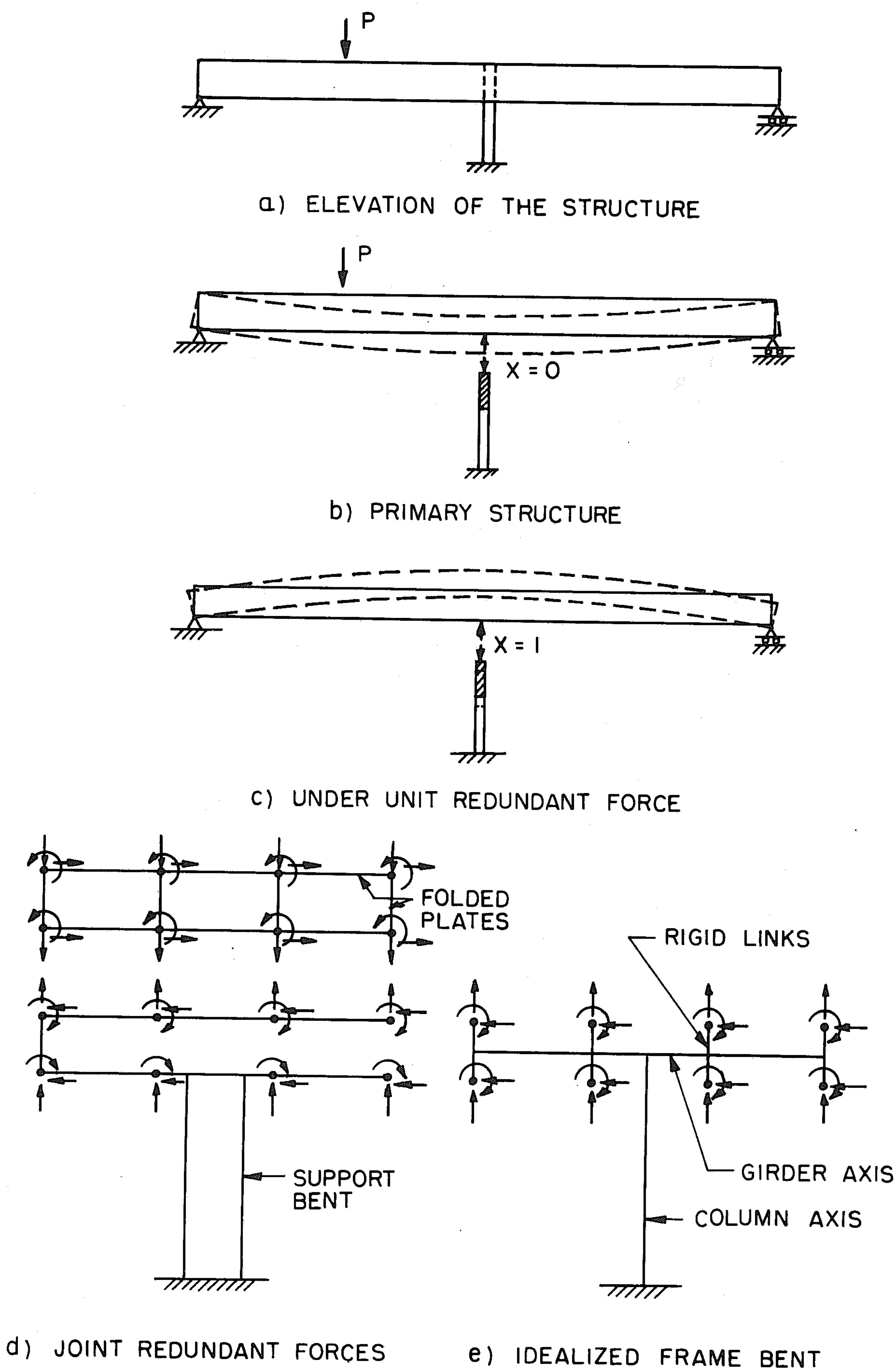


FIG. 3 ANALYSIS OF A FOLDED PLATE STRUCTURE ON A FLEXIBLE BENT

the redundants. Since the diaphragms are not externally supported, when subjected to interaction forces they can undergo three degrees of rigid body motion in their own plane in addition to the deformation of the diaphragms themselves. This condition requires that the interaction forces must be in self-equilibrium. The diaphragms are idealized as transverse beams in their own plane with zero stiffness normal to the plane. It is assumed that the diaphragms are connected to the folded plate structure at the joints only. For simplicity, a box girder bridge consisting of one diaphragm as shown in Fig. 4 is used for illustration. The procedure for solution is outlined below.

1. The primary folded plate structure which excludes the diaphragm is analyzed under the external loading. The joint displacements at the location of the diaphragm are calculated. A displacement vector similar to Eq. (2.1) can be written:

$$\{\delta\}_o = \begin{Bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_c \end{Bmatrix}_o \tag{2.6}$$

2. The flexibility matrix F_1 corresponding to the unit redundant forces acting on the primary structure at the location of the diaphragm is formed.

$$\begin{Bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_c \end{Bmatrix}_1 = \begin{bmatrix} F_{11} & F_{12} & \cdots & F_{1c} \\ F_{21} & & & \\ \vdots & & & \\ F_{c1} & & & F_{cc} \end{bmatrix}_1 \begin{Bmatrix} X_1 \\ X_2 \\ \vdots \\ X_c \end{Bmatrix}$$

or

$$\{\delta\}_1 = [F]_1 \{X\} \tag{2.7}$$

3. In order to satisfy the condition that the redundant joint forces must be in self-equilibrium, a new set of redundants is defined. Each redundant contains a set of self-equilibrating joint forces. The relation between the joint forces X and the new redundants $\overline{X}$ is defined by a force transformation matrix B.

$$\{X\} = [B] \{\overline{X}\} \tag{2.8}$$

The B matrix is formed by assuming the diaphragm is connected in a statically determinate manner to the folded state system, such as by a rigid connection having vertical, horizontal and rotational restraints at joint 7 (Fig. 5a). The interaction forces between the diaphragm and the folded plate at the remaining joints make up the new set of redundants. Applying each of these redundants $\overline{X}$ to the diaphragm alone (Fig. 5a), the necessary equilibrating support forces at joint 7 (Fig. 5c) are found and the resulting forces on the folded plate system (Fig. 5b) corresponding to the original X redundant system are found to form the B matrix.

Matrices B and $\overline{X}$ depend on how the diaphragm is assumed to be initially statically connected to the folded plate system. For example, the diaphragm could be assumed connected to the system by one pinned joint 2 (two restraints) and another roller joint 8 (one restraint) (Fig. 5a) rather than the fixed joint (three restraints) used above.

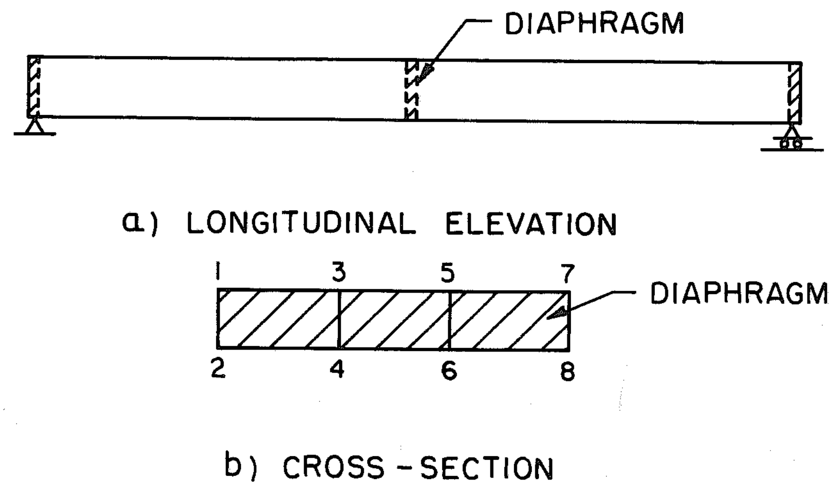


FIG. 4 CELLULAR SYSTEM WITH ONE DIAPHRAGM

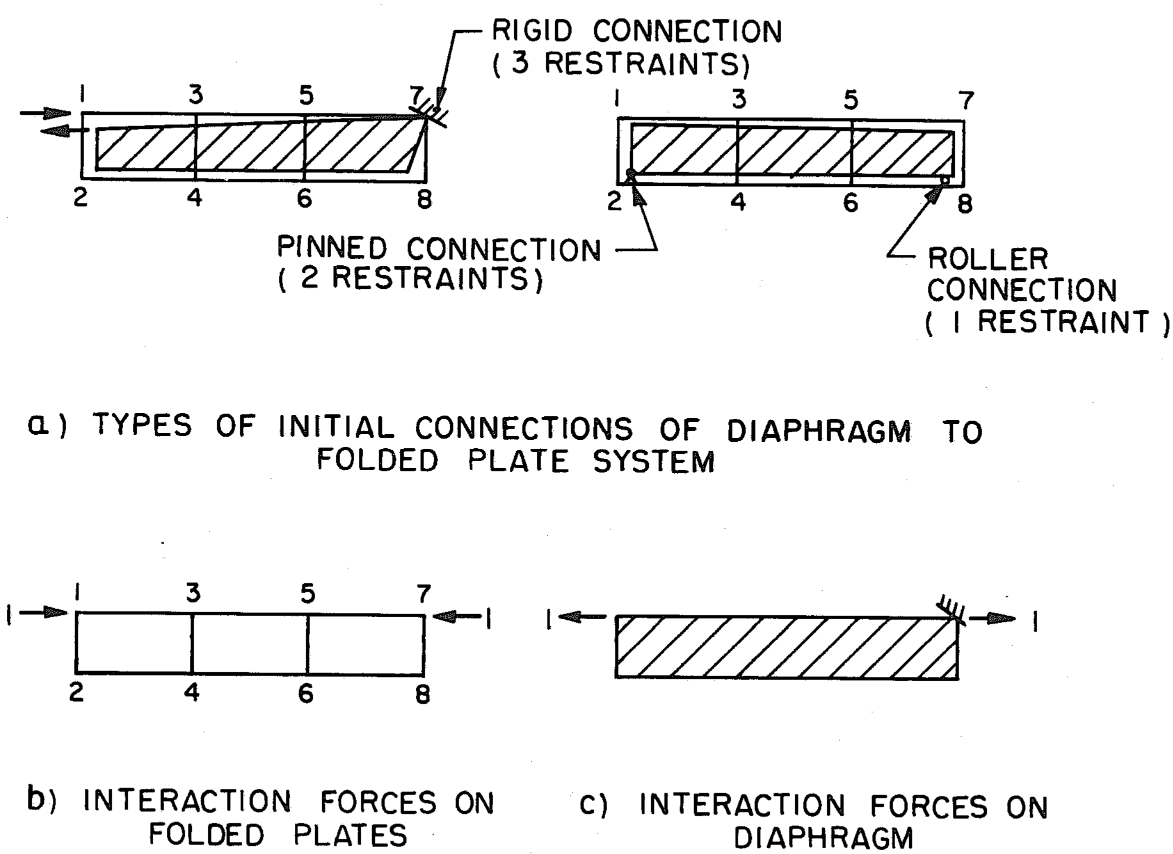


FIG. 5 INTERACTION BETWEEN DIAPHRAGM AND FOLDED PLATE SYSTEM

4. The transpose of the B matrix will also relate the relative displacements $\overline{\delta}$ between the diaphragm and the folded plate system, with the assumed initial connection, to the total or absolute displacements δ of the folded plate system.

$$\{\overline{\delta}\} = [B]^T \{\delta\} \quad (2.9)$$

$$\{\overline{\delta}\}_o = [B]^T \{\delta\}_o \quad (2.10)$$

$$\{\overline{\delta}\}_1 = [B]^T \{\delta\}_1 \quad (2.11)$$

5. Substituting Eqs. (2.7) and (2.8) into Eq. (2.11) yields

$$\{\overline{\delta}\}_1 = [B]^T [F]_1 [B] \{\overline{X}\}$$

$$= [\overline{F}]_1 \{\overline{X}\} \quad (2.12)$$

where $$[\overline{F}]_1 = [B]^T [F]_1 [B] \quad (2.13)$$

which is the modified flexibility matrix excluding the contribution due to the deformation of the diaphragm.

6. The flexibility matrix contributed by the deformation of the diaphragm may be formed by analyzing the diaphragm supported as it is initially connected to folded plate system. The disphragm may be idealized as an assemblage of simple beam elements (Fig. 6). Each beam element is defined by the properties along the elastic axis of the diaphragm. It is assumed that plane sections remain plane in defining displacements, at the interaction points at the top and bottom of the diaphragm (Fig. 6a). A force method of analysis is used to analyze this statically determinate system.

For each simple beam element (Fig. 6b), the following flexibility matrix is as given in the textbook by Przemieniecki [11].

$$\begin{Bmatrix} v_1 \\ v_2 \\ v_3 \end{Bmatrix} = \begin{bmatrix} \frac{L}{AE} & 0 & 0 \\ 0 & \frac{(4+\Phi)L}{12EI} & \frac{(2-\Phi)L}{12EI} \\ 0 & \frac{(2-\Phi)L}{12EI} & \frac{(4+\Phi)L}{12EI} \end{bmatrix} \begin{Bmatrix} s_1 \\ s_2 \\ s_3 \end{Bmatrix} \tag{2.14}$$

where

$$\Phi = \frac{12EI}{GA_s L^2} = 24(1+\nu) \frac{I}{A_s L^2}$$

or simply

$$\{v_p\} = \{f_p\} \{s_p\} \tag{2.15}$$

Assembling all the element flexibility matrices yields

$$\begin{Bmatrix} v_a \\ v_b \\ \vdots \\ v_i \end{Bmatrix} = \begin{bmatrix} f_a & & & \\ & f_b & & \\ & & \ddots & \\ & & & f_i \end{bmatrix} \begin{Bmatrix} s_a \\ s_b \\ \vdots \\ s_i \end{Bmatrix} \tag{2.16}$$

or

$$\{v\} = [f] \{s\} \tag{2.17}$$

Unit forces at the interaction points are successively applied (Fig. 6a) to form the force transformation matrix which relates the internal end forces of the beam elements and the interaction forces.

$$\{s\} = [b] \{\bar{X}\} \tag{2.18}$$

Then the relative displacements $\bar{\delta}_2$ between the diaphragm and the folded plate system due to the deformation of the diaphragm can be related to the internal displacements v using the principle of virtual work.

$$\{\bar{\delta}\}_2 = [b]^T \{v\} \tag{2.19}$$

Substituting Eqs. (2.17) and (2.18) into Eq. (2.19), gives

$$\{\bar{\delta}\}_2 = [b]^T [f] [b] \{\bar{x}\}$$

$$= [\bar{F}]_2 \{\bar{x}\} \tag{2.20}$$

where

$$[\bar{F}]_2 = [b]^T [f] [b] \tag{2.21}$$

7. Geometric compatability requires that relative displacement at the interaction points between the folded plate and the diaphragm, connected in the assumed statically determinate manner, must be equal to zero.

$$\{\bar{\delta}\} = \{\bar{\delta}\}_o + \{\bar{\delta}\}_1 + \{\bar{\delta}\}_2 = 0 \tag{2.22}$$

Substituting Eqs. (2.12) and (2.20) into Eq. (2.22), solve for $\bar{X}$.

$$\{\bar{\delta}\}_o + [\bar{F}]_1 \{\bar{X}\} + [\bar{F}]_2 \{\bar{X}\} = 0$$

or

$$\{\bar{\delta}\}_o + [\bar{F}] \{\bar{X}\} = 0 \tag{2.23}$$

where

$$[\bar{F}] = [\bar{F}]_1 + [\bar{F}]_2 \tag{2.24}$$

Therefore

$$\{\bar{X}\} = - [\bar{F}]^{-1} \{\bar{\delta}\}_o \tag{2.25}$$

The unknown joint interaction forces may be calculated from

Eq. (2.8)

$$\{X\} = [B]\ \{\overline{X}\} \tag{2.26}$$

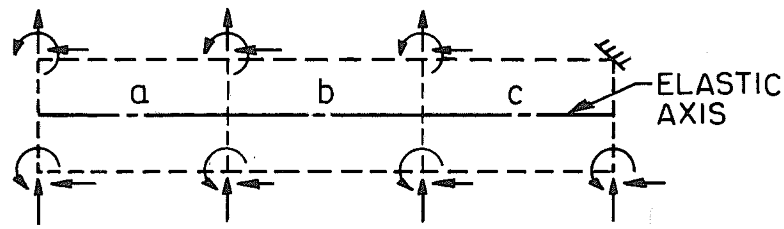
8. If there is more than one diaphragm and/or support bent in a structure, the procedure for analysis is essentially the same except the redundants at each diaphragm and support bent must be included. The procedure for analyzing a box girder bridge with two interior flexible diaphragms and one flexible support bent (Fig. 7) is outlined below for illustration purposes.

The displacement vector of the primary structure δ_o, the flexibility matrix, disregarding the deformation of the diaphragms and the bent F_1, and the force transformation matrix B may be partitioned as follows.

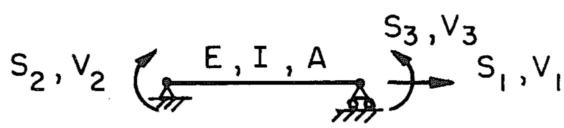
$$\{\delta\}_o = \begin{Bmatrix} \delta_I \\ \delta_{II} \\ \delta_{III} \end{Bmatrix}_o \tag{2.27}$$

$$[F]_1 = \begin{bmatrix} F_{I\ I} & F_{I\ II} & F_{I\ III} \\ F_{II\ I} & F_{II\ II} & F_{II\ III} \\ F_{III\ I} & F_{III\ II} & F_{III\ III} \end{bmatrix} \tag{2.28}$$

$$\begin{Bmatrix} X_I \\ X_{II} \\ X_{III} \end{Bmatrix} = \begin{bmatrix} B_I & 0 & 0 \\ 0 & B_{II} & 0 \\ 0 & 0 & B_{III} \end{bmatrix} \begin{Bmatrix} \overline{X}_I \\ \overline{X}_{II} \\ \overline{X}_{III} \end{Bmatrix} \tag{2.29}$$



a) IDEALIZED FLEXIBLE DIAPHRAGM



b) TYPICAL BEAM ELEMENT a , b OR c

FIG. 6 ANALYSIS OF THE FLEXIBLE DIAPHRAGM

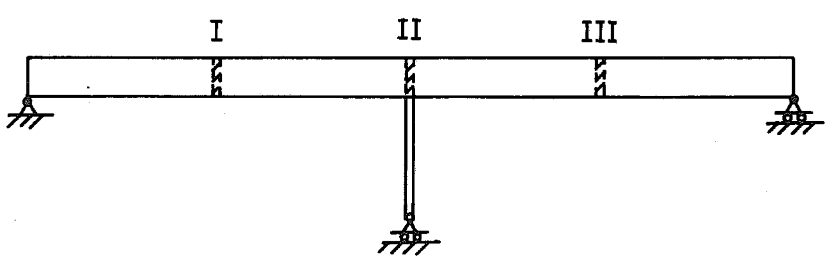


FIG. 7 BOX-GIRDER BRIDGE WITH TWO INTERIOR DIAPHRAGMS, I AND III, AND ONE SUPPORT BENT, II

where B_{II} is a unit matrix, since $X_{II} = \overline{X}_{II}$.

Then the tranformed displacement vector $\overline{\delta}_o$ and flexibility matrix $\overline{F}_1$ are found to be

$$\{\overline{\delta}\}_o = \begin{Bmatrix} \overline{\delta}_I \\ \overline{\delta}_{II} \\ \overline{\delta}_{III} \end{Bmatrix}_o \tag{2.30}$$

where $\overline{\delta}_N = B_N^T \delta_N$, for $N = I, II, III$

$$[\overline{F}]_1 = [B]^T [F]_1 [B] = \begin{bmatrix} \overline{F}_{I\,I} & \overline{F}_{I\,II} & \overline{F}_{I\,III} \\ \overline{F}_{II\,I} & \overline{F}_{II\,II} & \overline{F}_{II\,III} \\ \overline{F}_{III\,I} & \overline{F}_{III\,II} & \overline{F}_{III\,III} \end{bmatrix} \tag{2.31}$$

where $\overline{F}_{MN} = B_M^T \; F_{MN} \; B_N$ for $M, N = I, II, III$

Let $\overline{F}_I$, $\overline{F}_{III}$ denote the flexibility matrices of the diaphragms I and III, F_{II} the flexibility matrix of the support bent II. The total structural flexibility matrix including the contribution of the folded plate system, the flexible diaphragms and the flexible support bent becomes

$$[\overline{F}] = \begin{bmatrix} \overline{F}_{I\,I} + \overline{F}_I & \overline{F}_{I\,II} & \overline{F}_{I\,III} \\ \overline{F}_{II\,I} & \overline{F}_{II\,II} + F_{II} & \overline{F}_{II\,III} \\ \overline{F}_{III\,I} & \overline{F}_{III\,II} & \overline{F}_{III\,III} + \overline{F}_{III} \end{bmatrix} \tag{2.32}$$

The redundants may be found as

$$\{\overline{X}\} = - [\overline{F}]^{-1} \{\overline{\delta}\}_o \tag{2.33}$$

9. The final solution may be obtained by analyzing separately the simply supported folded plate structure, the planar frame bents and the diaphragms subjected to known external loading and redundant forces.

3. DESCRIPTION OF THE COMPUTER PROGRAM

3.1 Features of MUPDI3

MUPDI3 is an extended version of the original MUPDI program. The program was written in FORTRAN IV language and has been tested on the CDC 6400 computer at the University of California, Berkeley. It provides a rapid solution for a prismatic folded plate structure simply supported at the two ends and having up to 12 interior flexible diaphragms or flexible support bents. Besides this enhancement of the program's capability, the program also differs from MUPDI in the following respects.

1. Because of the increased storage requirement, an overlay system is adopted.

2. A girder moment integration option is added. If the structure (usually a box girder bridge) is divided into individual girders for design purposes, the moment taken by each individual girder may be calculated and printed out by this option.

3. In the MUPDI program the interactions between the diaphragms and the folded plate structure are idealized by concentrated forces at the joints and normal and in plane distributed forces for the plate elements. The interaction forces for the plate elements are not included in MUPDI3.

4. The initial connection between the interior diaphragm and the folded plate system is automatically generated internally in MUPDI3 program and thus need not be specified by the user.

5. MUPDI3 has an option for calculating internal forces and dislacements for the frame bents as well as the folded plate structure.

3.2 Structure, Storage Requirement and Flow Chart of the Program

The program consists of a main overlay and seven primary overlays. Each primary overlay consists of a group of subroutines. Their structure may be outlined as follows.

Main Overlay	Primary Overlay	Subroutines
Main Overlay (0,0) MUPDI3	Overlay (1,0)	Subroutines MAIN, KPLOAD, FIXFOR, SYMINV
	Overlay (2,0)	Subroutines FORMF, SIMSUM, CORF1
	Overlay (3,0)	Subroutines FRAME, ELSTIF, STIFF STACON, SYMINV
	Overlay (4,0)	Subroutine FLEXD
	Overlay (5,0)	Subroutines CORF2, ISIMEQ
	Overlay (6,0)	Subroutines EDGDIS, PLFOR, PINVAL, OPRINT, MOMPER, ADDM
	Overlay (7,0)	Subroutine FORCE

The main overlay remains in memory during execution while the seven primary overlays are called consecutively into memory by the main overlay. Loading of a primary overlay onto memory destroys the previously loaded primary overlay. The card decks of the overlays must be in strict order, however the order of the subroutines within each overlay is immaterial.

The field length required for running the program on the CDC 6400 computer at the University of California, Berkeley is $(110,000)_8 \approx (36,900)_{10}$. The storage allocation for each overlay may be tabulated as follows.

Overlays	Required Storage for the Overlay	Required Storage for the Execution*
OVERLAY (0,0)	$(23,521)_8$	
OVERLAY (1,0)	$(56,324)_8$	$(102,045)_8$
OVERLAY (2,0)	$(55,267)_8$	$(101,010)_8$
OVERLAY (3,0)	$(43,651)_8$	$(67,372)_8$
OVERLAY (4,0)	$(36,567)_8$	$(62,310)_8$
OVERLAY (5,0)	$(54,517)_8$	$(100,240)_8$
OVERLAY (6,0)	$(53,603)_8$	$(77,324)_8$
OVERLAY (7,0)	$(40,470)_8$	$(64,211)_8$

*Required Storage for the Execution = Required Storage for the Particular Overlay + Required Storage for OVERLAY (0,0).

Required Program Field Length = Max. (Required Storage for the Execution) + Field Length for Loader $= (110,000)_8$

A condensed flow chart and the brief descriptions of each primary overlay are presented in Figs. 8 and 9.

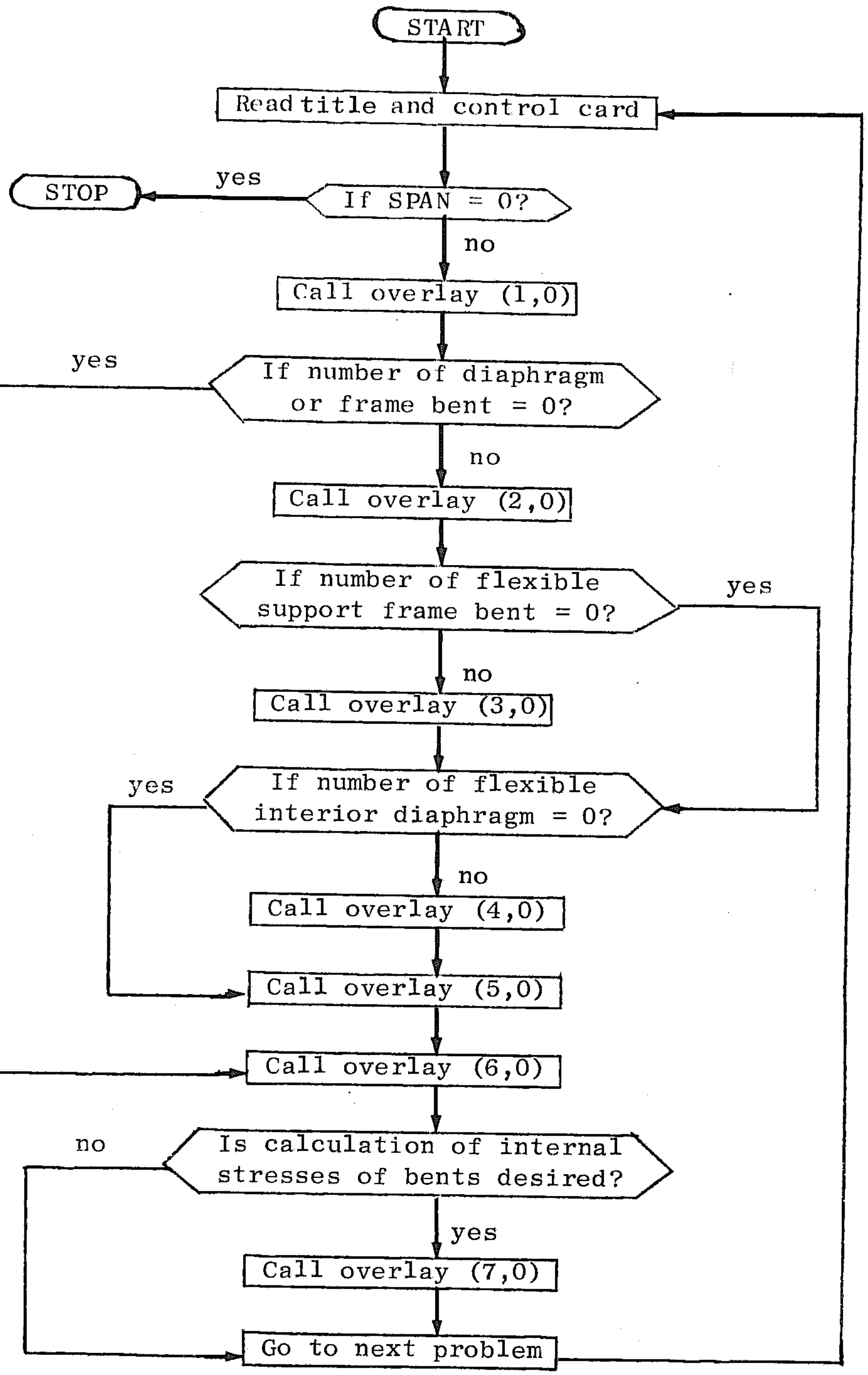


FIG. 8 FLOW CHART FOR MUPDI3

OVERLAY (1,0) -- Read and print input data. Resolve external load and unit interaction forces into harmonic components. Analyze the primary structure for each harmonic.

OVERLAY (2,0) -- Form the displacement vector δ_o, flexibility matrix F_1. Find the transformed $\overline{F}_1$ and $\overline{\delta}_o$ matrices.

OVERLAY (3,0) -- Analyze each type of frame bents by direct stiffness method. Form their flexibility matrices F_2.

OVERLAY (4,0) -- Form the flexibility matrix $\overline{F}_2$ for each type of flexible interior diaphragm.

OVERLAY (5,0) -- Form the total structure flexibility matrix by summing up the flexibility matrices. Solve for redundant forces.

OVERLAY (6,0) -- Calculate and print final joint displacements and internal forces for each plate element. Calculate the girder moments by integrating the stresses.

OVERLAY (7,0) -- Calculate the joint displacements, member end forces and support reactions for the frame bents.

FIG. 9 DESCRIPTION OF THE PRIMARY OVERLAYS

4. COMPUTER PROGRAM USAGE

4.1 Capabilities and Restrictions

The program provides a rapid solution for prismatic folded plate structures simply supported at the two ends having up to 12 interior diaphragms or supports. The diaphragms and supports may be either rigid or flexible. Diaphragms may be defined by flexible beams and supports may be defined by two dimensional planar frame bents. The number of interior diaphragms or supports is further restricted by the number of interaction forces which is limited to 120. Uniform or partial surface loads as well as line loads and concentrated loads may be applied anywhere on the folded plate structure.

Restrictions as to the maximum number of plates, joint, diaphragms, terms of Fourier series, type of frame bents etc. are given under input data in Appendix A.

4.2 Input and Output

Detailed descriptions of the input, output, and sign conventions are given in Appendix A. A brief description is given below.

The required input data includes:

(1) The geometry and dimensions of the structure in terms of the number of plates, joints, diaphragms, supporting frame bents, etc.

(2) Dimensions and material properties for each plate element.

(3) Magnitudes and locations of uniform and partial surface loads.

(4) Boundary conditions at the longitudinal joints. Any combination of known forces and given zero displacements may be used.

(5) Magnitudes and locations of additional concentrated joint loads.

(6) Location and interaction thickness of each diaphragm or bent, and indices for restraint conditions on each joint.

(7) Geometry, dimensions and material properties of each diaphragm or frame bent.

(8) Desired locations for final results in output.

(9) Neutral axis and division of the cross section into girders for the calculation of girder moments.

The output consists of:

(1) The complete input data is properly labelled and printed as a check.

(2) The interaction joint forces between the diaphragms or bents and the folded plate system are printed.

(3) Resulting joint displacements are given at specified locations.

(4) For each element all internal forces and displacements are printed for each transverse section specified across the plate width and at the x-coordinates specified along the plate length.

(5) Moment taken by each girder at the specified cross sections.

(6) For each flexible supporting frame bent the joint displacements, member end forces, applied joint loads and reactions are printed.

4.3 Special Considerations for the Use of MUPDI3

If the structure is symmetrical in the longitudinal direction about a transverse plane, a great saving in computing effort may be achieved by taking advantage of the symmetry or anti-symmetry of the loading with respect to this transverse plane, if it exists. For the case of a symmetrical structure subjected to symmetrical loading (Fig. 10a), only the odd terms of the Fourier series have to be included. For anti-symmetrical loading (Fig. 10b), only the even terms have to be included. This can be accomplished by giving the proper instruction on the control card. It should be noted that the loading includes the external loads as well as the redundant forces from each diaphragm or bent applied individually. Advantage of symmetrical loading can be taken in a case with one center bent or diaphragm (Fig. 10a). However, no advantage of symmetrical loading may be taken for spans with more than one disphragm or bent. Advantage of anti-symmetrical loading may be taken only in cases of simple spans with no intermediate diaphragms or bents (Fig. 10b).

If the cross section of the structure is symmetrical about a longitudinal plane, advantage of symmetry or anti-symmetry of the loading with respect to this plane may be taken by analyzing only half of the cross section and imposing proper boundary conditions at the longitudinal plane of symmetry. This is illustrated in Fig. 11.

The Fourier series expansion for a concentrated load at a point does not converge (Fig. 12c). However, output quantities such as displacements and membrane forces do converge but the longitudinal and transverse plate moments in the vicinity of the concentrated load converge very slowly or in some cases not at all. The analysis of spans with diaphragms or supports always involves expanding the inter-

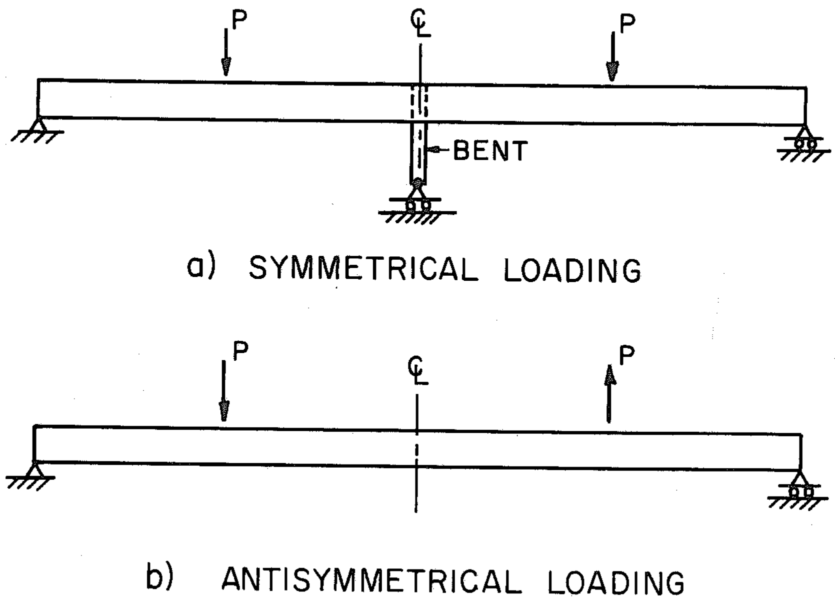


FIG. 10 LONGITUDINAL SYMMETRY AND ANTISYMMETRY

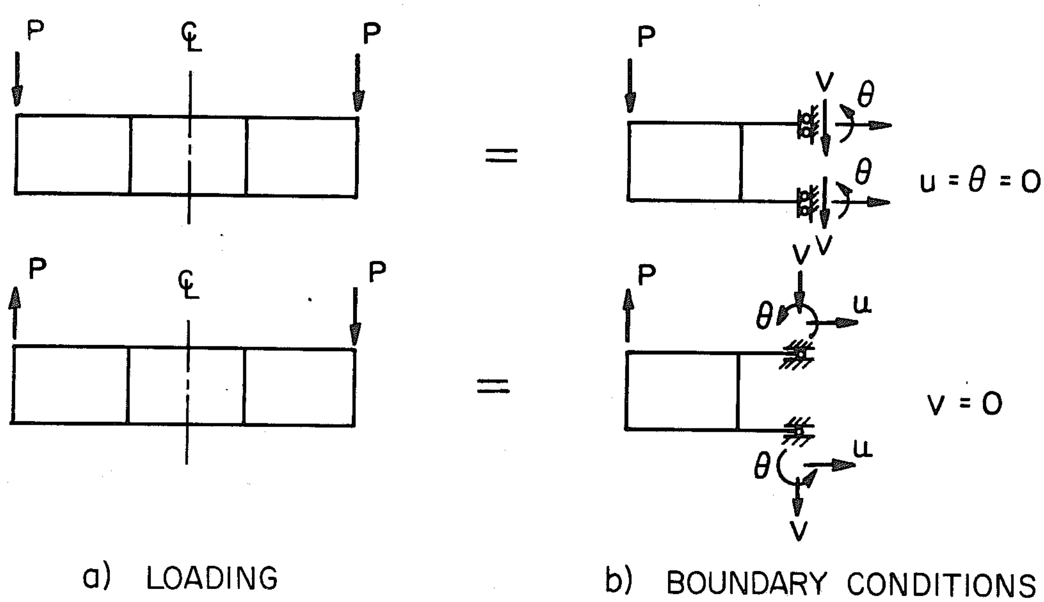


FIG. 11 TRANSVERSE SYMMETRY AND ANTISYMMETRY

action forces, acting over very narrow widths (Fig. 12b), in Fourier series. Therefore, it is advisable to specify a relatively high number for the maximum Fourier series limit. For design purposes, at least 80 (or 40 nonzero terms in symmetrical cases) should be adopted. A convergence study, in which the problem is run completely two or more times using successively an increasing number of harmonics, is recommended whenever detailed information is desired on internal forces and moments in the vicinity of concentrated external loads or interaction redundant forces.

The folded plate system and frame bent are assumed to interact only at discrete points. If the bents are connected continuously to the folded plates, some averaging process has to be used to obtain an appropriate interpretation of the internal forces and moments in the frame bents. This will be illustrated in Example 5.

Although the program does not give the internal forces in the flexible movable diaphragms, it outputs the interaction forces. The internal forces may be easily calculated by analyzing these diaphragms as beams subjected to the interaction forces, which is a statically determinate problem.

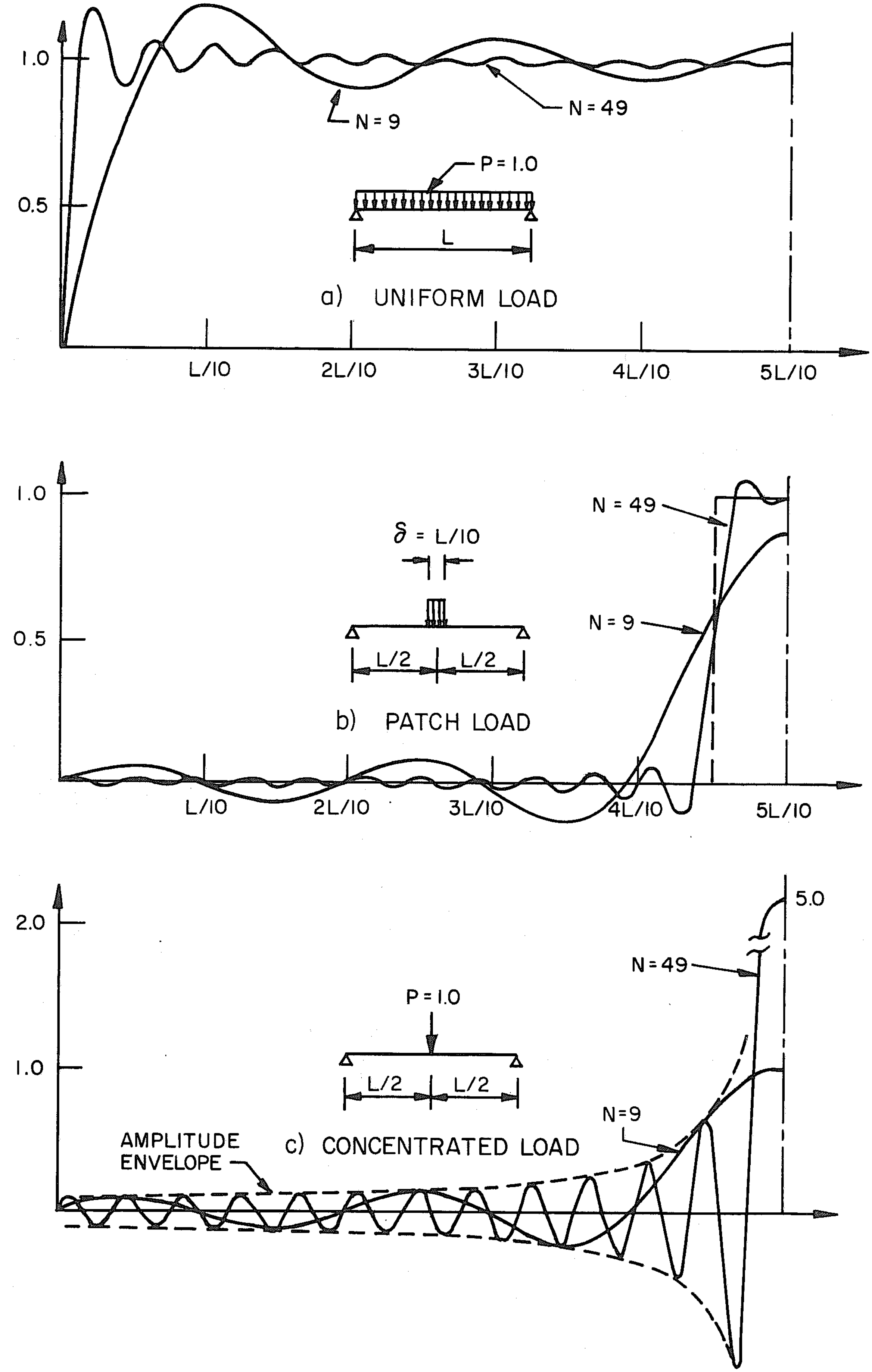


FIG. 12 FOURIER REPRESENTATION OF COMMON LOADING TYPES

5. EXAMPLES

5.1 General Remarks

Five examples have been chosen to verify the solution and to demonstrate the capabilities as well as the limitations of the method of analysis. Examples 1 and 2, dealing with the analysis of a continuous beam and a continuous slab respectively, serve to verify the solution. In these examples results are compared with solutions obtained from beam theory which may be considered exact for the purpose of comparison.

Example 3, involving the analysis of continuous slabs having rigid or flexible diaphragms or supporting bents, is intended to illustrate the effects of the flexibility of the diaphragms and bents. These effects are further illustrated in Example 4 which analyzes a continuous T-beam bridge with supporting bents of various flexibilities. The significance of neglecting the longitudinal restraint from the bents is also studied in Example 4.

In Example 5 a four cell, two span continuous box girder bridge is analyzed to demonstrate the practical application of the MUPDI3 program. It shows that a complete analysis giving the internal distribution of displacements, forces and moments in the bridge and the bents may be achieved by the application of the program.

100 harmonics are used in all the examples, and unless otherwise specified a modulus of elasticity of 432,000 ksf is adopted. Poisson's ratio is set equal to zero for Examples 1, 2 and 3; 0.17 for Examples 4, and 0.15 for Example 5.

5.2 Example 1 - Continuous Beam

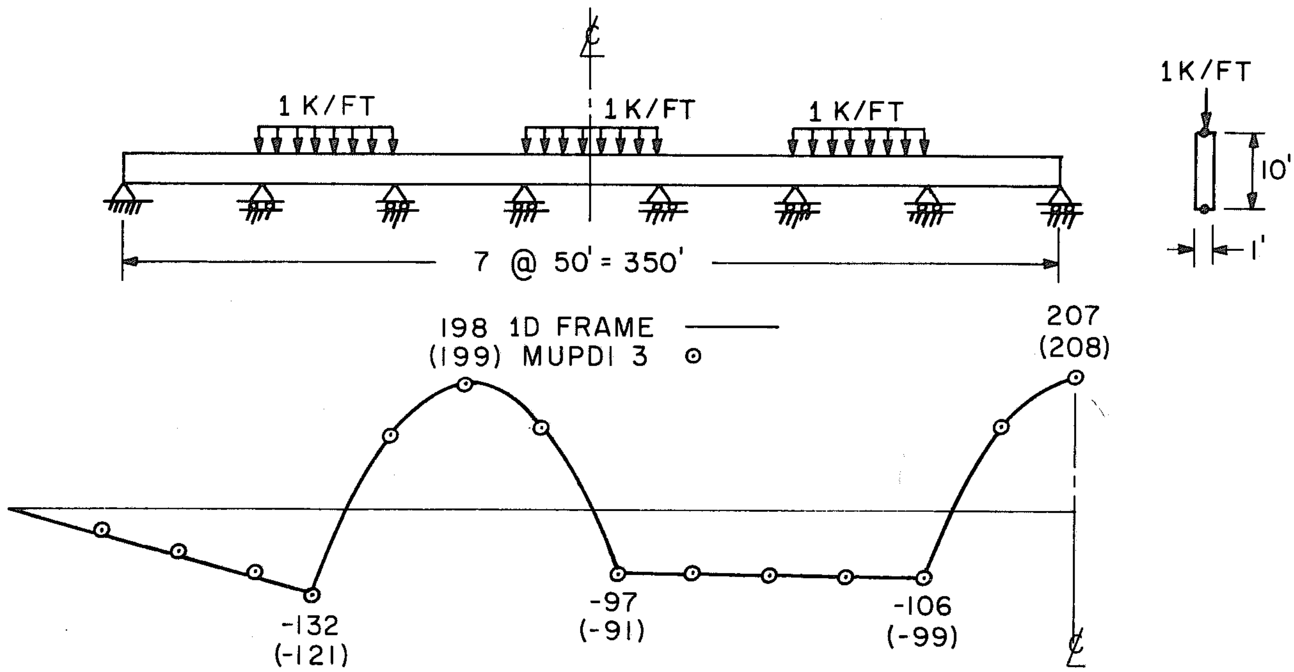
A continuous beam, having seven 50 ft spans and a cross-section 1 ft wide by 10 ft deep, is analyzed under two loading conditions:

Example 1A: 1 kip per ft uniformly distributed loads in three alternate spans;

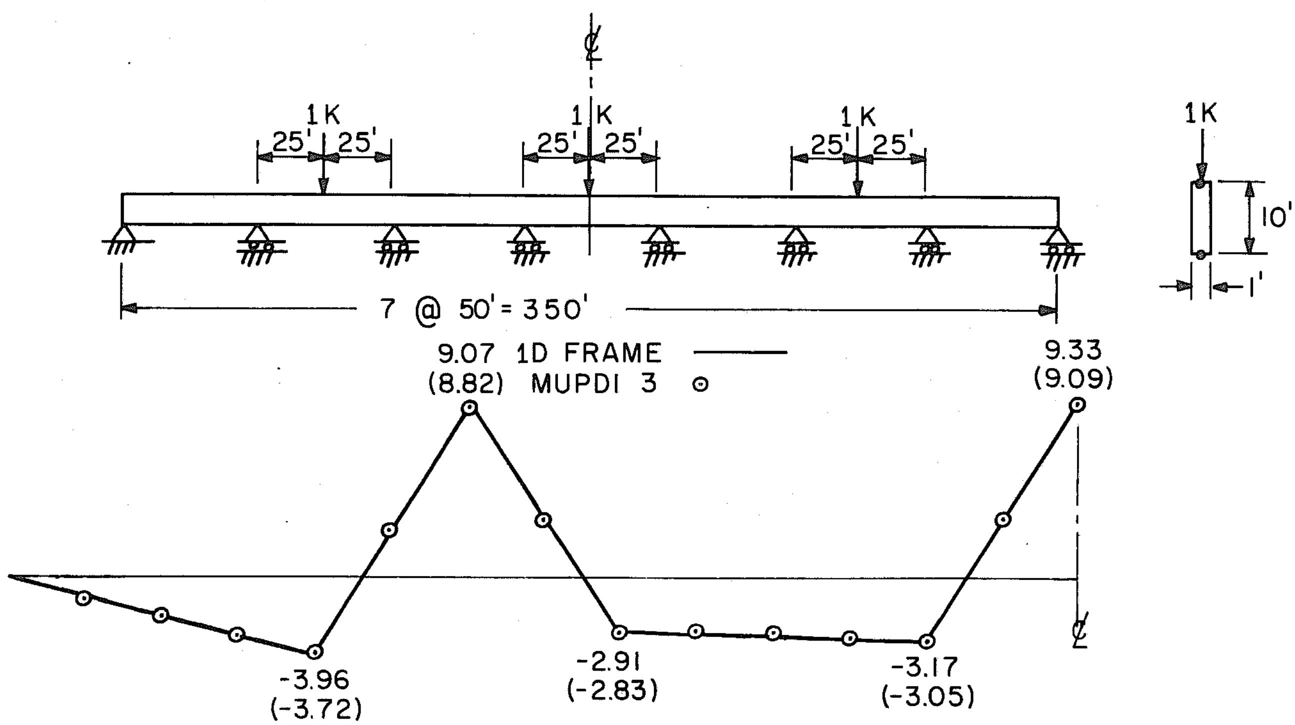
Example 1B: 1 kip concentrated loads at the centers of three alternate spans.

Details of the dimensions and loadings of the structure are shown in Fig. 13. In MUPDI3 the problem is treated as a plane stress problem with one element having nodes at the top and bottom of the beam section. The reaction forces at each intermediate support are assumed to be distributed uniformly over a one ft length in the longitudinal direction.

The resulting distributions of total section moments along the spans, found automatically in MUPDI3 by integrating the stresses at the specified sections, are compared with results from a solution by a 1DFRAME program which assumes each member as a one-dimensional element, and thus analyzes the structure by ordinary beam theory. Stresses found by MUPDI3 are somewhat non-linear over the depth and thus 13 points over the depth were used in the integration process to find the section moments. The comparison (Fig. 13) shows excellent agreement between these two solutions except in the vicinities of the concentrated loads or the intermediate supports, where the MUPDI3 solution always gives smaller moments than 1DFRAME. The deviation is due to the rounding effect of expanding a concentrated force or a distributed force over a very narrow width into a Fourier series, as pointed out in Section 4.3.



a) EXAMPLE 1A – DIMENSIONS, LOADING & MOMENTS (FT-KIPS)



b) EXAMPLE 1B – DIMENSIONS, LOADING & MOMENTS (FT-KIPS)

FIG. 13 EXAMPLE 1 –– CONTINUOUS BEAM

5.3 Example 2 - Continuous Slab

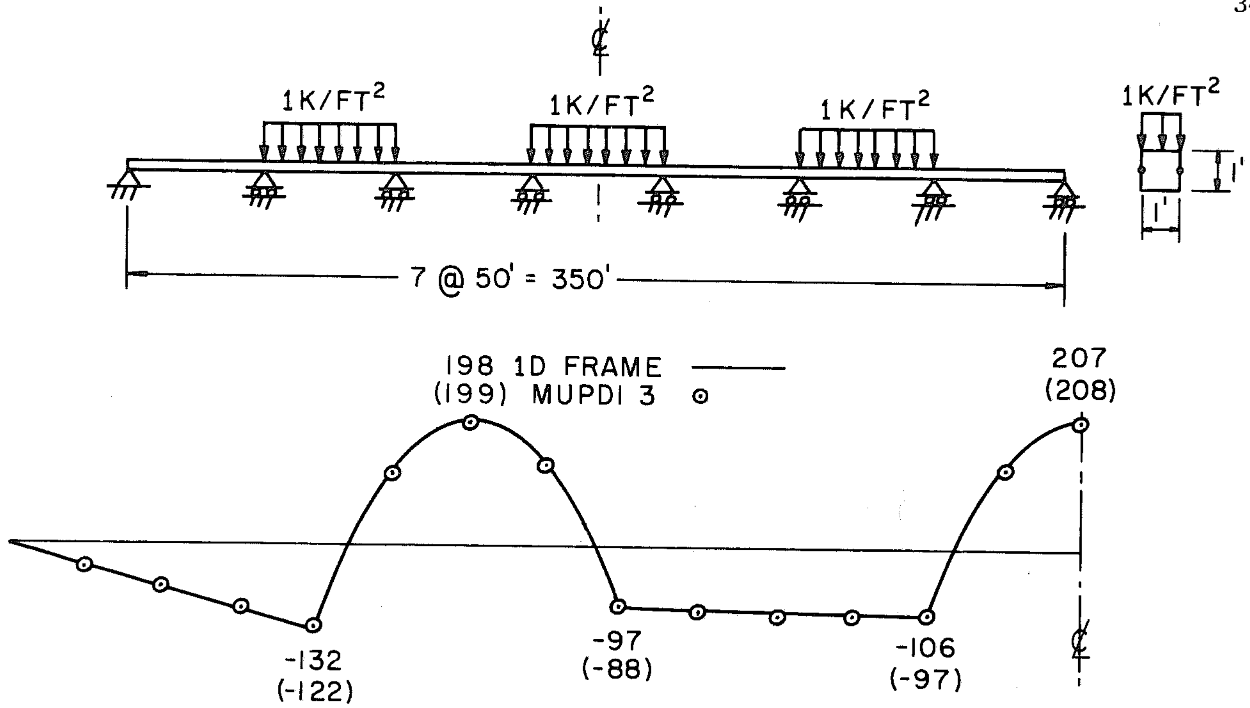
Similar to Example 1, a continuous slab, having seven 50 ft spans and a cross-section 1 ft thick by 1 ft wide, is analyzed under the following two loading conditions:

Example 2A: 1 kip per sq ft uniformly distributed loads in three alternate spans;

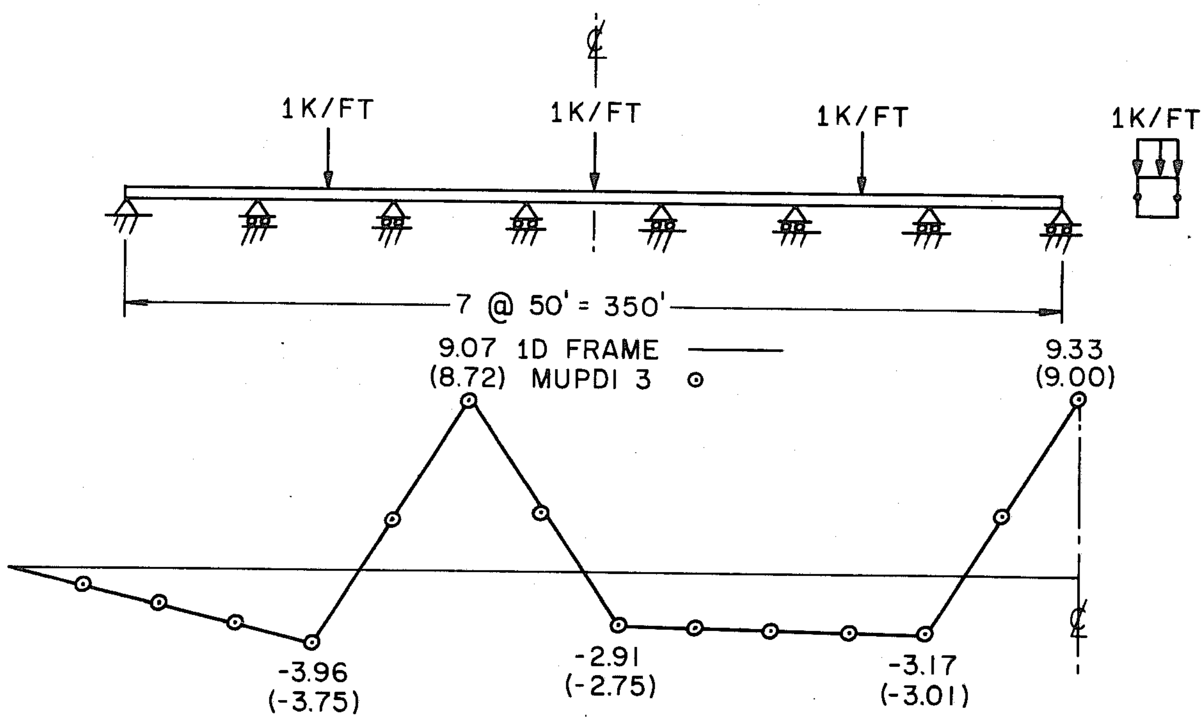
Example 2B: 1 kip per ft line loads at the centers of three alternate spans.

Refer to Fig. 14 for details of the dimensions and loadings. In MUPDI3 the problem is treated as a plate bending problem with one element, having nodes at the left and right edges of the slab cross-section. The reaction forces at each intermediate support are assumed to act over a length of one ft in the longitudinal direction. Section moments were found in MUPDI3 by integrating values at five points over the width of the section.

Similar conclusions to those in Example 1 can be drawn by comparing the resulting distributions of total section moments in the longitudinal direction, found automatically in MUPDI3 by integrating the plate bending moments over the slab width, with the 1DFRAME solution based on ordinary beam theory. Namely, except for the deviation due to the rounding effect of the Fourier series expansion, excellent overall agreement is found. MUPDI3 always gives smaller moments than 1DFRAME in the vicinities of line loads and the intermediate supports.



a) EXAMPLE 2A – DIMENSIONS, LOADING & MOMENTS (FT-KIPS)



b) EXAMPLE 1B – DIMENSIONS, LOADING & MOMENTS (FT-KIPS)

FIG. 14 EXAMPLE 2 — CONTINUOUS SLAB

5.4 Example 3 - Continuous Slab with Rigid or Flexible Diaphragms and Support Bents

A continuous slab, having five 50 ft spans and a cross-section 1 ft thick and 10 ft wide, is analyzed under two loading conditions and with rigid or flexible midspan diaphragms and support bents (Fig. 15). The load cases can be summarized as follows:

1. Center loads at the middles of three alternate spans (Fig. 15d) with two different diaphragm and support conditions:

   Example 3A: Rigid diaphragms and support bents;

   Example 3B: Flexible diaphragms and support bents.

2. Eccentric loads at the middles of three alternate spans (Fig. 15e) with two different diaphragm and support conditions:

   Example 3C: Rigid diaphragms and support bents;

   Example 3D: Flexible diaphragms and support bents.

Each of the flexible support bents consists of two vertical columns and one transverse girder, all with square cross-sections 2 ft by 2 ft (Fig. 15b). The flexible midspan diaphragms are 1 ft thick and 2 ft deep with the neutral axes coinciding with the middle surface of the slab (Fig. 15c). The cross-section of the continuous slab is divided into four equal plate elements. Only vertical interaction forces between the slab and the diaphragms or bents are specified in the solution at the five nodal points on the slab cross-section.

Results for the total section moments, vertical deflections and transverse moments at two typical cross-sections are shown in Figs. 16

and 17. The comparison indicates that for this particular example, the flexibility of the diaphragms and bents virtually has no effect on the total section moments and the vertical deflections. However, the distribution of the transverse slab moments is significantly altered by the flexibility of the diaphragms and the support bents.

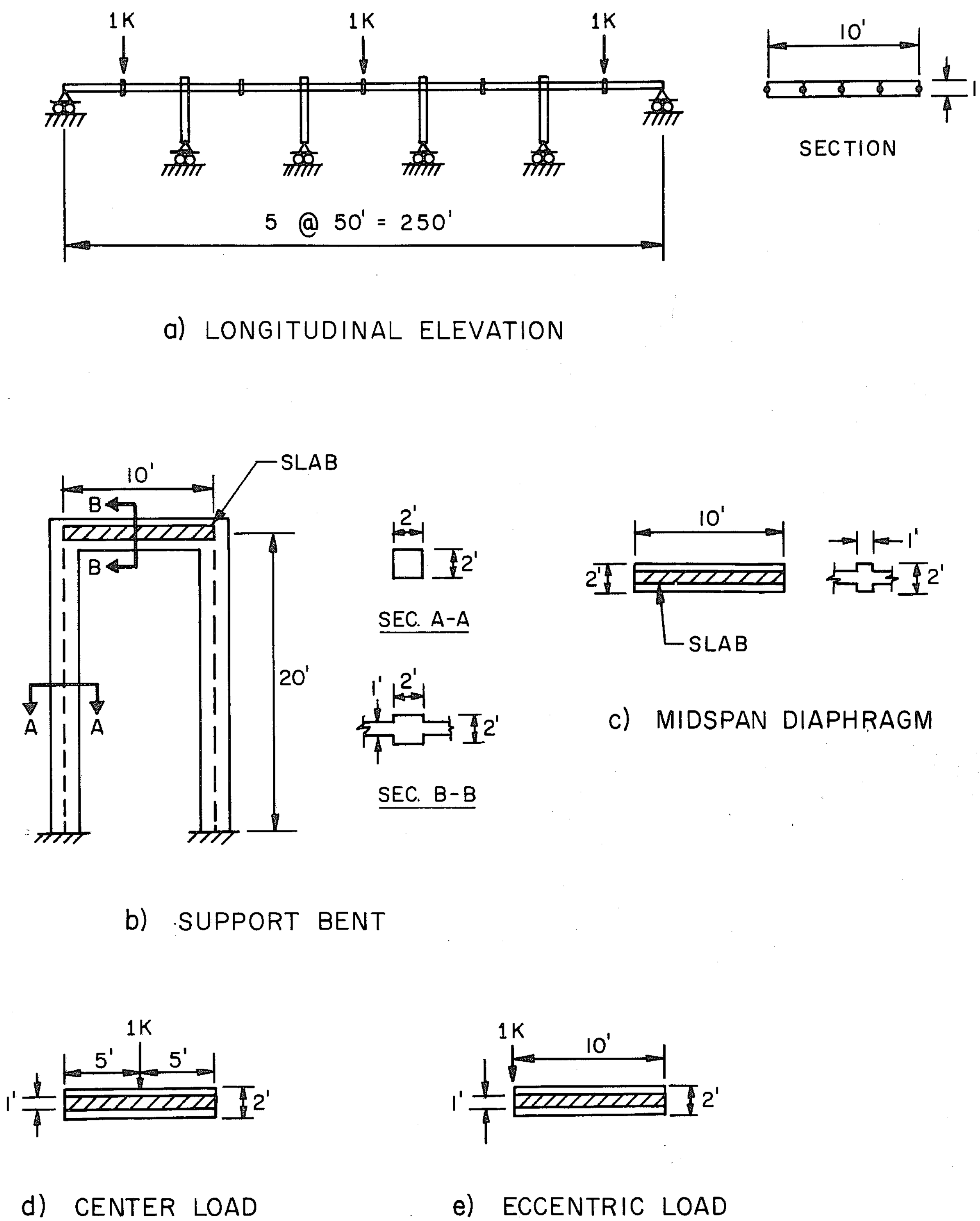
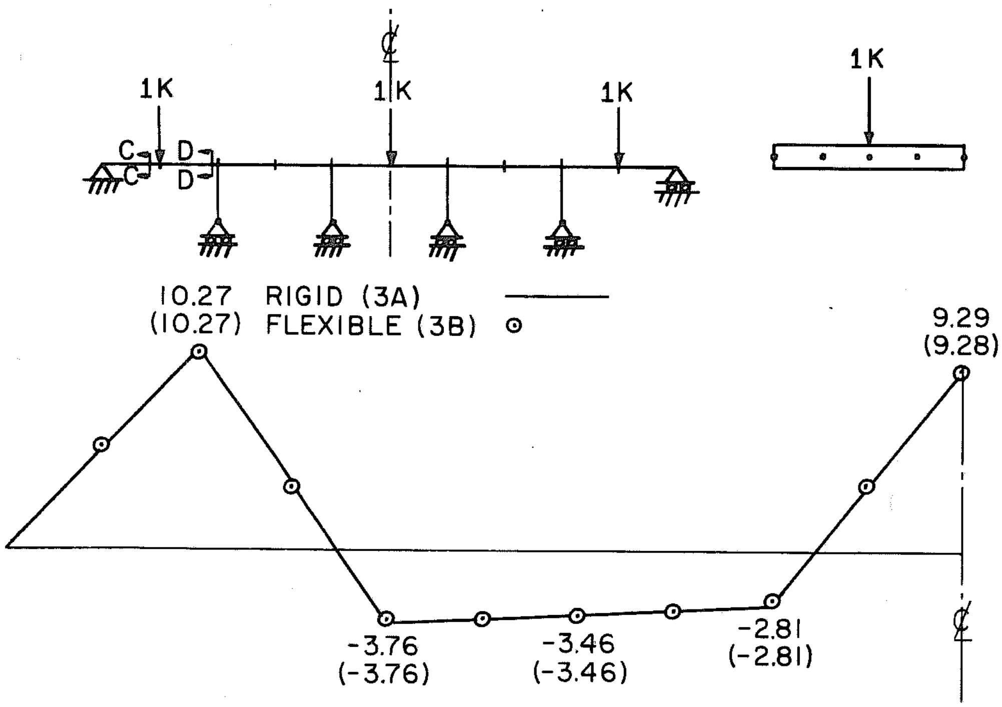
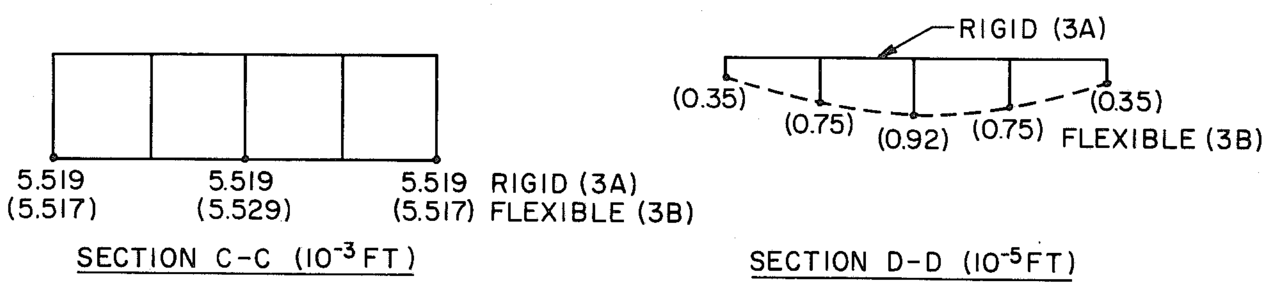


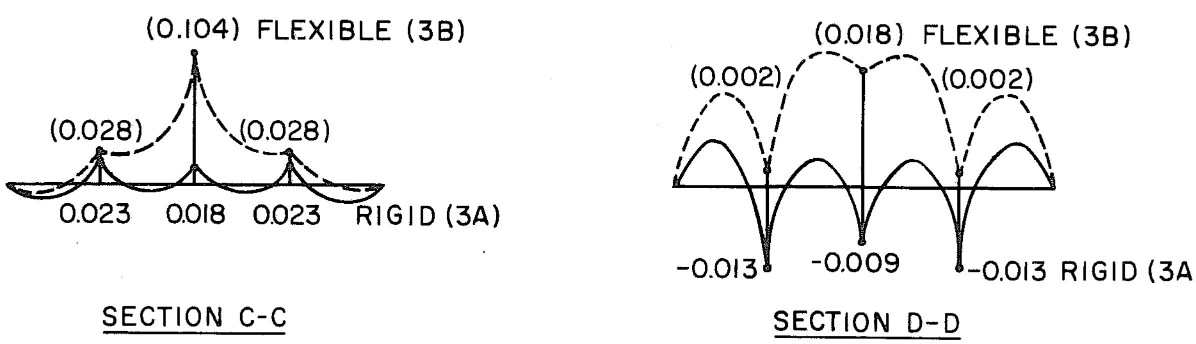
FIG. 15 EXAMPLE 3 — CONTINUOUS SLAB WITH RIGID OR FLEXIBLE DIAPHRAGMS AND SUPPORT BENTS



a) LOADING AND TOTAL SECTION MOMENTS (FT-KIPS)

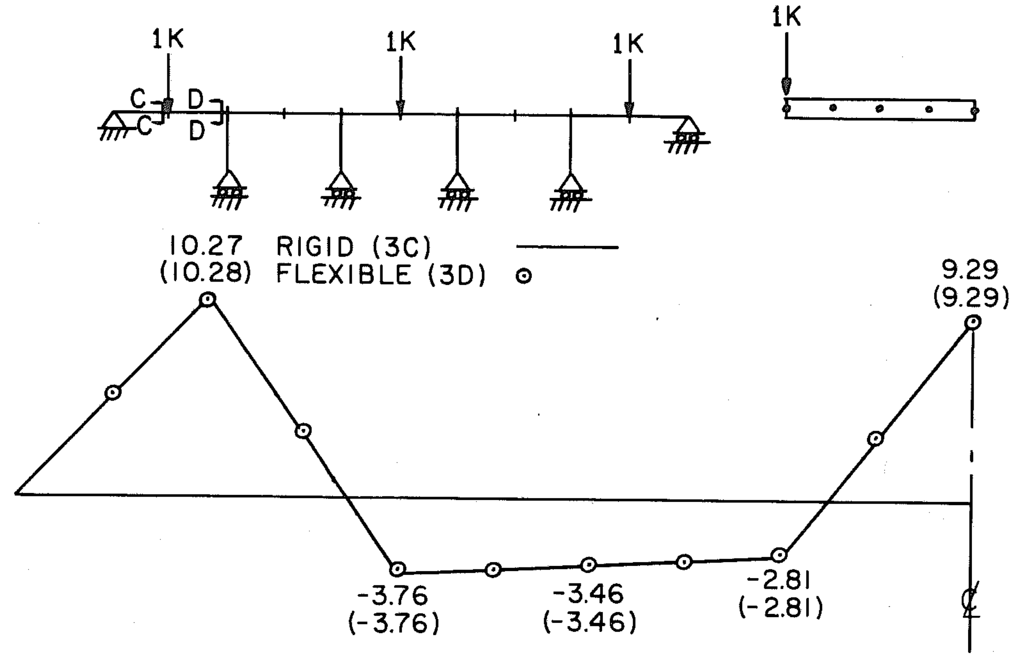


b) VERTICAL DEFLECTIONS

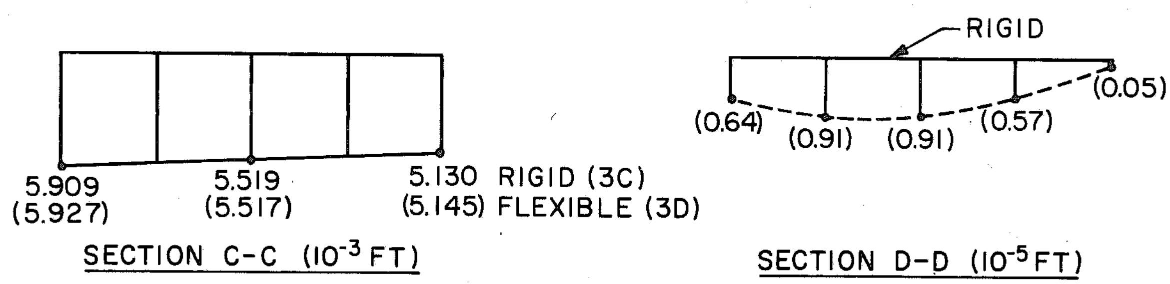


c) TRANSVERSE SLAB MOMENTS (FT-KIP/FT)

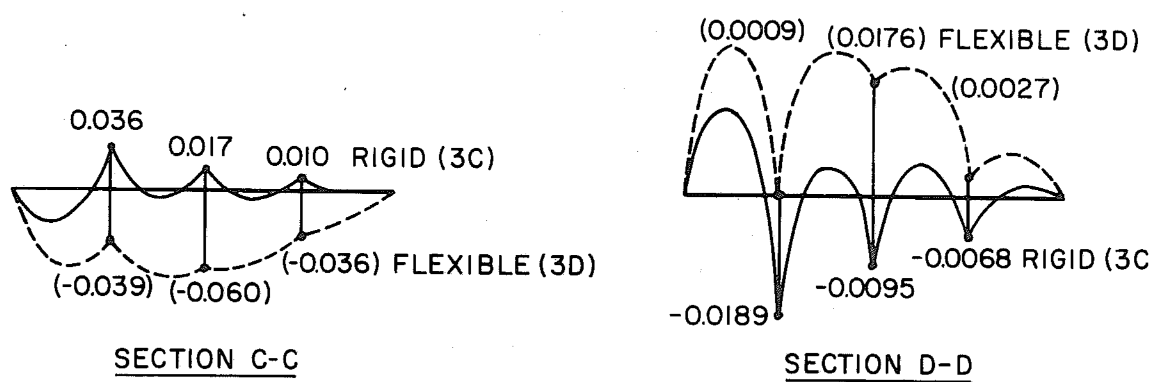
FIG. 16 EXAMPLE 3A (RIGID DIAPHRAGMS AND SUPPORT BENTS) AND EXAMPLE 3B (FLEXIBLE DIAPHRAGMS AND SUPPORT BENTS)



a) LOADING AND TOTAL SECTION MOMENTS (FT-KIPS)



b) VERTICAL DEFLECTIONS



c) TRANSVERSE SLAB MOMENTS (FT-KIP/FT)

FIG. 17 EXAMPLE 3C (RIGID DIAPHRAGMS AND SUPPORT BENTS) AND EXAMPLE 3D (FLEXIBLE DIAPHRAGMS AND SUPPORT BENTS)

5.5 Example 4 - Continuous T-Beam Bridge

For a further investigation of the effects of the flexibility of the diaphragms and bents, a two-span continuous T-beam highway bridge is analyzed with various flexibilities for the midspan diaphragms and the support bents. The bridge is first analyzed for a midspan concentrated load in both spans. One of the assumptions made in the MUPDI3 solution is that the support bents are planar frames incapable of providing longitudinal restraints to the folded plate system. To study the effects of this assumption, the bridge is further analyzed for a midspan concentrated load in one span only, with various heights for the bent column. Then the results are compared with those from a 1DFRAME solution which treats the entire bridge as a planar rigid frame made up of one-dimensional elements. The elastic properties of the frame members are defined by those of the corresponding gross bridge cross-section or bent column. Details of the structure and the loadings are described in Fig. 18. Load cases can be summarized as follows:

1. 1 kip concentrated loads at the centers of both spans:

   Example 4A: Rigid support at the center, with three different midspan diaphragm conditions:

   1. No midspan diaphragms,
   2. Normal midspan diaphragms,
   3. Rigid midspan diaphragms;

   Example 4B: Flexible support bent with a column 15 ft high and normal midspan diaphragms;

   Example 4C: Flexible support bent with a column 30 ft high and normal midspan diaphragms;

2. 1 kip concentrated load at the center of the left span:

Example 4D: Diaphragms and support bents same as Example 4A-2;

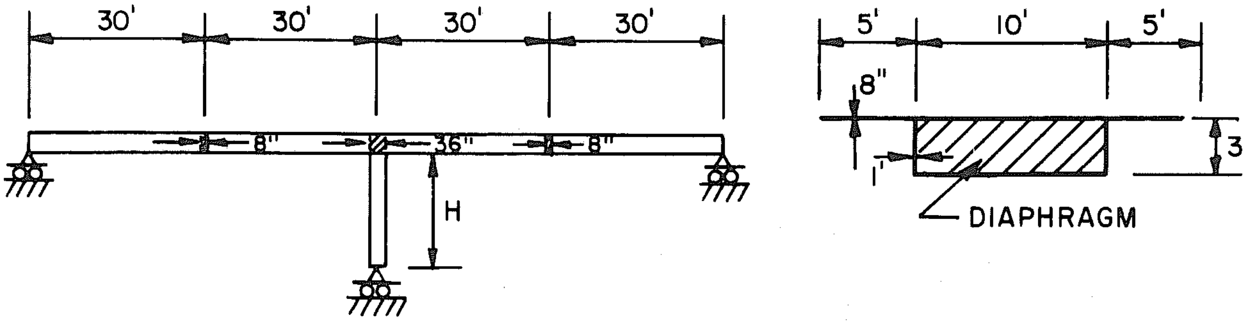
Example 4E: Diaphragms and support bents same as Example 4B;

Example 4F: Diaphragms and support bents same as Example 4C.

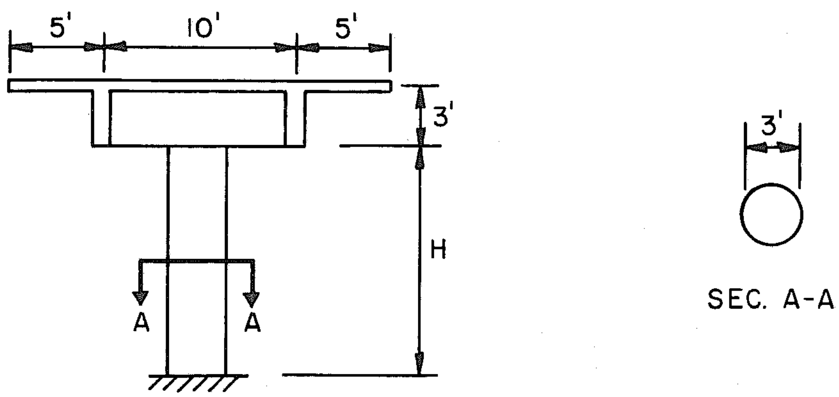
The resulting girder deflections and girder moments for Examples 4A-1, 4A-2 and 4A-3 are shown in Figs. 19 and 20. Girder moments were found automatically in MUPDI3 by integrating membrane stresses and plate bending moments at the specified sections. Comparison of these results indicates that the midspan diaphragms act to distribute the load more evenly to the two girders, however, good distribution is obtained even with no diaphragms. The differences in results for the rigid and normal diaphragm cases are very small, thus indicating rigid midspan diaphragms would be an adequate representation. The total section moments (sum of girder 1 and girder 2 moments) are compared with the 1DFRAME solution (Fig. 20).

In Figs. 21 and 22, the resulting girder deflections and girder moments for Examples 4A-2, 4B and 4C are compared with each other. It can be seen that the flexibility of the support bent has some influence on the results obtained.

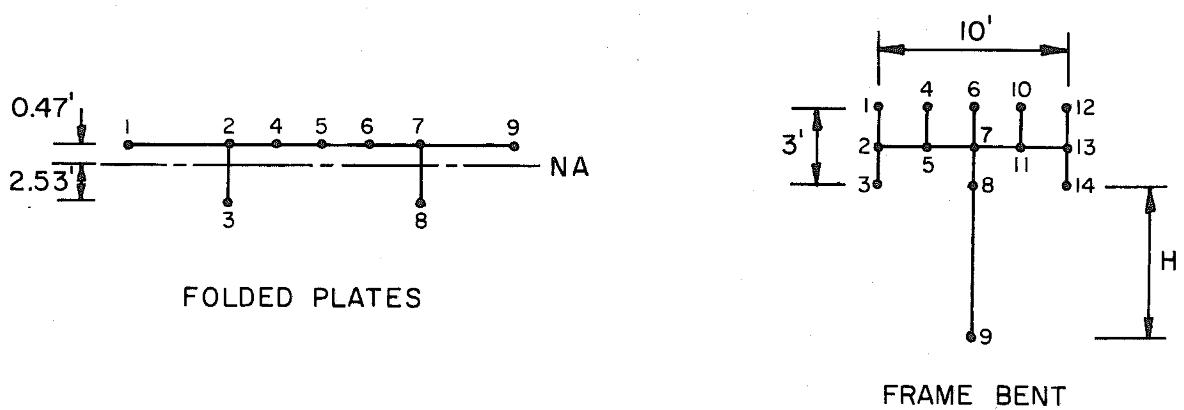
In Fig. 23, the total section moments from MUPDI3 for Examples 4D, 4E and 4F from MUPDI3, which does not include the longitudinal stiffness of the bent, are compared with those from a 1DFRAME solution which can consider the longitudinal stiffness of the bent. It can be observed that the effect of the longitudinal restraint is proportional to the stiffness of the column. However, it should be emphasized that MUPDI3 gives a complete and detailed description of both the longitudinal and transverse distribution of membrane forces, plate bending moments and displacements, while 1DFRAME can only give gross effects based on elementary beam theory. Note that the solutions of Examples 4A, 4B and 4C are not affected by the consideration of the longitudinal restraint, because of the symmetry of the loading with respect to the plane of the bent.



a) ELEVATION AND CROSS-SECTION OF THE BRIDGE

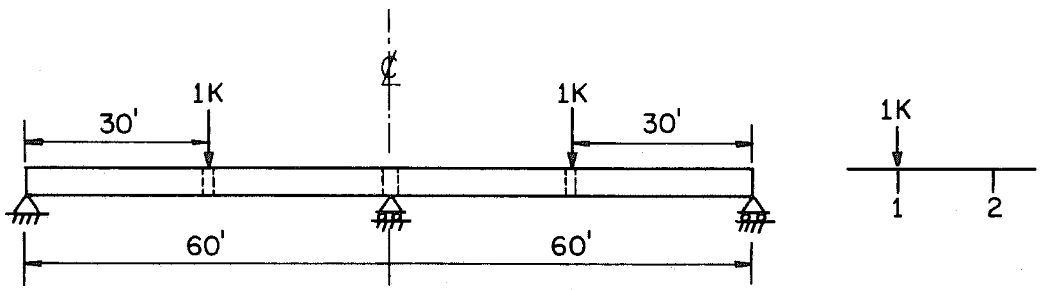


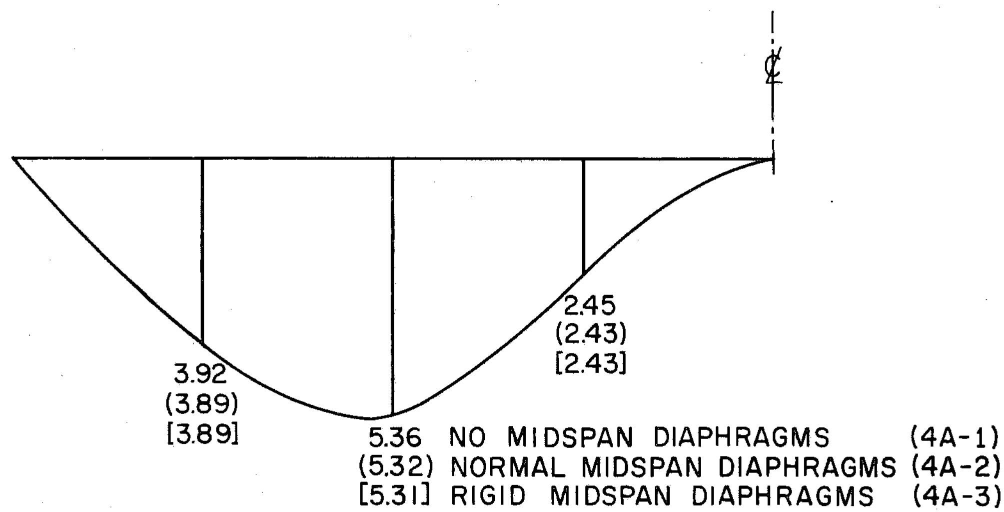
b) SUPPORT BENT



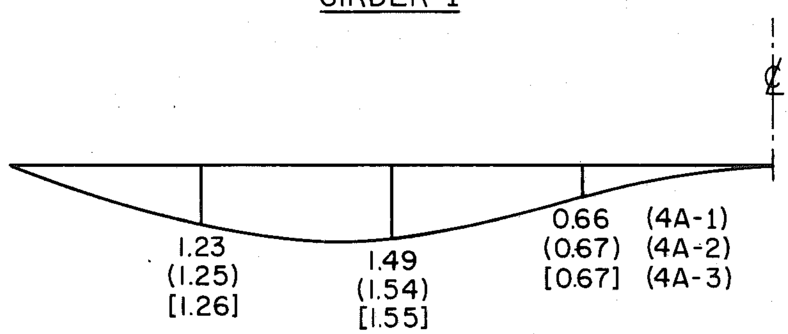
c) NODAL POINT NUMBERING

FIG. 18 EXAMPLE 4 — CONTINUOUS T-BEAM BRIDGE





GIRDER 1



GIRDER 2

FIG. 19 LONGITUDINAL DISTRIBUTION OF GIRDER DEFLECTIONS (10^{-4} FT) FOR EXAMPLES 4A-1, 4A-2 AND 4A-3

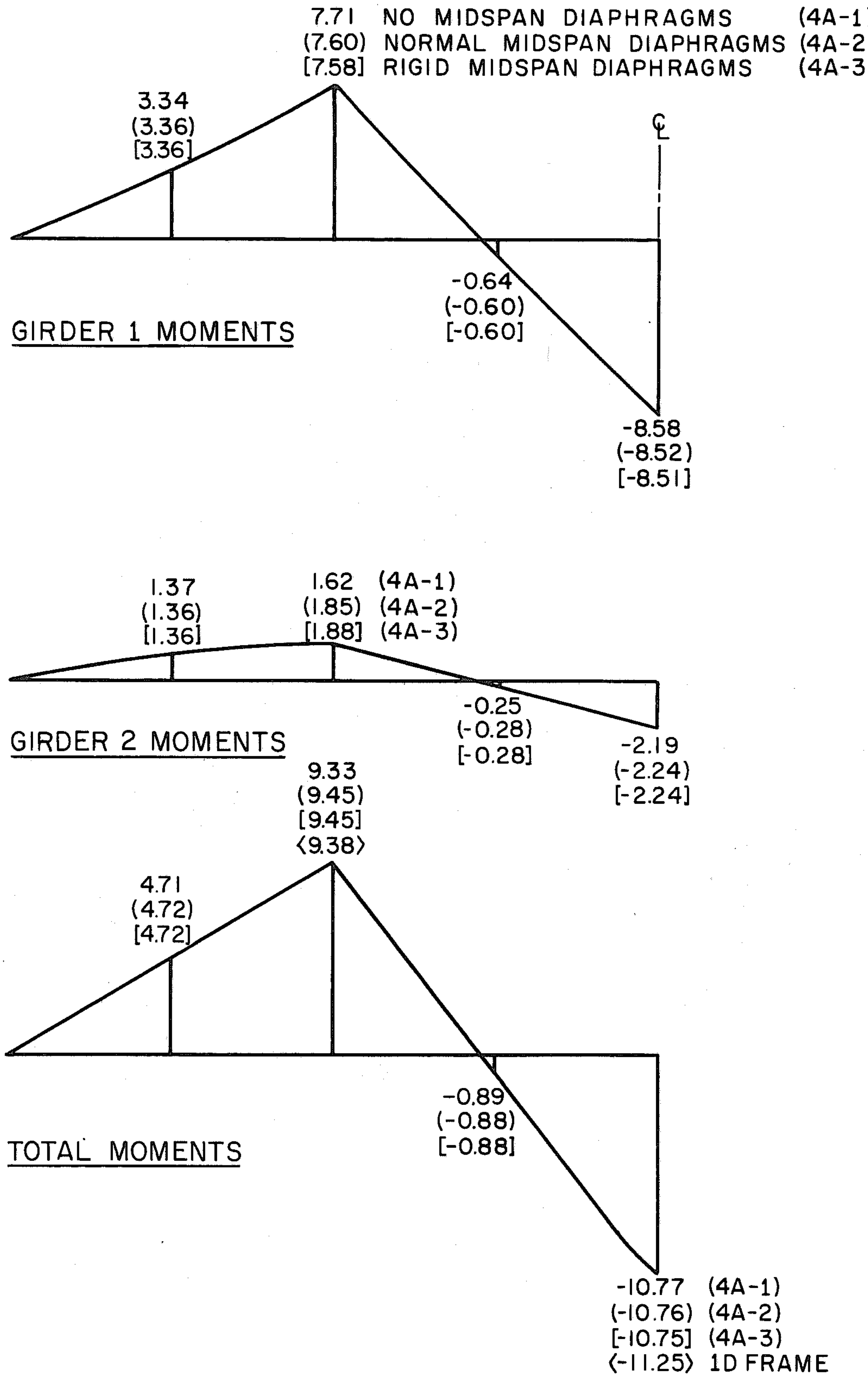


FIG. 20 LONGITUDINAL DISTRIBUTION OF GIRDER AND TOTAL MOMENTS (FT-KIPS) FOR EXAMPLES 4A-1, 4A-2 AND 4A-3

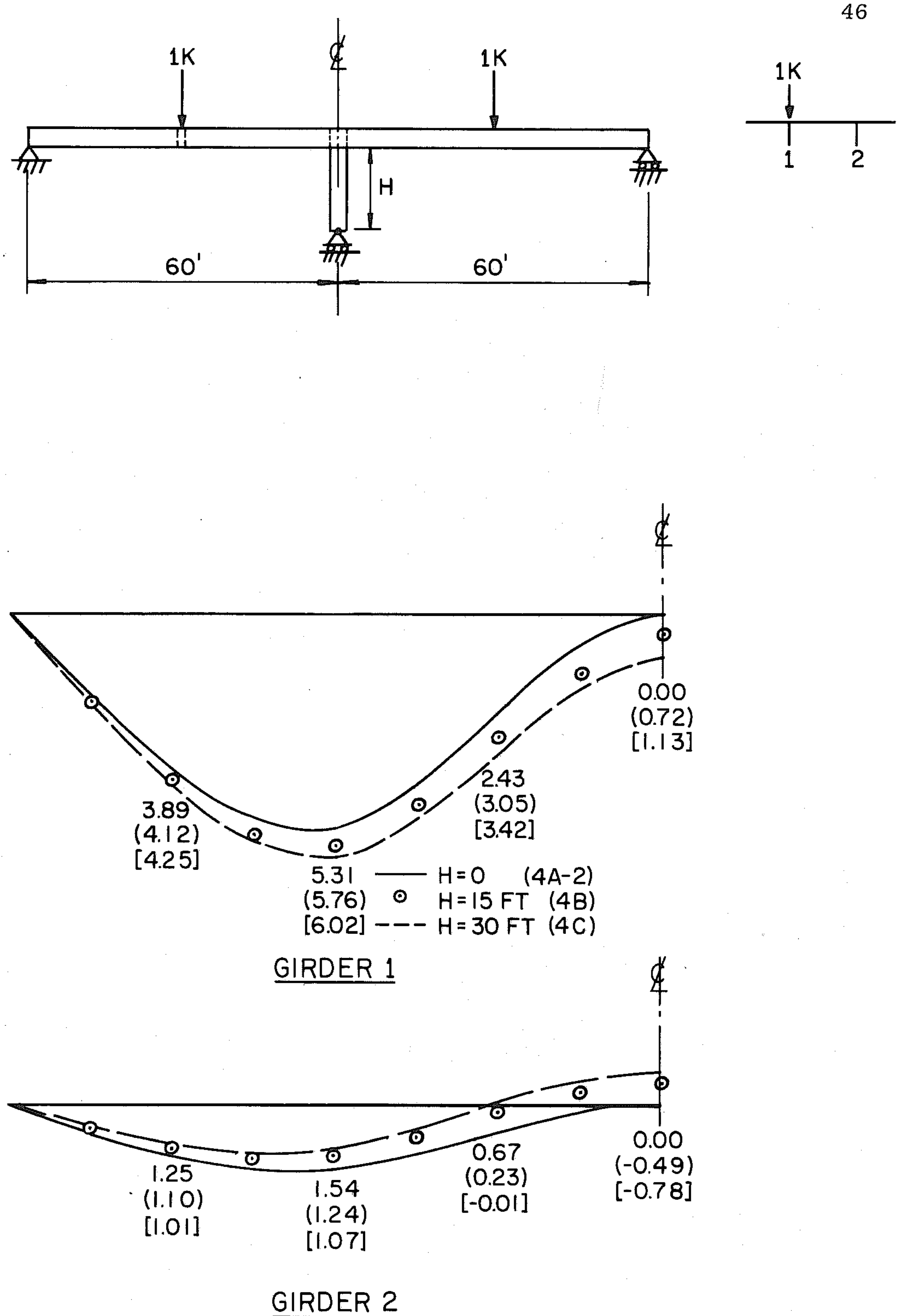


FIG. 21 LONGITUDINAL DISTRIBUTION OF GIRDER DEFLECTIONS (10^{-4} FT) FOR EXAMPLES 4A-2, 4B AND 4C

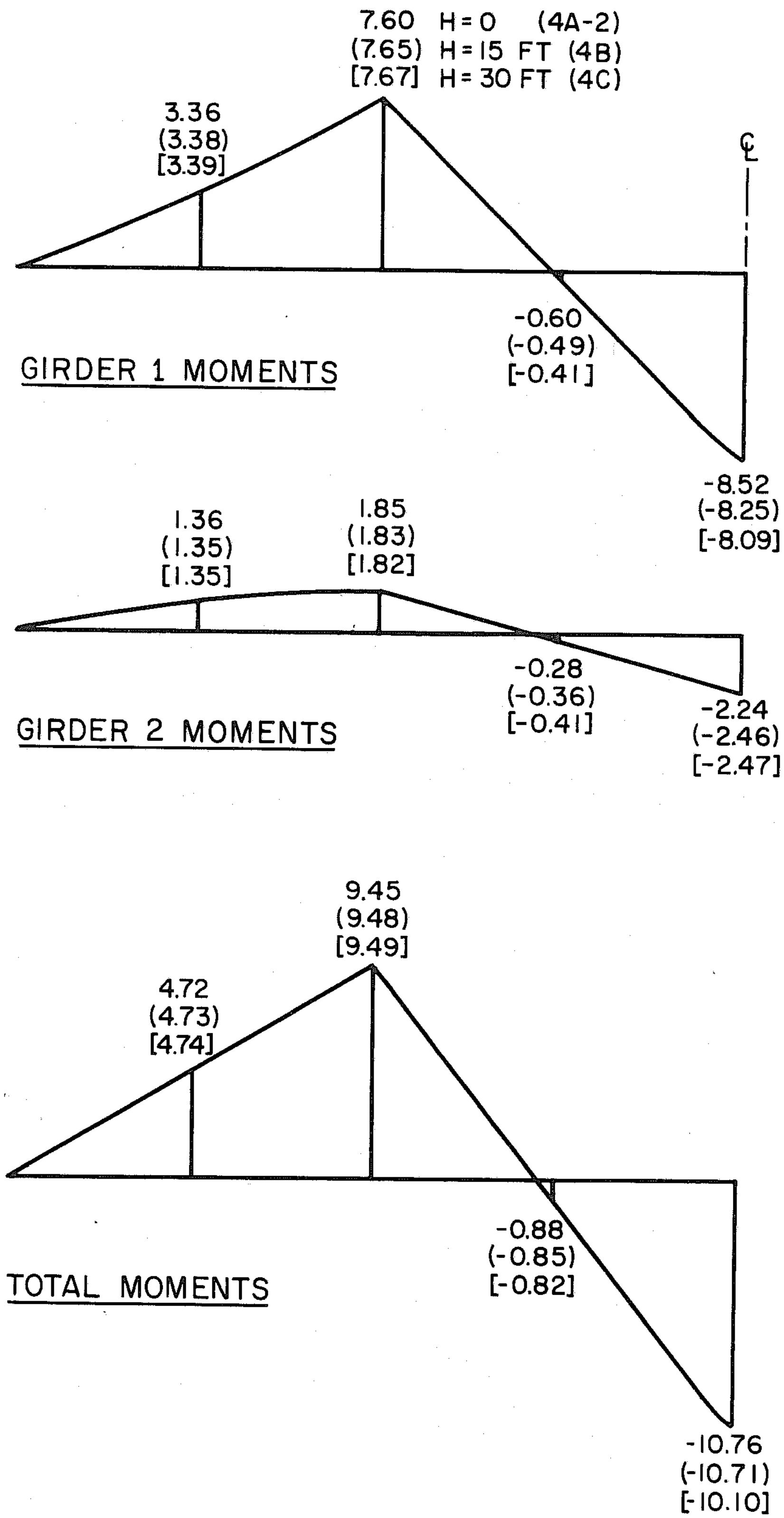


FIG. 22 LONGITUDINAL DISTRIBUTION OF GIRDER AND TOTAL MOMENTS (FT-KIPS) FOR EXAMPLES 4A-2, 4B AND 4C

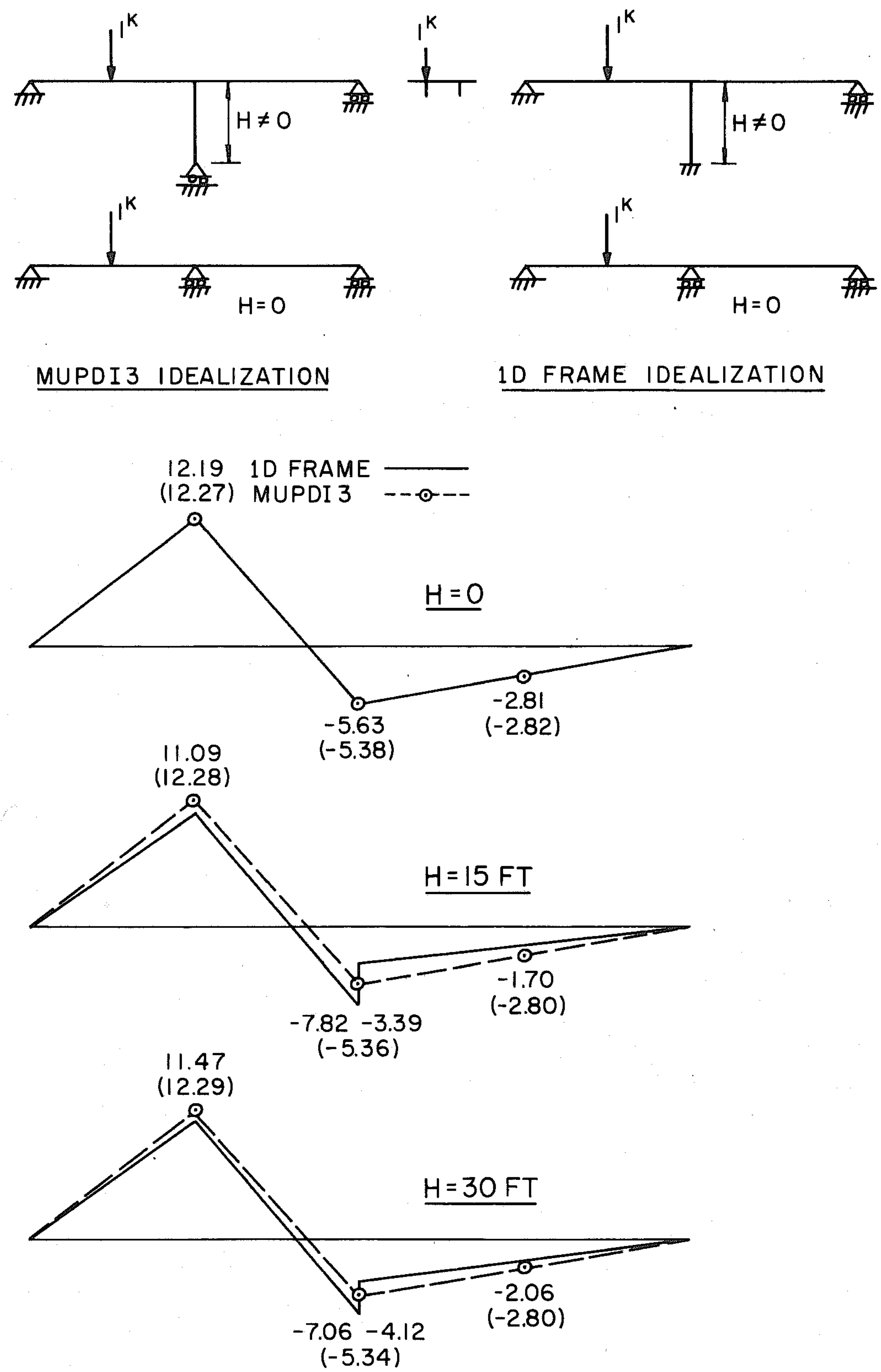


FIG. 23 LONGITUDINAL DISTRIBUTION OF TOTAL MOMENTS (FT-KIPS) FOR EXAMPLES 4D, 4E AND 4F

5.6 Example 5 - Continuous Box-Girder Bridge

A large scale two-span, four-cell reinforced concrete box girder bridge model is selected to demonstrate the practical application of the computer program. The bridge model was actually tested at the University of California, Berkeley as part of the continuing research program on box girder bridges. A report on this experimental study is given in Reference 9.

Detailed dimensions of the bridge are shown in Fig. 24. The nodal point and element numbering used in the MUPDI3 solution is shown in Fig. 25. A modulus of elasticity of 550,800 ksf is used for the top slab of the bridge cross-section, and 432,000 ksf is used for the rest of the structure. This data was obtained from control tests in the experimental program. The bridge is analyzed under two eccentric 100 kip concentrated loads at the top of an exterior web, one at each of the centers of the two spans. Only selected results of interest are presented in this report.

Figure 26 shows the longitudinal variation of the total moments taken by each girder. A vertical web and flanges consisting of a half bay width of top and bottom slabs on either side of the web define a single girder. Each circled point represents information from the computer output. It can be seen that the total section moment is more evenly distributed to the girders in the span with a diaphragm than in the span without a diaphragm. It is of interest to note that the location of points of inflection (points of zero moment) vary only slightly from girder to girder.

Figure 27 shows a free body of the portion of the bridge structure between the inflection points on either side of the bridge bent. A static check for vertical forces is made by summing the shears in the webs at the inflection points (68.0 + 68.3 = 136.3 kips) and comparing this sum with the computer output for the vertical reaction at the base of the bent column (137.3 kips). The check is good recognizing that the slab transverse shears are neglected. Note also that though the total shears in the two spans are almost identical, the distribution of these shears to individual girders is different in spans I and II, because of the existence of the midspan diaphragm in span I only.

Figure 28 indicates the magnitude and direction of the interaction forces between the folded plate system and the bent. Note that a horizontal, vertical and rotational connection was specified. The forces shown are those acting on the rectangular bent girder isolated as a free body. Again a static check was made to verify that the sum of the interaction forces equalled the output reaction at the base of the bent column, and the check was excellent.

Figure 29 gives the internal moments, shear forces and axial forces in the bent. Figure 30 graphically illustrates that the computer output should be plotted to make a proper estimate of actual girder moments which would exist if a continuous interaction were used instead of the discretized system needed in the computer program.

If desired, the amount of participation of the top and bottom slabs of the cellular system with the rectangular bent girder section in carrying the transverse moment in the bent can be found by integrating the membrane forces in the top and bottom slab through section A-A in Fig. 27.

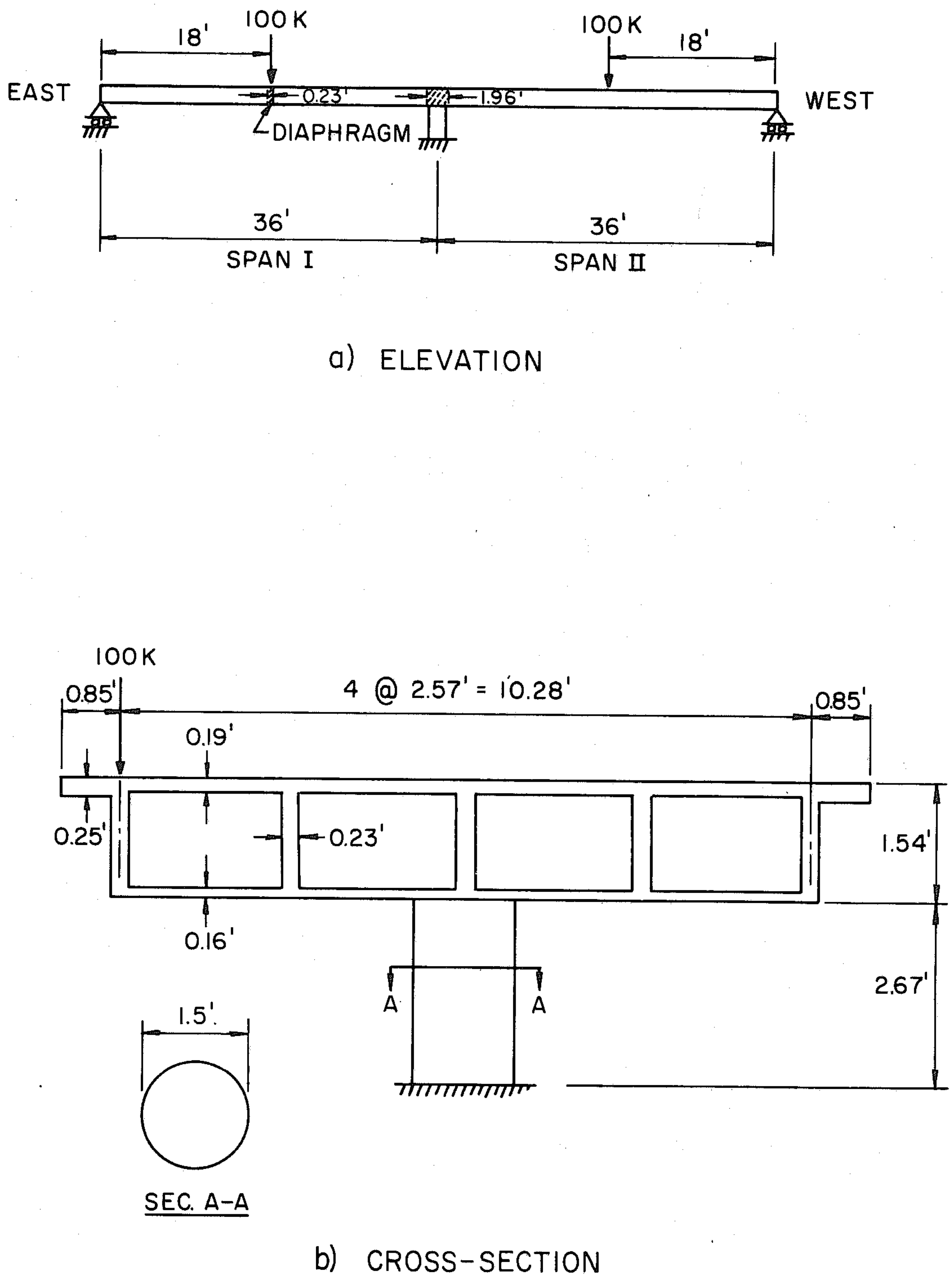
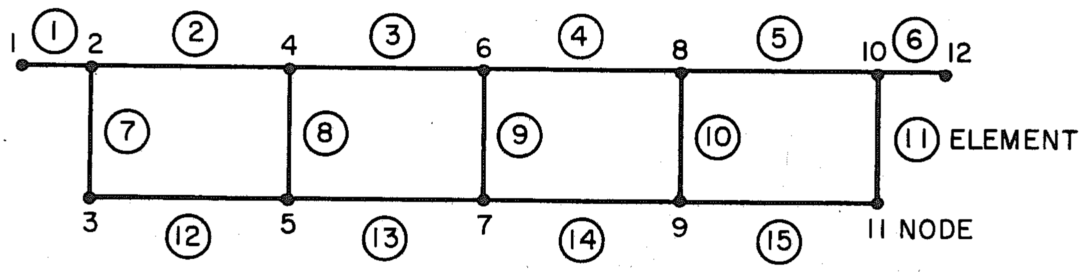
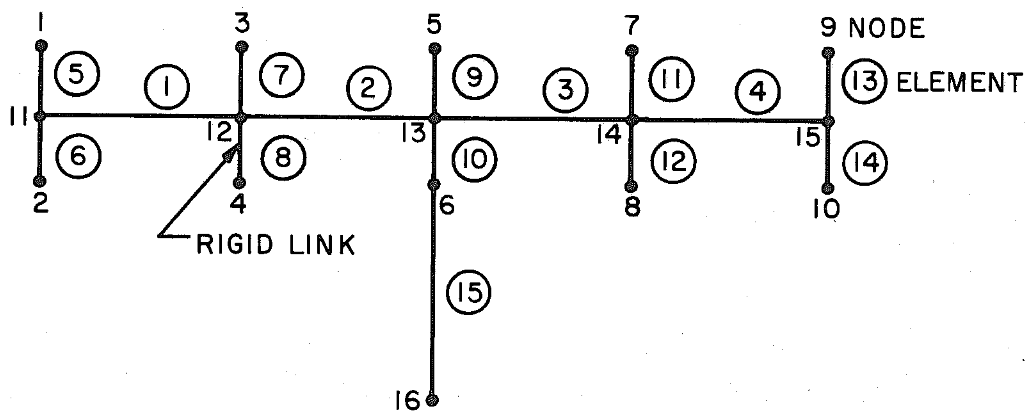


FIG. 24 DIMENSIONS AND LOADING FOR EXAMPLE 5



a) FOLDED PLATE SYSTEM



b) FRAME BENT

FIG. 25 NODAL POINT AND ELEMENT NUMBERING FOR EXAMPLE 5

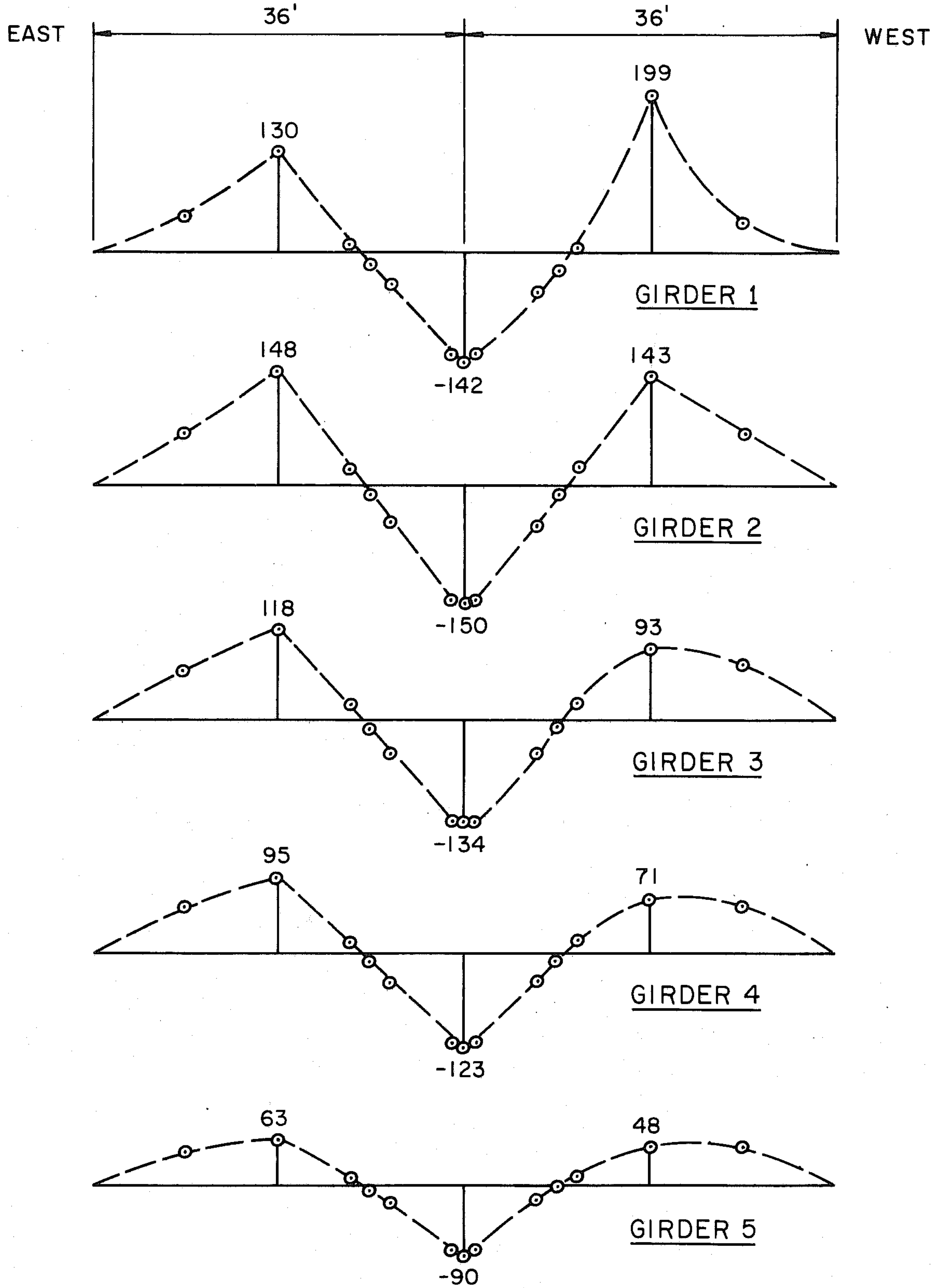


FIG. 26 LONGITUDINAL VARIATION OF MOMENTS (FT-KIPS) TAKEN BY EACH GIRDER - EXAMPLE 5

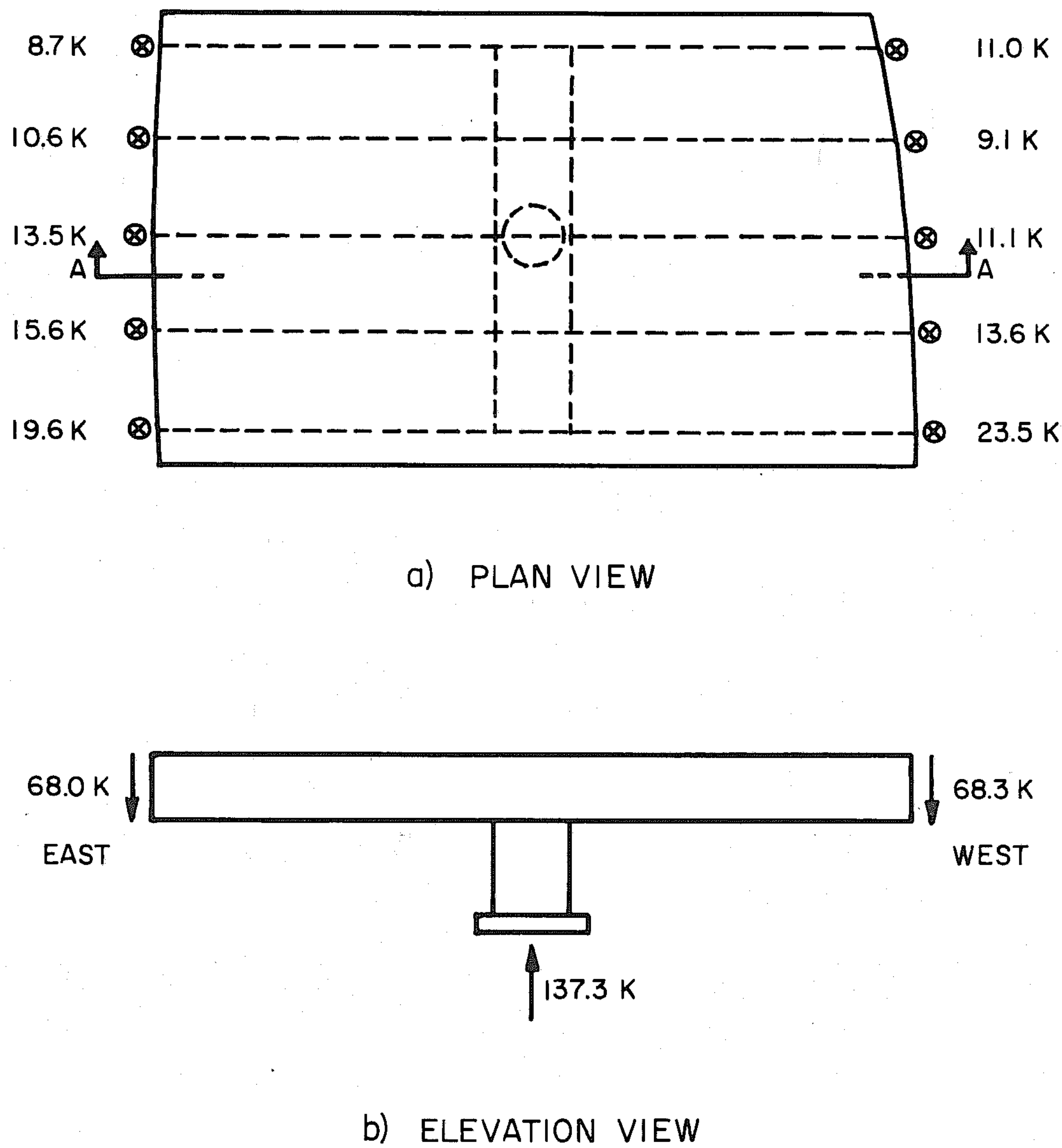


FIG. 27 FORCES ACTING ON THE BENT AND THE ADJACENT PORTION OF BRIDGE – EXAMPLE 5

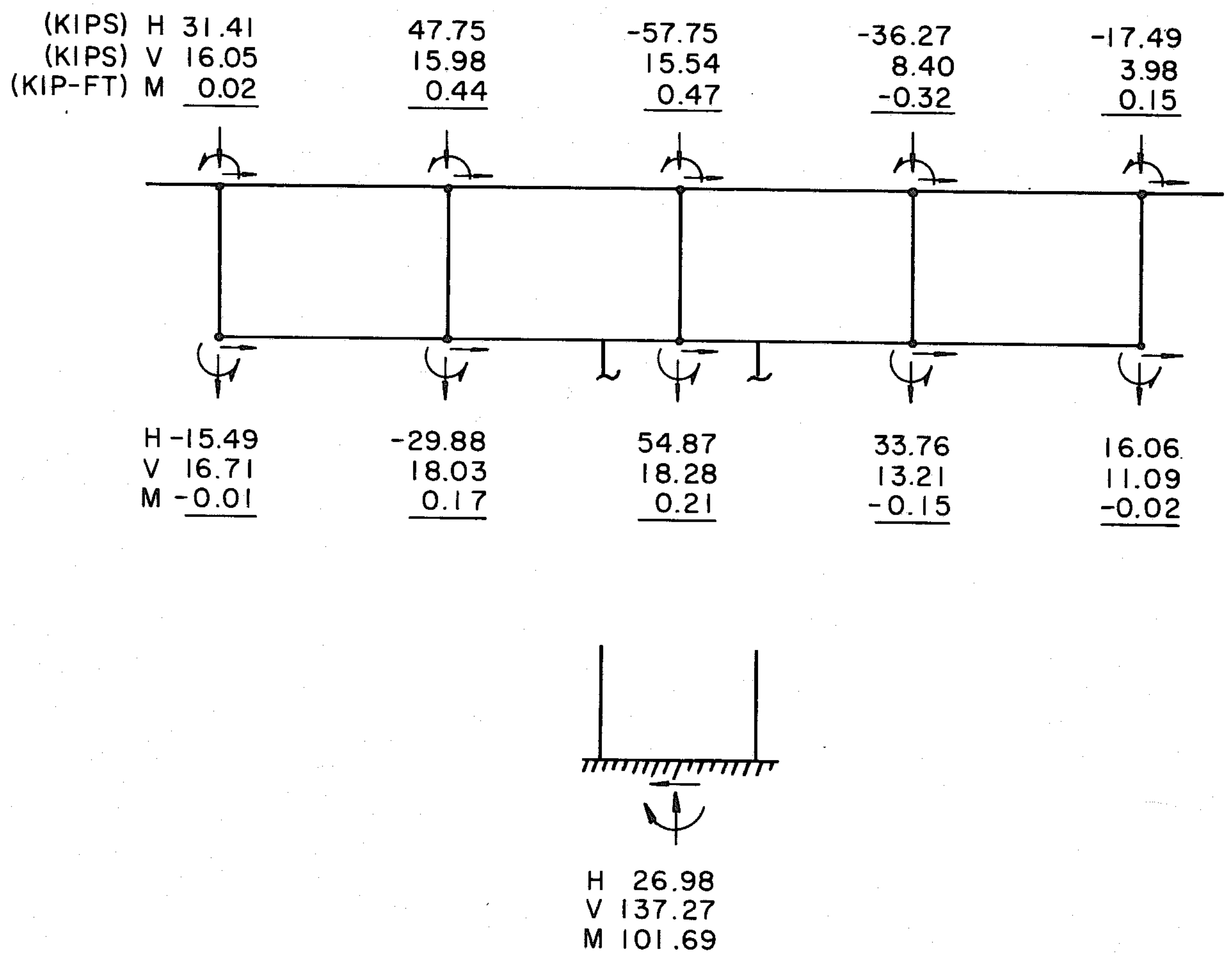


FIG. 28 INTERACTION FORCES ACTING ON THE BENT – EXAMPLE 5

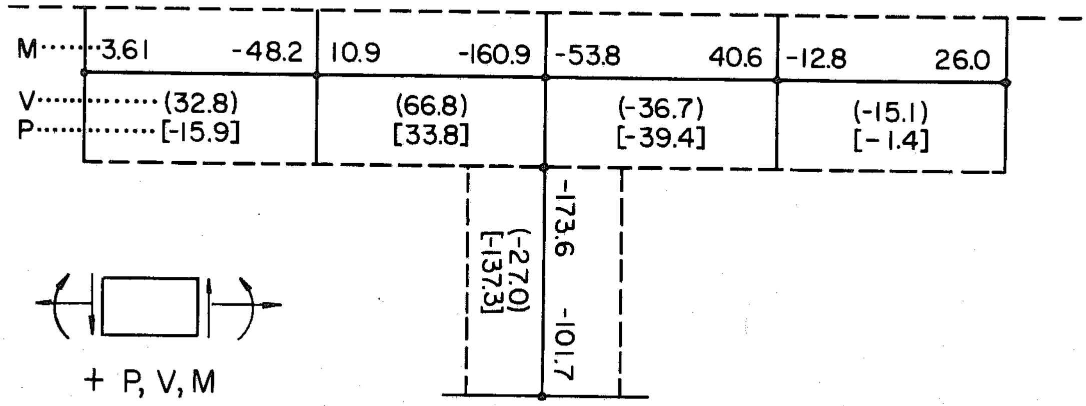


FIG. 29 MOMENTS (FT-KIPS), SHEAR FORCES (KIPS) AND AXIAL FORCES (KIPS) IN THE BENT - EXAMPLE 5

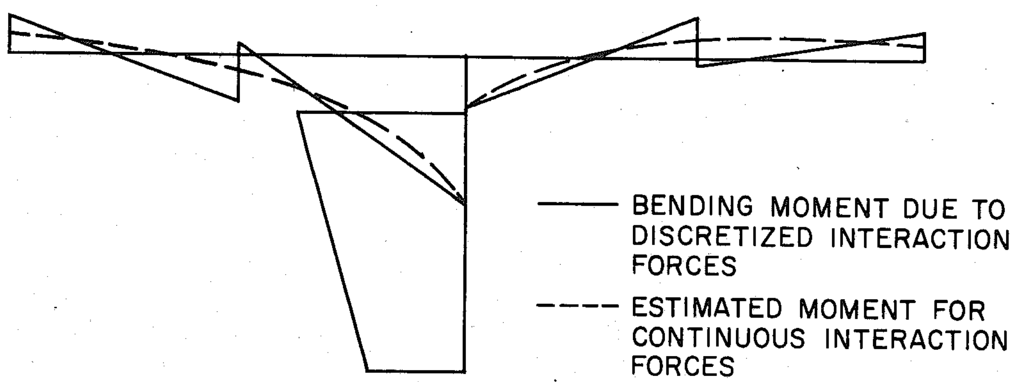


FIG. 30 BENDING MOMENT DIAGRAM FOR THE SUPPORT BENT- EXAMPLE 5

6. CONCLUSIONS AND RECOMMENDATIONS FOR IMPLEMENTATION

A computer program has been presented for the analysis of continuous highway bridges with flexible interior diaphragms or support bents. A complete and detailed description of the response of the structure to an arbitrary loading as well as the interaction between the bridge and the support bents can be obtained by the implementation of the program on a high speed digital computer. The input requires only the geometry and material properties of the structure, magnitudes and locations of the applied loading and the boundary conditions.

The program can be used to establish rational criteria for simplified methods of analysis and design for bridges and support bents by analyzing a number of bridge structures, in which important design parameters such as cross-sectional dimensions, spans and flexibility of the support bents are varied to determine their effect on the bridge response. The program can also be used as a direct analytical tool for the design of unusual bridges having cross-sections, supporting bents or diaphragms which do not conform to those covered in the simplified design methods developed for standard specifications.

A FORTRAN IV source listing is given in Appendix C for those wishing to implement the program directly onto their available computer. Information on the availability of source decks may be obtained from the authors. It is suggested that the input data given in Appendix B for Example 5 be used as a check case when implementing the program. Finally, it would be appreciated if any inconsistencies or errors are found in the program that they be brought to the attention of the authors.

7. ACKNOWLEDGEMENTS

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Mr. G. D. Mancarti, Assistant Bridge Engineer, and Mr. R. E. Davis, Senior Bridge Engineer, of the Research and Development Section, provided close liaison from the Bridge Department, Division of Highways, State of California.

The support of the Computer Center at the University of California, Berkeley, is gratefully acknowledged for providing its facilities.

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Copies of research reports, References 1 to 9 above, have been placed on file with the U. S. Department of Commerce and may be obtained on request at $3.00 per copy by writing to the following address:

National Technical Information Service
Operations Division
Springfield, Virginia 22151

The accession number, shown in parenthesis in the reference list, should be used when ordering a particular report.

APPENDIX A

MUPDI3 USER'S GUIDE

UNIVERSITY OF CALIFORNIA
February 1971

Department of Civil Engineering
Faculty Investigator: A. C. Scordelis

Computer Program for Analysis of Folded Plates Simply Supported at the Ends with Interior Flexible Diaphragms or Planar Rigid Frame Support Bents

IDENTIFICATION:

MUPDI 3 - Analysis of Folded Plate Structures with Interior Flexible Diaphragms or Planar Rigid Frame Support Bents
Programmed by: K. S. Lo and C. S. Lin
University of California, February 1971

PURPOSE:

The program provides a rapid solution for cellular or open folded plate structures simply supported at the two ends and having up to twelve interior flexible diaphragms or supporting frame bents between the two ends. Uniform or partial surface loads, as well as line loads and concentrated loads, may be applied anywhere on the structure. Resulting joint diaplacements and the internal forces, moments and displacements in the folded plate elements, and the one dimensional frame elements may be found.

RESTRICTIONS:

Restrictions as to the maximum number of plates, joints, diaphragms or frame bents, etc. are given under input data and remarks.

DESCRIPTION:

The computer solution uses a direct stiffness method for the folded plate system. Compatibility at the interior flexible diaphragms or supporting frame bents is accomplished by a force (flexibility) method of analysis. The Goldberg-Leve equations are used to evaluate plate fixed edge forces, stiffnesses and final internal forces, moments, and displacements. A harmonic analysis with up to 100 non-zero terms of the appropriate Fourier Series is used for the loads. The flexible transverse diaphragms may be treated either as a beam having a rectangular cross-section or as a beam of arbitrary cross-section with a given cross-sectional area and moment of inertia. The flexible supporting frame bents are analyzed as two dimensional planar frames. A special moment integration option permits the evaluation of the moment and the percentage of the total moment of a cross section taken by each girder of a box girder bridge. The program is written in FORTRAN IV language.

FORM OF INPUT DATA:

Consistency in units used must be strictly adhered to in input of data.

1. FIRST CARD - title of the problem.

2. SECOND CARD - CONTROL CARD (F 10.0, 11 I 4)

Col. 1 to 10 - total overall span length = SPAN

Col. 11 to 14 - number of types of plate = NPL, max. 15

Col. 15 to 18 - number of elements = NEL, max. 30

Col. 19 to 22 - number of joints = NJT, max. 20

Col. 23 to 26 - number of diaphragms (includes frame bents) = NDIAPH, max. 12

Col. 27 to 30 - number of x-coordinates at which results are desired = NXP, max. 14

Col. 31 to 34 - maximum Fourier series limit = MHARM, max. 100 for NCHECK = 0; max. 200 for NCHECK = +1 or -1

Col. 35 to 38 - check on odd or even harmonics = NCHECK
+1 to work on odd series only (sym.)
0 to include all series
-1 to work on even series only (anti-sym.)

Col. 39 to 42 - moment integration option = MCHECK
0 no moment integration
1 moment integration desired

Col. 43 to 46 - number of types of flexible supporting frame bents = NBT, max. 8

Col. 47 to 50 - number of types of flexible movable diaphragms = NFMD, max. 8

Col. 51 to 54 - FORCE program option (calculates internal forces and displacements in frame bents)
0 to skip FORCE program
1 to execute FORCE program

3. THIRD CARD -- x-coordinates at which results are desired (10F 7.3) = XP; use additional card if needed

4. NEXT CARDS -- one card for each diaphragm (I 10, 2F 10.0, 2I 4)

Col. 1 to 10 - diaphragm number = I

Col. 11 to 20 - x-coordinate at which diaphragm exists = DIAPHX(I)

Col. 21 to 30 - diaphragm or bent interaction thickness in longitudinal direction = DIADEL(I)

Col. 31 to 34 - diaphragm classification code = KODIA(I)
1 for externally supported rigid diaphragm
2 for movable rigid diaphragm
3 for flexible supporting frame bent
4 for flexible movable diaphragm

Col. 35 to 38 - type number of supporting bent or flexible movable diaphragm = KDIP(I), leave blank if the diaphragm is rigid, therefore 1 or 2 above. (See paragraphs 13 and 15 for type description)

5. <u>NEXT CARDS</u> -- One card for each type of plate (I10, 5F10.0)

Col. 1 to 10 - type number = I

Col. 11 to 20 - horizontal projection of plate = H(I)

Col. 21 to 30 - vertical projection of plate = V(I)

Col. 31 to 40 - plate thickness = TH(I)

Col. 41 to 50 - modulus of elasticity = E(I)

Col. 51 to 60 - Poisson's ratio = FNU(I)

6. <u>NEXT CARDS</u> -- One card for each element (5I4, 3F10.0)
Uniform loads given below exist over entire plate

Col. 1 to 4 - element number - I

Col. 5 to 8 - joint I = NPI(I)
Col. 9 to 12 - joint J = MPJ(I)
} maximum absolute difference = 4

Col. 13 to 16 - type of plate used = KPL(I)

Col. 17 to 20 - number of transverse sections, for internal forces and displacements output = NSEC(I), maximum 12, if NSEC = 0 no internal forces or displacements will be output.

Col. 21 to 30 - dead load (P/PL-area; force per unit surface area) = DL(I)

Col. 31 to 40 - uniform horizontal load (P/V-area; force per unit vertical projected area) = HL(I)

Col. 41 to 50 - uniform vertical load (P/H-area; force per unit horizontal projected area) = VL(I)

7. NEXT CARD --- Col. 1 to 4 - number of partial surface loads (I4) - NSURL, maximum 50

8. NEXT CARD -- One card for each partial surface load (I10, 4F10.0) no cards required if NSURL = 0. Loads given below are uniform over plate width and have a length equal to that given under SURDEL

Col. 1 to 10 - element number = LEL

Col. 11 to 20 - horizontal load, P/V-area (P/V-length if line load is applied) = SURHL

Col. 21 to 30 - vertical load, P/H-area (P/H-length if line load is applied) = SURVL

Col. 31 to 40 - location from left support to center of distributed length = SURXI

Col. 41 to 50 - distributed length in x-direction (= 0 for line load) = SURDEL
If SURDEL ≠ 0, input SURHL and SURVL as force/ unit area
If SURDEL = 0, input SURHL and SURVL as force/ unit width

9. NEXT CARDS -- One card for each joint (I10, 4F10.0, 4I2, 2X, 3I2). All Joints require a card.

Col. 1 to 10 - joint number = I

Col. 11 to 20 - applied horizontal joint force or displacement = AJFOR (1,I)

Col. 21 to 30 - applied vertical joint force or displacement = AJFOR (2,I)

Col. 31 to 40 - applied joint moment or rotation = AJFOR (3,I)

Col. 41 to 50 - applied longitudinal joint force or displacement = AJFOR (4,I)

Col. 52 --- index for horizontal force or displacement (can be 0, 1, 2, or 3) = LCASE (1,I)

Col. 54 --- index for vertical force or displacement, (can be 0, 1, 2 or 3) = LCASE (2,I)

Col. 56 --- index for moment or rotation, (can be 0, 1, 2 or 3) = LCASE (3,I)
0 for given zero force

1 for uniformly distributed force (input uniform force/unit length for AJFOR)
2 for concentrated force at midspan (input total force for AJFOR)
3 for given zero displacement

Col. 58 --- index for longitudinal force or displacement, can be (0, 2, or 3) = LCASE (4,I)
0 for given zero force
2 for prestress P at each end (input total force at one end for AJFOR, + away from midspan)
3 for given zero displacement

Joint Restraint Conditions (from diaphragms or bents)

Col. 62 --- index for horizontal restraint = JFOR (1,I)

Col. 64 --- index for vertical restraint = JFOR (2,I)

Col. 66 --- index for rotational restraint = JFOR (3,I)
zero punch to consider restraint from diaphragms or bents
non-zero punch to neglect restraint from diaphragms or bents

10. <u>NEXT CARD</u> -- Col. 1 to 4 - number of concentrated joint loads (I4) = NCONL, maximum 50

11. <u>NEXT CARDS</u> -- One card for each concentrated joint load (I10, 6F10.0) No cards required if NCONL = 0. More than one location along a joint may be loaded, but each location requires a separate card.

Col. 1 to 10 - joint number = LJT

Col. 11 to 20 - total horizontal force = CONHL

Col. 21 to 30 - total certical force = CONVL

Col. 31 to 40 - total moment = CONM

Col. 41 to 50 - total longitudinal force P (note--it must be balanced by one -P somewhere along the same joint) = CONS

Col. 51 to 60 - location from left support to center of load = CONXI

Col. 61 to 70 - distributed length in x-direction (= 0 for concentrated load) = CONDEL

12. NEXT CARD DECK -- For girder moment integration - no cards required if no moment integration called for on CONTROL CARD (paragraph 2). The accuracy of the integration depends on the number of transverse sections (NSEC) in paragraph 6. Normally, NSEC = 4 is recommended.

a. FIRST CARD (2I4)

Col. 1 to 4 - number of points along x-axis at which girder moments are desired = NOXMP, maximum 14

Col. 5 to 8 - number of girders = NBOX, maximum 10

b. SECOND CARD (10F 7.3)

Col. 1 to 70 - x coordinates at which girder moments are desired = X(I), must be a subset of the coordinates listed in paragraph 3.

c. NEXT CARDS -- (3I4, 3F10.0) - one card for each element

Col. 1 to 4 - element number = I

Col. 5 to 8 - first girder number to which this element belongs = NGIEL (I,1); if it belongs to two, list that which is nearest to node I first; girders are numbered from left to right

Col. 9 to 12 - second girder number to which this element belongs = NGIEL (I,2); punch zero if no second girder

Col. 13 to 22 - vertical distance from assumed section neutral axis to node I = DNAI (I), downward is positive

Col. 23 to 32 - vertical distance from assumed section neutral axis to node J = DNAJ (J), downward is positive

Col. 33 to 42 - horizontal distance from node I to the dividing point if the element belongs to two girders = XDIV (I), rightward is positive.

13. NEXT CARD DECK - Flexible supporting frame bent cards - no cards if no bents called for on CONTROL CARD (paragraph 2). One set of the following cards for each type of supporting bent. The type numbers should be ascending consecutive integers starting from 1.

a. CONTROL CARD (6I5)

Col. 1 to 5 - frame type number

Col. 6 to 10 - number of elements

Col. 11 to 15 - number of nodal points (maximum 80)

Col. 16 to 20 - number of materials (maximum 10)

Col. 21 to 25 - number of element section property cards (maximum 200)

Col. 26 to 30 - number of elastic support cards (maximum 40)

b. <u>MATERIAL PROPERTY CARDS</u> (I5, E10.0, F10.0)

Col. 1 to 5 - material identification number (any number from 1 to 10)

Col. 6 to 15 - Young's modulus

Col. 16 to 25 - Poisson's ratio

c. <u>ELASTIC SUPPORT CARDS</u> (I5, 3F10.0) - skip if no elastic supports

Col. 1 to 5 - identification number (any number from 1 to 40)

Col. 6 to 15 - SX (X component of spring stiffness)

Col. 16 to 25 - SY (Y component of spring stiffness)

Col. 26 to 35 - SZ (rotational spring stiffness)

d. <u>SECTION PROPERTY CARDS</u> (I5, 3F10.0)

Col. 1 to 5 - identification number (any number from 1 to 200)

Col. 6 to 15 - axial area

Col. 16 to 25 - shear area (leave blank if shear deformations are to be neglected)

Col. 26 to 35 - moment of inertia

e. <u>NODAL POINT DATA CARDS</u> (2I5, 2F10.0, 2I5) - one for each frame bent node

Col. 1 to 5 - nodal point number

Col. 6 to 10 - joint boundary condition code, a three digit number in Cols. 8, 9, 10, use 1 for zero displacement, otherwise use 0, (col. 8 - X displacement, Col. 9 - Y displacement, Col. 10 - Z rotation)

Col. 11 to 20 - global X coordinate

Col. 21 to 30 - global Y coordinate

Col. 31 to 35 - elastic support identification number (leave blank if no elastic support)

Col. 36 to 40 - corresponding nodal point number in the folded plate system (leave blank if not connected to folded plate system) = NFP(N)

f. <u>ELEMENT DATA CARDS</u> (5I5, I10) - one for each frame bent element

Col. 1 to 5 - identification number

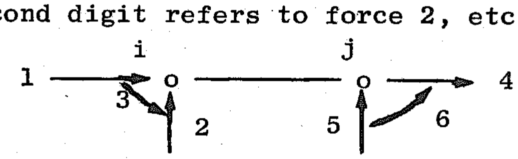
Col. 6 to 10 - node I

Col. 11 to 15 - node J

Col. 16 to 20 - material identification number

Col. 21 to 25 - section property identification number

Col. 26 to 35 - element code - The element code is a six digit number in columns 30 to 35 which permits member end releases (e.g., pin ends). Use 1 for zero member end force, otherwise use 0 or leave blank. The first digit corresponds to member end force 1 in the following diagram. The second digit refers to force 2, etc.



14. <u>Repeat</u> preceding frame bent card deck for each frame type number.

15. <u>NEXT CARD DECK</u> - <u>Flexible movable diaphragm cards</u> - 2 cards for each type of flexible movable diaphragm. No cards if no flexible movable diaphragms called for on CONTROL CARD (paragraph 2).

a. <u>FIRST CARD</u> (2I4)

Col. 1 to 4 - type number

Col. 5 to 8 - option code (option for the two ways of inputing data)
1 option one
2 option two

b. SECOND CARD - use either option one or two.

(1) Option one (5F10.0) diaphragm assumed to have rectangular cross-section

Col. 1 to 10 - diaphragm thickness = DITH

Col. 11 to 20 - diaphragm depth = DIDP (neutral axis is assumed at mid-depth)

Col. 21 to 30 - code for vertical location of diaphragm neutral axis with respect to joint 1 of folded plate system = CODE
+1.0 if neutral axis above joint 1
-1.0 if neutral axis below joint 1

Col. 31 to 40 - modulus of elasticity = DIE

Col. 41 to 50 - Poisson's ratio = DINU

(2) Option two (6F10.0)

Col. 1 to 10 - moment of inertia of diaphragm cross-section = DIPHI

Col. 11 to 20 - area of cross-section = DIPHA

Col. 21 to 30 - shear area of cross-section = DIAS (leave blank if shear deformations are to be neglected.)

Col. 31 to 40 - vertical distance from diaphragm neutral axis to joint 1 of folded plate system = CC
+ if neutral axis above joint 1
- if neutral axis below joint 1

Col. 41 to 50 - modulus of elasticity = DIE

Col. 51 to 60 - Poisson's ratio = DINU

16. Repeat preceding card deck for each type of flexible movable diaphragm.

17. All of the above data cards (paragraphs 1 to 16) are repeated for next problem to be solved.

18. Two blank cards are added at the end of the data deck.

REMARKS

1. Number all elements of the same plate type in consecutive groups if

possible. This will save some computer time when calculating internal forces.

2. Select joint numbering so as to minimize maximum absolute difference between joint numbers for any plate element. See sketches on page A14.

3. The maximum total number of connections between the folded plate system and all of the diaphragms and bents must be equal to or less than 120. Therefore, assuming there are a total of M zero indices for JFOR, horizontal, vertical or rotational joint restraints, then (M) x NDIAPH ≤ 120.

OUTPUT DESCRIPTION

The output consists of two parts:

a) Input check printout
b) Results

a) Input check printout

The complete input is properly labelled and printed, and may be used to check up on possible errors in punching, field specifications, and order of the cards.

b) Results

The final results consist of the following quantities: (see pages A12 and A13 for sign convention)

1. If NDIAPH is not zero, the interaction (restraint) joint forces between each diaphragm or bent and the folded plate system are printed.

2. Resulting displacements at joints.
Horizontal, vertical, rotational, and longitudinal displacements of the folded plates are given successively for each joint.

3. Internal element forces and displacements.
For each plate element the following quantities are printed:

   1. Longitudinal moment per unit length; M_x

   2. Transverse moment per unit length; M_y

   3. Torsional moment per unit length; M_{xy}

   4. Normal shear on transverse section per unit length; Q_x

5. Normal shear on longitudinal section per unit length; Q_y

6. Longitudinal membrane force per unit length; N_x

7. Transverse membrane force per unit length; N_y

8. Membrane shear per unit length; N_{xy}

9. Longitudinal displacement; u

10. Transverse displacement; v

11. Normal displacement; w

Each of these quantities is printed for each transverse section specified across the plate width and at the x-coordinates specified along the plate length.

4. If MCHECK = 1, the following quantities are printed at the specified cross-sections:

   1. Moment taken by each girder;

   2. Percentages of total moment at the section taken by each girder;

   3. The resultant longitudinal tensile force and compressive force taken by each girder.

5. If KFOR = 1, the following quantities are printed for each flexible supporting frame bent:

   1. Joint displacements;

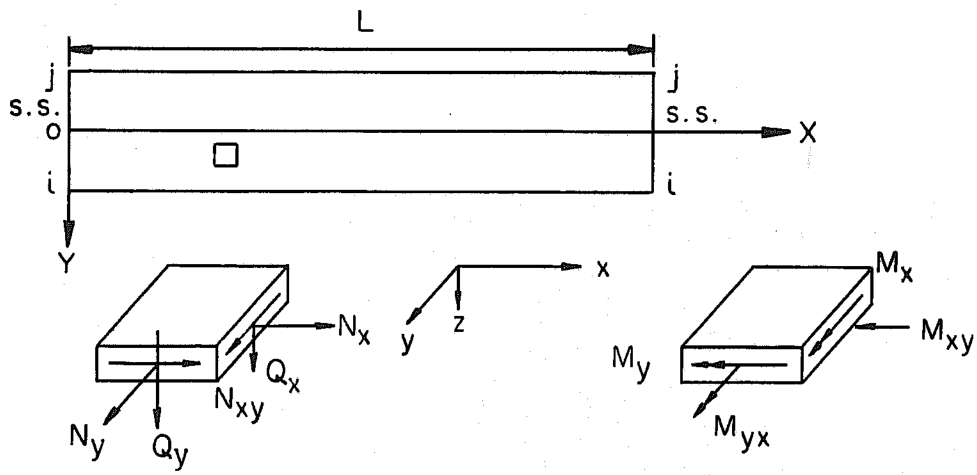
   2. Member end forces;

   3. Applied joint loads (i.e., interaction forces acting on the frame bent) and reactions.

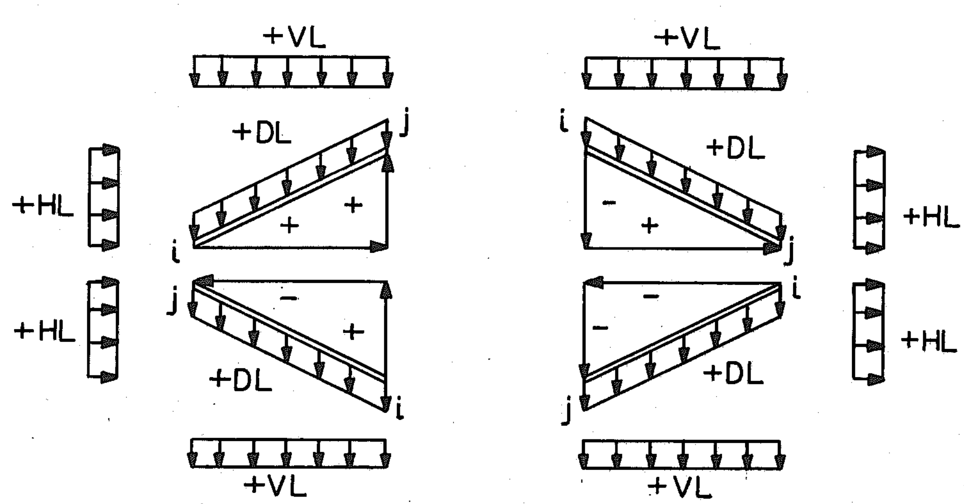
SIGN CONVENTIONS

a) Sign Conventions for the Folded Plate System

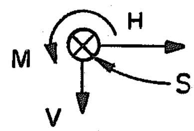
1. Internal Forces for Plate Element



2. Surface Loads and Projections of Plate Element (assumed looking towards origin)



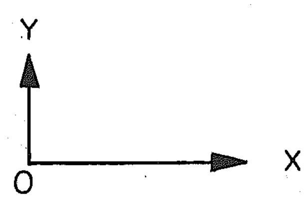
3. External Joint Forces or Displacements (also applicable to the interaction forces between folded plate system and supporting frame bents or diaphragms, acting on the folded plate system)



positive when towards the origin of the plate system

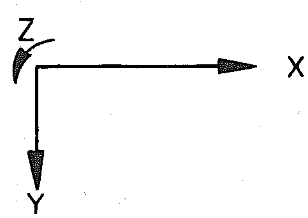
b) Sign Conventions for the Supporting Frame Bents (assumed looking towards the origin of the folded plate system)

1. Coordinate System for the Geometry of the Frame Bents (Note this is independent of folded plate coordinate system)

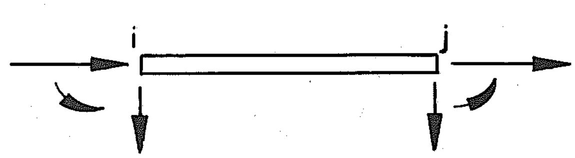


(origin can be arbitrary)

2. Joint Forces and Displacements (Joint forces include interaction forces and reactions acting on the supporting frame bent)

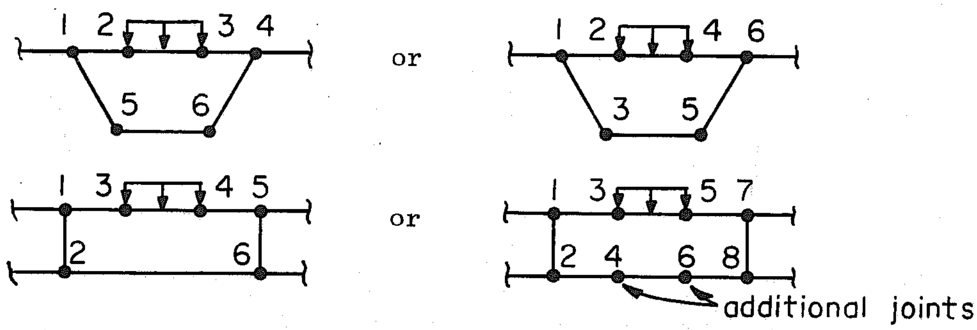


3. Positive Member End Forces



ALTERNATE METHODS OF NUMBERING JOINTS OF THE FOLDED PLATE SYSTEM

(Section assumed looking towards origin)



APPENDIX B

LISTING OF INPUT DATA FOR EXAMPLE 5

```
MUPDI3--REPORT EXAMPLE 5--9/29/71
      72.    4   15  12    2  13 100    0    1    1    1    1
    9.      18.      25.      27.      29.      35.      36.      37.      43.      45.
   47.      54.      63.
         1           18.      0.234    4    1
         2           36.      1.958    3    1
         1          0.854        0.     0.2552   550800.       0.15
         2          2.573        0.     0.1875   550800.       0.15
         3          2.573        0.     0.1615   432000.       0.15
         4             0.     1.539     0.2344   432000.       0.15
   1    1    2    1    8                                   1  1
   2    2    4    2    8                                   1  1
   3    4    6    2    8                                   1  1
   4    6    8    2    8                                   1  1
   5    8   10    2    8                                   1  1
   6   10   12    1    8                                   1  1
   7    3    2    4    8                                   1  1
   8    5    4    4    8                                   1  1
   9    7    6    4    8                                   1  1
  10    9    8    4    8                                   1  1
  11   11   10    4    8                                   1  1
  12    3    5    3    8                                   1  1
  13    5    7    3    8                                   1  1
  14    7    9    3    8                                   1  1
  15    9   11    3    8                                   1  1
   0
         1                                                          1  1  1
         2
         3
         4
         5
         6
         7
         8
         9
        10
        11
        12                                                          1  1  1
   2
         2                     100.                           18.         1.
         2                     100.                           54.         1.
  13    5
    9.      18.      25.      27.      29.      35.      36.      37.      43.      45.
   47.      54.      63.
   1    1    0   -0.687    -0.687
   2    1    2   -0.687    -0.687     1.286
   3    2    3   -0.687    -0.687     1.286
   4    3    4   -0.687    -0.687     1.286
   5    4    5   -0.687    -0.687     1.286
   6    5    0   -0.687    -0.687
   7    1    0    0.852    -0.687
   8    2    0    0.852    -0.687
   9    3    0    0.852    -0.687
  10    4    0    0.852    -0.687
  11    5    0    0.852    -0.687
  12    1    2    0.852     0.852     1.286
  13    2    3    0.852     0.852     1.286
```

```
14    3    4      0.852       0.852       1.286
15    4    5      0.852       0.852       1.286
  1    15    16       2       2       0
  1    0.432+6          0.15
  2   0.432+11          0.15
  1        3.02         2.52        0.595
  2        1.77         1.59        0.248
  1               0.854       1.539               2
  2               0.854                           3
  3               3.427       1.539               4
  4               3.427                           5
  5                  6.       1.539               6
  6                  6.                           7
  7               8.573       1.539               8
  8               8.573                           9
  9              11.146       1.539              10
 10              11.146                          11
 11               0.854         0.77
 12               3.427         0.77
 13                  6.         0.77
 14               8.573         0.77
 15              11.146         0.77
 16   111            6.       -2.667
  1    11    12       1       1
  2    12    13       1       1
  3    13    14       1       1
  4    14    15       1       1
  5     1    11       2       1
  6    11     2       2       1
  7     3    12       2       1
  8    12     4       2       1
  9     5    13       2       1
 10    13     6       2       1
 11     7    14       2       1
 12    14     8       2       1
 13     9    15       2       1
 14    15    10       2       1
 15     6    16       1       2
 1    1
    0.234        1.539          -1.    432000.        0.15
```

APPENDIX C

FORTRAN IV LISTING OF MUPDI3

Considerable time, effort and expense have gone into the development of this computer program. It is obvious that it should be used only under the conditions and assumptions for which it was developed. These are described in the report. Although the program has been extensively tested by the authors, no warranty is made regarding the accuracy and reliability of the program and no responsibility is assumed by the authors or the sponsors of this research project.

```
      OVERLAY(MASTER,0,0)
      PROGRAM     MUPDI3(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,
     1 TAPE2,TAPE3,TAPE4,TAPE7,TAPE8,TAPE9)
C
C*************************************************************************
C     LINEAR ELASTIC ANALYSIS FOR FOLDED PLATE STRUCTURES SIMPLY
C     SUPPORTED AT THE ENDS WITH RIGID OR FLEXIBLE INTERIOR DIAPHRAGMS
C     OR SUPPORT BENTS
C                             PROGRAMMED BY K.S.LO AND C.S.LIN
C                             UNIVERSITY OF CALIFORNIA, DECEMBER 1971
C*************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,TITLE(12),SPACE(941)
      COMMON/PERM/NDXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
      COMMON/FXDM/IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),
     1 XDOD(120),BF(3,120),IT
      COMMON/PARAM/NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(8)
     1 ,NUSPRG(8),NPT(8),NPR(80)
C
   11 FORMAT(12A6)
   15 FORMAT(1H1,12A6)
   12 FORMAT(F10.0,11I4)
C
  101 READ 11,(TITLE(I),I=1,12)
      READ 12,SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR
      IF(SPAN)999,999,102
  102 PRINT 15,(TITLE(I),I=1,12)
      CALL OVERLAY(6HMASTER,1,0)
      IF(NDIAPH.EQ.0) GO TO 110
      CALL OVERLAY(6HMASTER,2,0)
      IF(NBT.NE.0) CALL OVERLAY(6HMASTER,3,0)
      IF(NFMD.NE.0) CALL OVERLAY(6HMASTER,4,0)
      CALL OVERLAY(6HMASTER,5,0)
  110 CALL OVERLAY(6HMASTER,6,0)
      IF(KFOR.EQ.1) CALL OVERLAY(6HMASTER,7,0)
      GO TO 101
  999 STOP
      END
```

```
      OVERLAY(MASTER,1,0)
      PROGRAM    MAIN
C
C***********************************************************************
C     READ AND PRINT INPUT DATA. RESOLVE EXTERNAL LOADS AND UNIT
C     INTERACTION FORCES INTO HARMONIC COMPONENTS. ANALYZE THE PRIMARY
C     STRUCTURE FOR EACH HARMONIC.
C***********************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60),CF(120)
      COMMON/FOLD/DL(30),NPDIF(30),AJP(80),LJT(50),PTTT(80,81),A(4,4),
     1 FK,CONHL(50),CONVL(50),CONM(50),CONS(50),CONXI(50),CONDEL(50),
     2 BIGK(80,20),SMALLK(8,8,15),PTOT(80),P(8,15),SERIES(2),BTAV(4),
     3 RBAR(4),DUMMY(4763),L1,L2,DISP(80,81)
      COMMON/PERM/NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MDPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
      DIMENSION D(20),AJFOR(4,20),LIND(80)
      EQUIVALENCE (LIND,LCASE),(AJP,AJFOR),(D,DUMMY)
C
C     FORMAT STATEMENTS
C
    6 FORMAT (I6,4E16.6)
    8 FORMAT (I10,4F10.0)
    9 FORMAT (I10,5F10.0)
   10 FORMAT(94HOEXECUTION OF THE FORCE PROGRAM (INTERNAL FORCES AND DIS
     1PLACEMENTS IN FRAME BENT) IS REQUESTED)
   13 FORMAT (41HOCALCULATIONS SKIP ALL ODD FOURIER SERIES)
   14 FORMAT (42HOCALCULATIONS SKIP ALL EVEN FOURIER SERIES)
   15 FORMAT(41HOINTEGRATION OF GIRDER MOMENTS IS DESIRED)
   16 FORMAT(15HOSPAN LENGTH = F8.3/28HONUMBER OF TYPES OF PLATE = I2/
     1 22HONUMBER OF ELEMENTS = I3/20HONUMBER OF JOINTS = I3/24HONUMBER
     2OF DIAPHRAGMS =  I2/56HONUMBER OF X-COORDINATES AT WHICH RESULTS A
     3RE DESIRED = I2/27HOMAXIMUM HARMONIC NUMBER = I3/
     4 53HONUMBER OF TYPES OF FLEXIBLE SUPPORTING FRAME BENT = I2/
     5 49HONUMBER OF TYPES OF FLEXIBLE MOVABLE DIAPHRAGM = I2)
   17 FORMAT (10F7.3)
   18 FORMAT (////46H PRINT RESULTS AT CROSS-SECTIONS OF X EQUAL TO/(10F
     112.3))
   19 FORMAT (I10,6F10.0)
   20 FORMAT (5I4,3F10.0)
   21 FORMAT (93H1PL TYPE          H-PROJ.              V-PROJ.
     1 THICKNESS               E               V)
   22 FORMAT (I5,4E20.8,F10.3)
   23 FORMAT (74H1   ELE      I      J    PL  NSEC          DL          UNIF HL
     1     UNIF VL         )
   24 FORMAT (5I6,3F12.3    )
   25 FORMAT (35H1NUMBER OF PARTIAL SURFACE LOADS = I3//70H   ELE
     1   H-LOAD            V-LOAD            LOCATION        LOAD WIDTH)
```

```
   26 FORMAT (I6,6E16.6)
   27 FORMAT (I10,4F10.0,4I2,2X,3I2)
   28 FORMAT (39H1INPUT LOADS OR DISPLACEMENTS AT JOINTS//89X,21H RESTRA
     1INT CONDITIONS/86H JOINT        HORIZONTAL IH          VERTICAL IV
     2      ROTATIONAL IM      LONGITUDINAL IS 7X,13H RH   RV   RM)
   29 FORMAT (I6,4(E17.6,I3),5X,3I5)
   30 FORMAT (//37H IH,IV,IM,IS = 0 FOR GIVEN ZERO FORCE/44H
     1    1 FOR UNIF. DISTRIBUTED FORCE/81H                   2 MEANS CONC. F
     2ORCE AT MIDSPAN FOR IH, IV, IM AND PRESTRESS FOR IS/44H
     3    3 FOR GIVEN ZERO DISPLACEMENT)
   31 FORMAT (38H1NUMBER OF CONCENTRATED JOINT LOADS = I3//102H JOINT
     1        H-LOAD          V-LOAD           MOMENT     LONG. FORCE
     2    LOCATION       LOAD WIDTH)
   50 FORMAT(I10,2F10.0,2I4)
   51 FORMAT(/////76H DIAPHRAGM    LOCATION(X-COORD.)   INTERACT. THICK.
     1    CLASSIFICATION     TYPE/(I6,F20.4,F21.6,2I14))
   52 FORMAT(30HODIAPHRAGM CLASSIFICATION CODE/43H     1  EXTERNALLY SUPP
     1ORTED RIGID DIAPHRAGM/30H     2  MOVABLE RIGID DIAPHRAGM/37H     3
     2FLEXIBLE SUPPORTING FRAME BENT/33H     4  FLEXIBLE MOVABLE DIAPHRAG
     3M/42H TYPE NUMBER = 0 IF THE DIAPHRAGM IS RIGID)
   53 FORMAT (//60H RH,RV,RM =       0    - TO CONSIDER RESTRAINT FROM DIA
     1PHRAGMS/59H             NON-ZERO - TO NEGLECT RESTRAINT FROM DIAPHR
     2AGMS)
   60 FORMAT(2I4)
   61 FORMAT (//51H ERROR- INCOMPATIBLE X-COORDINATE FOR GIRDER MOMENT)
   62 FORMAT(3I4,3F10.0)
   63 FORMAT(1H1,70H ADDITIONAL INFORMATION FOR DETERMINATION OF GIRDER
     1MOMENT PERCENTAGES    ///,
     2 30H NO. OF SECTIONS FOR RESULTS = ,I6/,
     3 30H NO. OF GIRDERS               = ,I6)
   64 FORMAT(///29H RESULTS ARE DESIRED AT  X = /,(10F10.3))
   65 FORMAT(////56H ELE.NO.  BELONGS TO GIRDERS     DNAI       DNAJ
     1XDIV//(I6,8X,2I6,F12.3,F10.3,F10.3))
C
C      READ AND PRINT INPUT DATA
C
      PRINT 16,SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NBT,NFMD
      IF(NCHECK)103,105,104
  103 PRINT 13
      GO TO 105
  104 PRINT 14
  105 IF(MCHECK.EQ.1) PRINT 15
      IF(KFOR.EQ.1) PRINT 10
      READ 17,(XP(I),I=1,NXP)
      PRINT 18,(XP(I),I=1,NXP)
      IF(NDIAPH)802,802,801
  801 READ 50,(I,DIAPHX(I),DIADEL(I),KODIA(I),KDTP(I),J=1,NDIAPH)
      PRINT 51,(I,DIAPHX(I),DIADEL(I),KODIA(I),KDTP(I),I=1,NDIAPH)
      PRINT 52
  802 READ 9, (I,H(I),V(I),TH(I),E(I),FNU(I),J=1,NPL)
      READ 20,(I,NPI(I),NPJ(I),KPL(I),NSEC(I),DL(I),HL(I),VL(I),J=1,NEL)
      PRINT 21
      PRINT 22,(I,H(I),V(I),TH(I),E(I),FNU(I),I=1,NPL)
      PRINT 23
```

```
      PRINT24,(I,NPI(I),NPJ(I),KPL(I),NSEC(I),DL(I),HL(I),VL(I),I=1,NEL)
      READ 20, NSURL
      IF (NSURL) 107,107,106
  106 READ 8, (LEL(I),SURHL(I),SURVL(I),SURXI(I),SURDEL(I),I=1,NSURL)
      PRINT 25, NSURL
      PRINT 6,(LEL(I),SURHL(I),SURVL(I),SURXI(I),SURDEL(I),I=1,NSURL)
  107 DO 110 L=1,NJT
  110 READ 27, I,(AJFOR(J,I),J=1,4),(LCASE(K,I),K=1,4),(JFOR(M,I),M=1,3)
      PRINT 28
      DO 111 I=1,NJT
  111 PRINT 29,  I,(AJFOR(J,I),LCASE(J,I),J=1,4),(JFOR(K,I),K=1,3)
      PRINT 30
      PRINT 53
      READ 20, NCONL
      IF (NCONL) 109,109,108
  108 READ 19, (LJT(I),CONHL(I),CONVL(I),CONM(I),CONS(I),CONXI(I),CONDEL
     1(I),I=1,NCONL)
      PRINT 31, NCONL
      PRINT 26,(LJT(I),CONHL(I),CONVL(I),CONM(I),CONS(I),CONXI(I),CONDEL
     1(I),I=1,NCONL)
  109 CONTINUE
      IF (MCHECK) 1006,1006,1002
 1002 DO 1003 I=1,NEL
      IE=KPL(I)
      HS(I)=H(IE)
 1003 VS(I)=V(IE)
      READ 60,NOXMP,NBOX
      READ 17,(XMP(I),I=1,NOXMP)
      READ 62,(I,NGIEL(I,1),NGIEL(I,2),DNAI(I),DNAJ(I),XDIV(I),J=1,NEL)
      PRINT 63,NOXMP,NBOX
      PRINT 64,(XMP(I),I=1,NOXMP)
      PRINT 65,(I,NGIEL(I,1),NGIEL(I,2),DNAI(I),DNAJ(I),XDIV(I),I=1,NEL)
      DO 1010 I=1,NOXMP
      DO 1007 J=1,NXP
      IF(XP(J).EQ.XMP(I)) GO TO 1009
 1007 CONTINUE
      PRINT 61
      GO TO 1010
 1009 MOPX(I)=J
 1010 CONTINUE
      DO 1005 I=1,NOXMP
      DO 1005 J=1,NBOX
      BOXMOM(I,J)=0.
      COMP(I,J)=0.
 1005 TENS(I,J)=0.
 1006 CONTINUE
C
      PI=3.14159265
      MX=4*NJT
      IF (NDIAPH) 803,803,804
  803 CHPLRE=1.
      MPC1=1
      GO TO 122
C
```

```
C      FIND X AND Y COORDINATES WITH ORIGIN AT JOINT 1
C
  804 XORD(1)=0.
      YORD(1)=0.
      NPDIF(1)=-1
      DO 113 I=2,NJT
  113 NPDIF(I)=1
      II=1
  114 DO 118 K=1,NEL
      L=KPL(K)
      I=NPI(K)
      J=NPJ(K)
      IF (NPDIF(I)+NPDIF(J)) 118,115,118
  115 IF (NPDIF(I)+1) 116,116,117
  116 XORD(J)=XORD(I)+H(L)
      YORD(J)=YORD(I)+V(L)
      NPDIF(J)=-1
      II=II+1
      GO TO 118
  117 XORD(I)=XORD(J)-H(L)
      YORD(I)=YORD(J)-V(L)
      NPDIF(I)=-1
      II=II+1
  118 CONTINUE
      IF(II-NJT)114,122,114
C
C      COMPUTE PLATE WIDTH (PWTH) AND SET H=H/PWTH, V=V/PWTH
C
  122 DO 125 I=1,NPL
      PWTH(I)=SQRT(H(I)**2+V(I)**2)
      H(I)=H(I)/PWTH(I)
  125 V(I)=V(I)/PWTH(I)
C
C      MODIFY SUR. LOADS FOR ELE.(VL=ZL,HL=YL) AND CHECK FOR MAX. BAND WI
C         ALSO SET NPI=NPI*4-4, NPJ=NPJ*4-4
C
      NXBAND=0
      DO 130 I=1,NEL
      J=KPL(I)
      VL(I)=VL(I)*ABS(H(J))+DL(I)
      HL(I)=HL(I)*ABS(V(J))
      ZL=VL(I)*H(J)+HL(I)*V(J)
      YL=VL(I)*V(J)-HL(I)*H(J)
      VL(I)=ZL
      HL(I)=YL
      NPDIF(I)=NPJ(I)-NPI(I)
      K=IABS(NPDIF(I))
      IF (NXBAND-K) 126,127,127
  126 NXBAND=K
  127 NPI(I)=NPI(I)*4-4
  130 NPJ(I)=NPJ(I)*4-4
      MAXJTD=NXBAND
      NXBAND=NXBAND*4+4
C
```

```
C     MODIFY PARTIAL SURFACE LOADS (VL=ZL,HL=YL)
C
      IF (NSURL) 135,135,132
  132 DO 133 I=1,NSURL
      K=LEL(I)
      J=KPL(K)
      SURVL(I)=SURVL(I)*ABS(H(J))
      SURHL(I)=SURHL(I)*ABS(V(J))
      ZL=SURVL(I)*H(J)+SURHL(I)*V(J)
      YL=SURVL(I)*V(J)-SURHL(I)*H(J)
      SURVL(I)=ZL
  133 SURHL(I)=YL
C
C     MODIFY LCASE (LIND) MATRIX AND PRESTRESS FORCES
C
  135 DO 136 I=1,MX
  136 LIND(I)=LIND(I)+1
      DO 138 I=1,NJT
      IF (LCASE(4,I)-3) 138,137,138
  137 LCASE(4,I)=LCASE(4,I)+2
      AJFOR(4,I)=AJFOR(4,I)*4./SPAN
  138 CONTINUE
C
C     SET UP INDMP MATRIX AND MPC,MPC1,MPCOL
C
      IF (NDIAPH) 540,540,805
  805 MPCOL=0
      DO 523 I=1,NJT
      DO 523 J=1,3
      IF (LCASE(J,I)-4) 521,520,521
  520 JFOR(J,I)=1
      GO TO 523
  521 IF (JFOR(J,I)) 523,522,523
  522 MPCOL=MPCOL+1
      INDMP(MPCOL)=(I-1)*4+J
  523 CONTINUE
      MPC1=MPCOL+1
      MPC=MPCOL
C
C     CYCLE FOR EACH HARMONIC IS INITIATED
C
  540 REWIND 3
      IF (NCHECK) 140,141,142
  140 N1=2
      GO TO 143
  141 N1=1
      N2=1
      GO TO 144
  142 N1=1
  143 N2=2
C
  144 DO 700 NN=N1,MHARM,N2
      DO 145 J=1,NXBAND
      DO 145 I=1,MX
```

```
  145 BIGK(I,J) = 0.
C
C     SPAN AND K ARE GENERALIZED
C
      FN=NN
      FK=FN*PI/SPAN
C
C     FOURIER MULTIPLIERS ARE COMPUTED
C
      N3=(-1)**NN
      IF (N3) 152,155,155
  152 SERIES(1)=4./(FN*PI)
      SERIES(2)=2./SPAN*(-1.)**((NN+3)/2)
C
C   STIFFNESS AND COEFF MATRICES OF EACH PLATE IS COMPUTED BY SUBROUTINE
C
  155 CALL KPLOAD
C
C     ASSEMBLE BIGK MATRIX
C
      DO 210 L=1,NEL
      K=KPL(L)
      M=NPI(L)
      N=NPJ(L)
      DO 201 I=1,4
      II=M+I
      IJ=N+I
      IK=I+4
      DO 201 J=1,4
      BIGK(II,J)=BIGK(II,J)+SMALLK(I,J,K)
  201 BIGK(IJ,J)=BIGK(IJ,J)+SMALLK(IK,J+4,K)
      IF (NPDIF(L)) 205,202,202
  202 IK=N-M-4
      DO 203 I=1,4
      II=M+I
      DO 203 J=5,8
      IJ=IK+J
  203 BIGK(II,IJ)=BIGK(II,IJ)+SMALLK(I,J,K)
      GO TO 210
  205 IK=M-N
      N=N-4
      DO 206 I=5,8
      II=N+I
      DO 206 J=1,4
      IJ=IK+J
  206 BIGK(II,IJ)=BIGK(II,IJ)+SMALLK(I,J,K)
  210 CONTINUE
C
C     COMPUTE AND ASSEMBLE FIXED END FORCES FOR ELE. BY SUBROUTINE FIXFO
C
      DO 215 I=1,MX
  215 PTOT(I)=0.0
      IF (N3) 211,221,221
  211 DO 220 L=1,NEL
```

```
      K=KPL(L)
  220 CALL  FIXFOR (H(K),V(K),HL(L),VL(L),NPI(L),NPJ(L),P,15,PTOT,80,K)
C
C     COMPUTE AND ASSEMBLE FIXED END FORCES FOR PARTIAL SURFACE LOADS
C
  221 IF (NSURL) 231,231,222
  222 DO 230 I=1,NSURL
      L=LEL(I)
      K=KPL(L)
C     FIND EQUIVALENT UNIF. LOAD FOR THIS HARMONIC
      IF (SURDEL(I)) 223,224,223
  223 C=SIN(FK*SURXI(I))*SIN(FK*SURDEL(I)/2.)
      GO TO 225
  224 C=SIN(FK*SURXI(I))*FK/2.
  225 EQH=SURHL(I)*C
      EQV=SURVL(I)*C
  230 CALL  FIXFOR (H(K),V(K),EQH,EQV,NPI(L),NPJ(L),P,15,PTOT,80,K)
C
C     CALCULATE INPUT JOINT LOADS AND SUBTRACT FIXED END FORCES
C
  231 IF (N3) 232,239,239
  232 DO 238 I=1,MX
      K=LIND(I)
      GO TO (233,234,235,238,236),K
  233 PTOT(I)=-PTOT(I)
      GO TO 238
  234 PTOT(I)=AJP(I)*SERIES(1)-PTOT(I)
      GO TO 238
  235 PTOT(I)=AJP(I)*SERIES(2)-PTOT(I)
      GO TO 238
  236 PTOT(I)=AJP(I)-PTOT(I)
  238 CONTINUE
      GO TO 241
  239 DO 240 I=1,MX
C
C     ADD CONCENTRATED JOINT LOADS
C
  240 PTOT(I)=-PTOT(I)
  241 IF (NCONL) 251,251,242
  242 DO 250 I=1,NCONL
      J=LJT(I)*4-4
      C=FK*CONXI(I)
      IF (CONDEL(I)) 244,244,243
  243 XX=FK*CONDEL(I)/2.
      EQH=2./(XX*SPAN)*SIN(XX)
      EQS=EQH*COS(C)
      EQH=EQH*SIN(C)
      GO TO 245
  244 XX=2./SPAN
      EQH=XX*SIN(C)
      EQS=XX*COS(C)
  245 PTOT(J+1)=PTOT(J+1)+EQH*CONHL(I)
      PTOT(J+2)=PTOT(J+2)+EQH*CONVL(I)
      PTOT(J+3)=PTOT(J+3)+EQH*CONM(I)
```

```
  250 PTOT(J+4)=PTOT(J+4)+EQS*CONS(I)
C
C     SET UP PTTT MATRIX (WITH 1'S AND 0'S), LAST VECTOR FOR EXTERNAL LO
C
  251 IF (NDIAPH) 650,650,630
  630 DO 645 J=1,MPCOL
      DO 640 I=1,MX
  640 PTTT(I,J)=0.0
      K=INDMP(J)
  645 PTTT(K,J)=1.0
C
  650 DO 651 I=1,MX
C
C     CHECK FOR GIVEN 0 DISPL. AND MODIFY BIGK, PTOT MATRICES
C
  651 PTTT(I,MPC1)=PTOT(I)
      DO 260 J=1,NJT
      DO 260 I=1,4
      IF (LCASE(I,J)-4) 260,252,260
  252 IL=(J-1)*4+I
      DO 253 L=1,NXBAND
  253 BIGK(IL,L)=0.0
      DO 254 L=1,MPC1
  254 PTTT(IL,L)=0.
      K=J-MAXJTD
      L=MAX0(K,1)
      DO 255 M=L,J
      N=(J-M)*4+I
      II=(M-1)*4
      DO 255 IJ=1,4
      IK=II+IJ
  255 BIGK(IK,N)=0.0
      BIGK(IL,I)=1.0
  260 CONTINUE
C
C     INVERT DIAGONAL K AND MODIFY BIGK AND PTTT FOR BACKSUBSTITUTION
C
      N=0
  300 N=N+1
      IL=N*4
      L=IL-4
      DO 301 I=1,4
      K=I+L
      DO 301 J=1,4
  301 A(I,J)=BIGK(K,J)
      CALL SYMINV(A,4,4)
      K=NJT-N
      IF (K) 400,400,302
C
  302 M=MIN0(K,MAXJTD)
      IK=M*4
      DO 305 I=1,4
      II=I+L
      DO 305 J=1,4
```

```
  305 BIGK(II,J)=A(I,J)
C
      J=0
      DO 340 IM=1,M
      DO 340 IN=1,4
      J=J+1
      IJ=J+4
C
      DO 320 I=1,4
  320 BTAV(I)=BIGK(L+1,IJ)*A(1,I)+BIGK(L+2,IJ)*A(2,I)+BIGK(L+3,IJ)*
     1A(3,I)+BIGK(L+4,IJ)*A(4,I)
C
      K=J+IL
      DO 330 I=1,MPC1
  330 PTTT(K,I)=PTTT(K,I)-(BTAV(1)*PTTT(L+1,I)+BTAV(2)*PTTT(L+2,I)
     1+BTAV(3)*PTTT(L+3,I)+BTAV(4)*PTTT(L+4,I))
C
      IS=0
      IU=IM*4-3
      DO 340 I=IU,IK
      IT=I+4
      IS=IS+1
      BIGK(K,IS)=BIGK(K,IS)-(BTAV(1)*BIGK(L+1,IT)+BTAV(2)*BIGK(L+2,IT)
     1+BTAV(3)*BIGK(L+3,IT)+BTAV(4)*BIGK(L+4,IT))
  340 CONTINUE
      GO TO 300
C
C     START BACKSUBSTITUTION AND SOLVE FOR UNKNOWN JOINT DISPLACEMENTS
C
C     L=IL-4      SEE AFTER STATEMENT 300
  400 DO 403 K=1,MPC1
      RBAR(1)=PTTT(L+1,K)
      RBAR(2)=PTTT(L+2,K)
      RBAR(3)=PTTT(L+3,K)
      RBAR(4)=PTTT(L+4,K)
      DO 403 I=1,4
      J=I+L
  403 DISP(J,K)=A(I,1)*RBAR(1)+A(I,2)*RBAR(2)+A(I,3)*RBAR(3)+A(I,4)*
     1 RBAR(4)
C     N=NJT        FROM STATEMENT 300
  410 N=N-1
      IF (N) 440,440,411
  411 M=MINO((NJT-N),MAXJTD)*4+4
      IN=N*4
      IL=IN-4
      IM=IL+1
      DO 425 K=1,MPC1
      DO 415 I=5,M
      J=I+IL
  415 D(I)=DISP(J,K)
      DO 420 I=1,4
      II=IL+I
      C=0.0
      DO 418 J=5,M
```

```
  418 C=C+BIGK(II,J)*D(J)
  420 RBAR(I)=PTTT(II,K)-C
      DO 425 I=IM,IN
  425 DISP(I,K)=BIGK(I,1)*RBAR(1)+BIGK(I,2)*RBAR(2)+BIGK(I,3)*RBAR(3)
     1 +BIGK(I,4)*RBAR(4)
      GO TO 410
C
C     WRITE DISP ON TAPE 3
C
  440 WRITE (3) ((DISP(I,J),I=1,MX),J=1,MPC1)
  700 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE KPLOAD
C
C*****************************************************************************
C     COMPUTE STIFFNESS,FIXED END FORCES,INTERNAL DISPLACEMENTS DUE TO
C     UNIT EDGE DISPLACEMENTS AND UNIT CORRECTIVE FORCES FOR EACH TYPE
C     OF PLATE
C*****************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20)
      COMMON/FOLD/DL(30),NPDIF(30),AJP(80),LJT(50),PTTT(80,81),A(4,4),
     1 FK,CONHL(50),CONVL(50),CONM(50),CONS(50),CONXI(50),CONDEL(50),
     2 BIGK(80,20),SMALLK(8,8,15),PTOT(80),P(8,15),SERIES(2),BTAV(4),
     3 RBAR(4),DUMMY(4763),L1,L2,DISP(80,81)
      DIMENSION SK(8,8),SKA(8,8)
      DIMENSION D(15),B(15),SM(8,8,15)
C
      EQUIVALENCE (FK,WPI),(SPAN,PL),(D,PWTH),(B,TH),(SM,SMALLK),
     1 (DUMMY,SK),(DUMMY(65),SKA)
C
      WPI2=WPI**2
      WPI3=WPI**3
C
      DO 100 L=1,NPL
      U=FNU(L)
      HD=H(L)
      VD=V(L)
C
C      COMPUTAT+ON CONSTANTS A-E FO-MED
C
      D1=E(L)*B(L)**3/(12.*(1.-U**2))
      D2=E(L)*B(L)/((1.+U)**2)*WPI
      G=WPI*D(L)
      EG=EXP(-G)
      EG2=EG*EG
      C=1.+EG2
      CS=1.-EG2
      EG=EG*2.
      G=G*EG
      CC=EG+C
      SS=C-EG
      G1=G+CS
      G2=G-CS
      G3=(3.-U)*CS/(1.+U)
      G4=G-G3
      G3=G+G3
C
C     DISPLACEMENT TRANSFORMATION MATRIX
C     DO 516 I=1,8
```

```
C      DO 516 J=1,8
C 516  A(I,J)=0.
C      A(1,3)=1.
C      A(2,7)=1.
C      A(3,1)=-VD
C      A(3,2)=-HD
C      A(4,5)=VD
C      A(4,6)=HD
C      A(5,4)=1.
C      A(6,8)=1.
C      A(7,1)=-HD
C      A(7,2)=VD
C      A(8,5)=HD
C      A(8,6)=-VD
C
C      STIFFNESS MATRIX FOR SINGLE PLATE IS LOADED
C
       SK(1,1)=+D1*WPI*(CC/G1-SS/G2)
       SK(1,2)=-D1*WPI*(CC/G1+SS/G2)
       SK(1,3)=+D1*WPI2*(CS/G1-CS/G2-1.+U)
       SK(1,4)=-D1*WPI2*(CS/G1+CS/G2)
       SK(2,1)=SK(1,2)
       SK(2,2)=SK(1,1)
       SK(2,3)=SK(1,4)
       SK(2,4)=SK(1,3)
       SK(3,1)=SK(1,3)
       SK(3,2)=SK(1,4)
       SK(3,3)=+D1*WPI3*(SS/G1-CC/G2)
       SK(3,4)=-D1*WPI3*(SS/G1+CC/G2)
       SK(4,1)=SK(1,4)
       SK(4,2)=SK(1,3)
       SK(4,3)=SK(3,4)
       SK(4,4)=SK(3,3)
       SK(5,5)=+D2*(-SS/G4+CC/G3)
       SK(5,6)=-D2*(SS/G4+CC/G3)
       SK(5,7)=-D2*(CS/G4-CS/G3+1.+U)
       SK(5,8)=-D2*(CS/G4+CS/G3)
       SK(6,5)=SK(5,6)
       SK(6,6)=SK(5,5)
       SK(6,7)=SK(5,8)
       SK(6,8)=SK(5,7)
       SK(7,5)=SK(5,7)
       SK(7,6)=SK(5,8)
       SK(7,7)=+D2*(-CC/G4+SS/G3)
       SK(7,8)=-D2*(CC/G4+SS/G3)
       SK(8,5)=SK(5,8)
       SK(8,6)=SK(5,7)
       SK(8,7)=SK(7,8)
       SK(8,8)=SK(7,7)
C
C      STIFFNESS MATRIX * TRANSFORMATION MATRIX
C
       DO 10 I=1,4
       J=I+4
```

```
      SKA(I,1)=-SK(I,3)*VD
      SKA(I,2)=-SK(I,3)*HD
      SKA(I,3)= SK(I,1)
      SKA(I,4)= 0.0
      SKA(I,5)= SK(I,4)*VD
      SKA(I,6)= SK(I,4)*HD
      SKA(I,7)= SK(I,2)
      SKA(I,8)= 0.0
      SKA(J,1)=-SK(J,7)*HD
      SKA(J,2)= SK(J,7)*VD
      SKA(J,3)= 0.0
      SKA(J,4)= SK(J,5)
      SKA(J,5)= SK(J,8)*HD
      SKA(J,6)=-SK(J,8)*VD
      SKA(J,7)= 0.0
   10 SKA(J,8)= SK(J,6)
C
C     TRANSPOSED TRANSFORMATION MATRIX*STIFFNESS*TRANSFORMATION MATRIX
C
      DO 20 I=1,8
      SM(1,I,L)=-SKA(3,I)*VD-SKA(7,I)*HD
      SM(2,I,L)=-SKA(3,I)*HD+SKA(7,I)*VD
      SM(3,I,L)= SKA(1,I)
      SM(4,I,L)= SKA(5,I)
      SM(5,I,L)= SKA(4,I)*VD+SKA(8,I)*HD
      SM(6,I,L)= SKA(4,I)*HD-SKA(8,I)*VD
      SM(7,I,L)= SKA(2,I)
   20 SM(8,I,L)= SKA(6,I)
C
C     CALCULATE FIXED END FORCES FOR ZL=1, YL=1
C
   30 P(1,L)=4.*(2.*CS/G1-1.)/(WPI3*PL)
      P(2,L)=-P(1,L)
      P(3,L)=8.*SS/(G1*WPI2*PL)
      P(4,L)=-P(3,L)
      BB=4.0/((1.+U)*WPI2*PL)
      P(6,L)=BB*(4.*CS/G3-1.-U)
      P(5,L)=-P(6,L)
      P(8,L)=4.*BB*SS/G3
      P(7,L)=-P(8,L)
  100 CONTINUE
  200 RETURN
      END
```

```
      SUBROUTINE FIXFOR (HD,VD,YL,ZL,NPI,NPJ,P,M,PTOT,N,K)
C
C***********************************************************************
C     COMPUTE AND ASSEMBLE FIXED END FORCES INTO PTOT MATRIX
C***********************************************************************
C
      DIMENSION P(8,M),PTOT(N)
C
      PTOT(NPI+1)=PTOT(NPI+1)-VD*ZL*P(3,K)-HD*YL*P(7,K)
      PTOT(NPI+2)=PTOT(NPI+2)-HD*ZL*P(3,K)+VD*YL*P(7,K)
      PTOT(NPI+3)=PTOT(NPI+3)+ZL*P(1,K)
      PTOT(NPI+4)=PTOT(NPI+4)+YL*P(5,K)
      PTOT(NPJ+1)=PTOT(NPJ+1)+VD*ZL*P(4,K)+HD*YL*P(8,K)
      PTOT(NPJ+2)=PTOT(NPJ+2)+HD*ZL*P(4,K)-VD*YL*P(8,K)
      PTOT(NPJ+3)=PTOT(NPJ+3)+ZL*P(2,K)
      PTOT(NPJ+4)=PTOT(NPJ+4)+YL*P(6,K)
      RETURN
      END
```

```
      SUBROUTINE SYMINV(A,NMAX,NSIZE)
C
C***************************************************************************
C       INVERSE A SYMMETRICAL MATRIX
C***************************************************************************
C
      DIMENSION A(NSIZE,NSIZE)
C
      DO 5 N=1,NMAX
    5 A(N,1)=A(1,N)
C
   20 DO 160 N=1,NMAX
   30 PIVOT=A(N,N)
   40 A(N,N)=-1.
   50 DO 60 J=1,NMAX
   60 A(N,J)=A(N,J)/PIVOT
   80 DO 145 I=1,NMAX
   90 IF(N-I) 95,145,95
   95 IF(A(I,N)) 100,145,100
  100 DO 140 J=I,NMAX
  110 IF(N-J) 120,140,120
  120 A(I,J)=A(I,J)-A(I,N)*A(N,J)
  130 A(J,I)=A(I,J)
  140 CONTINUE
  145 CONTINUE
  150 DO 160 I=1,NMAX
  160 A(I,N)=A(N,I)
C
  163 DO 165 I=1,NMAX
  164 DO 165 J=1,NMAX
  165 A(I,J)=-A(I,J)
  250 RETURN
      END
```

```
      OVERLAY(MASTER,2,0)
      PROGRAM    FORMF
C
C*********************************************************************
C     FORM THE FLEXIBILITY MATRIX (FMAT) DUE TO RESTRAINING FORCES FROM
C     THE DIAPHRAGMS OR BENTS
C*********************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20)
      COMMON/FOLD/FMAT(120,120),DINP(120),L1,L2,DISP(80,81)
C
      DIMENSION SINKX(12),D(12)
C
C     INITIATION AND SET F MATRIX = 0
C
      KK=MPC*NDIAPH
      DO 144 I=1,KK
      DINP(I)=0.
      DO 144 J=1,KK
  144 FMAT(I,J)=0.0
      REWIND 3
C
C     CYCLE FOR EACH HARMONIC IS INITIATED
C
      DO 700 NN=N1,MHARM,N2
      FN=NN
      FK=FN*PI/SPAN
C
C     FIND UNIT LOADS' COEFFICIENTS AND HARMONIC MULTIPLIERS
C
  440 DO 450 I=1,NDIAPH
      S=SIN(FK*DIAPHX(I))
      IF (DIADEL(I)) 444,444,443
  443 XX=FK*DIADEL(I)/2.
      D(I)=2./(XX*SPAN)*SIN(XX)*S
      GO TO 450
  444 XX=2./SPAN
      D(I)=XX*S
  450 SINKX(I)=S
C
C     READ DISP FROM TAPE 3
C
      READ (3) ((DISP(I,J),I=1,MX),J=1,MPC1)
C
C     CALCULATE AND SUM UP FMAT AND DINP MATRICES
C
  500 CALL SIMSUM (SINKX,D)
  700 CONTINUE
```

```
CALL CORF1
RETURN
END
```

```
      SUBROUTINE SIMSUM (SINKX,D)
C
C***********************************************************************
C     CALCULATE AND SUM UP FMAT AND DINP MATRICES
C***********************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60)
      COMMON/FOLD/FMAT(120,120),DINP(120),L1,L2,DISP(80,81)
      DIMENSION SINKX(12),D(12)
C
  500 DO 510 I=1,MPCOL
      K=INDMP(I)
      DO 510 J=1,MPC1
  510 DISP(I,J)=DISP(K,J)
C
      IF(NDIAPH.EQ.1) GO TO 530
  520 DO 522 L=2,NDIAPH
      C=SINKX(L)
      C1=SINKX(1)*D(L)
      C2=SINKX(L)*D(1)
      M=(L-1)*MPCOL
      DO 522 I=1,MPCOL
      K=M+I
      DINP(K)=DINP(K)+DISP(I,MPC1)*C
      DO 522 J=1,MPCOL
      FMAT(K,J)=FMAT(K,J)+DISP(I,J)*C2
  522 FMAT(J,K)=FMAT(J,K)+DISP(J,I)*C1
      DO 524 M=2,NDIAPH
      IM=(M-1)*MPCOL
      DO 524 N=2,NDIAPH
      IN=(N-1)*MPCOL
      C=SINKX(M)*D(N)
      DO 524 I=1,MPCOL
      K=IM+I
      DO 524 J=1,MPCOL
      L=IN+J
  524 FMAT(K,L)=FMAT(K,L)+DISP(I,J)*C
  530 C=SINKX(1)*D(1)
      C1=SINKX(1)
      DO 535 I=1,MPCOL
      DINP(I)=DINP(I)+DISP(I,MPC1)*C1
      DO 535 J=1,MPCOL
  535 FMAT(I,J)=FMAT(I,J)+DISP(I,J)*C
      RETURN
      END
```

```
      SUBROUTINE CORF1
C
C***********************************************************************
C     FIND THE TRANSFORMED FMAT AND DINP MATRICES
C***********************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60)
      COMMON/FOLD/FMAT(120,120),DINP(120),L1,L2,DISP(80,81)
C
      COMMON/FXDM/IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),
     1 XDOD(120),BF(3,120),IT
      DIMENSION JNUM(2),B(3,120),
     1 KB12(3),SD(3),BT(3,120),                             SFM(3,120),
     2 DD(4,20),KK(3)
C
      EQUIVALENCE (JNUM(1),JN1),(SFM,BT)
C
   43 FORMAT (////45H INITIAL DISPLACEMENTS AT POINTS OF RESTRAINT/
     1 (I4,E17.8,4(I7,E17.8)))
C
C
C     PRINT INITIAL DISPLACEMENTS
C
      K=MPC*NDIAPH
  100 PRINT 43, (I,DINP(I),I=1,K)
C
C     CHANGE SIGN OF INITIAL DISPLACEMENTS
  200 DO 201 I=1,K
C
C     CHECK DIAPHRAGMS WHICH ARE EXTERNALLY SUPPORTED
C
  201 DINP(I)=-DINP(I)
      II=0
      DO 210 I=1,NDIAPH
      IF(KODIA(I).EQ.2.OR.KODIA(I).EQ.4) GO TO 210
      II=II+1
      NDIA(II)=I
  210 CONTINUE
C
C     CHECK IF ALL DIAPHRAGMS ARE EXTERNALLY SUPPORTED
C
      IF(NDIA(II).EQ.II) GO TO 800
C
C     GENERATING INITIAL CONNECTIONS
C
  300 KK(1)=0
      KK(2)=0
      KK(3)=0
```

```
      DO 1000 I=1,NJT
      DO 1000 J=1,3
      IF(LCASE(J,I).EQ.4) GO TO 1010
 1000 CONTINUE
      GO TO 1050
 1010 JN1=I
      JN2=0
      IC(1,1)=1
      IC(2,1)=1
      IC(3,1)=1
      KK(J)=1
      IF(J.EQ.3) GO TO 1030
      JJ=J+1
      DO 1020 LB=JJ,3
      IF(LCASE(LB,I).EQ.4) KK(LB)=1
 1020 CONTINUE
 1030 II=I+1
      DO 1040 IB=II,NJT
      DO 1040 LD=1,3
      IF(LCASE(LD,IB).EQ.4) KK(LD)=1
 1040 CONTINUE
      IF (KK(1)*KK(2)*KK(3).EQ.1) GO TO 800
      GO TO 400
C
 1050 DO 1060 I=1,NJT
      IF (JFOR(2,I).EQ.0) GO TO 1070
 1060 CONTINUE
 1070 JN1=I
      JJ=JN1+1
      C1=XORD(JN1)
      CT=0.
      IC(2,1)=1
      JN2=JJ
      IF(JFOR(1,JN1).EQ.0) GO TO 1090
      IC(1,1)=0
      DO 1080 I=JJ,NJT
      IF(JFOR(1,I).NE.0.OR.JFOR(2,I).NE.0) GO TO 1080
      CT1=ABS(XORD(I)-C1)
      IF (CT1.LE.CT) GO TO 1080
      CT=CT1
      JN2=I
 1080 CONTINUE
      GO TO 1110
 1090 IC(1,1)=1
      DO 1100 I=JJ,NJT
      IF (JFOR(2,I).NE.0) GO TO 1100
      CT1=ABS(XORD(I)-C1)
      IF(CT1.LE.CT) GO TO 1100
      CT=CT1
      JN2=I
 1100 CONTINUE
 1110 IC(2,2)=1
      IF (IC(1,1).EQ.1) GO TO 1120
      IC(1,2)=1
```

```
      C2=YORD(JN2)
      GO TO 1130
 1120 IC(1,2)=0
      C2=YORD(JN1)
 1130 IC(3,1)=0
      IC(3,2)=0
      IBTYPE=2
      GO TO 509
C
C     TO FORM TRANSFORMATION MATRIX
C
  400 IBTYPE=1
      C1=XORD(JN1)
      C2=YORD(JN1)
      I=0
      DO 410 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      B(1,J)=-1.
      B(1,J1)=0.
      B(1,J2)=0.
      B(2,J)=0.
      B(2,J1)=-1.
      B(2,J2)=0.
      B(3,J)=YORD(I)-C2
      B(3,J1)=XORD(I)-C1
  410 B(3,J2)=-1.
      DO 415 I=1,MPCOL
      J=INDMP(I)
      DO 415 K=1,3
  415 B(K,I)=B(K,J)
C
  460 K=0
      DO 465 I=1,NJT
      IF (I-JN1) 463,466,463
  463 DO 465 J=1,3
      IF (JFOR(J,I)) 465,464,465
  464 K=K+1
      INDB(K)=K
  465 CONTINUE
  466 KB=0
      L=K
      DO 480 J=1,3
      IF (JFOR(J,JN1)) 480,470,480
  470 L=L+1
      IF (IC(J,1)) 473,471,473
  471 K=K+1
      INDB(K)=L
      GO TO 480
  473 KB=KB+1
      KB12(KB)=L
      DO 474 M=1,MPC
  474 B(KB,M)=B(J,M)
```

```
  480 CONTINUE
      GO TO 700
C
C
  509 CC=XORD(JN2)-C1
      IF (ABS(CC).LE.0.00001) GO TO 490
      C=1./CC
      GO TO 510
  490 JN2=0
      IC(1,1)=1
      IC(2,1)=1
      IC(3,1)=1
      GO TO 400
C
  510 I=0
      DO 518 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      BT(2,J)=-(YORD(I)-C2)*C
      BT(2,J1)=-(XORD(I)-C1)*C
      GO TO (518,513),IBTYPE
C
  513 BT(3,J)=-1.
      BT(1,J)=-BT(2,J)
      BT(1,J1)=-BT(2,J1)-1.
      BT(3,J1)=0.
  515 BT(1,J2)=-C
      BT(2,J2)=C
  518 BT(3,J2)=0.
      DO 519 I=1,MPCOL
      J=INDMP(I)
      DO 519 K=1,3
  519 BT(K,I)=BT(K,J)
C
  560 K=0
      L=0
      KB=0
      II=1
      DO 580 IT=1,2
      IJ=JNUM(IT)
      DO 565 I=II,NJT
      IF (I-IJ) 563,566,563
  563 DO 565 J=1,3
      IF (JFOR(J,I)) 565,564,565
  564 L=L+1
      K=K+1
      INDB(K)=L
  565 CONTINUE
  566 DO 579 J=1,3
      IF (JFOR(J,IJ)) 579,570,579
  570 L=L+1
      IF (IC(J,IT)) 572,571,572
  571 K=K+1
```

```
      INDB(K)=L
      GO TO 579
  572 KB=KB+1
      KB12(KB)=L
      GO TO (579,573),IBTYPE
C
  573 GO TO (574,576),J
  574 DO 575 M=1,MPC
  575 B(KB,M)=BT(3,M)
      GO TO 579
  576 DO 577 M=1,MPC
  577 B(KB,M)=BT(IT,M)
  579 CONTINUE
      II=JN1+1
  580 CONTINUE
C
  700 MBCOL=MPC-KB
      IF (K-MBCOL) 710,730,710
  710 K=K+1
      DO 720 I=K,MBCOL
      J=I+KB
  720 INDB(I)=J
  730 DO 740 I=1,MBCOL
      J=INDB(I)
      DO 740 K=1,KB
  740 B(K,I)=B(K,J)
C
C     FIND B TRANSPOSE * FMAT AND B TRANSPOSE * DINP
C
      IT=NDIAPH*MPC
      II=1
      DO 766 I=1,NDIAPH
      IF (II-NDIA(I)) 768,765,768
  765 II=II+1
  766 KTEM(I+1)=MPC*I
C
  768 IJ=(II-1)*MPC
      IK=II
      IL=IJ
      DO 778 IS=II,NDIAPH
C
      IF (NDIA(IK)-IS) 772,769,772
  769 IK=IK+1
      DO 771 J=1,MPC
      K=J+IJ
      M=J+IL
      DO 770 L=1,IT
  770 FMAT(K,L)=FMAT(M,L)
  771 DINP(K)=DINP(M)
      IJ=IJ+MPC
      GO TO 777
C
  772 DO 774 I=1,KB
      J=KB12(I)+IL
```

```
      SD(I)=DINP(J)
      DO 774 K=1,IT
  774 SFM(I,K)=FMAT(J,K)
C
      DO 776 I=1,MBCOL
      M=I+IJ
      K=INDB(I)+IL
      DO 775 J=1,IT
      FMAT(M,J)=FMAT(K,J)
      DO 775 L=1,KB
  775 FMAT(M,J)=FMAT(M,J)+B(L,I)*SFM(L,J)
      DINP(M)=DINP(K)
      DO 776 L=1,KB
  776 DINP(M)=DINP(M)+B(L,I)*SD(L)
      IJ=IJ+MBCOL
  777 IL=IL+MPC
      KTEM(IS+1)=IJ
  778 CONTINUE
      KTEM(1)=0
C
C     FIND B TRANSPOSE* FMAT * B
C
      IT=IJ
      IJ=(II-1)*MPC
      IL=IJ
      IK=II
      DO 798 IS=II,NDIAPH
C
      IF (NDIA(IK)-IS) 792,789,792
  789 IK=IK+1
      DO 791 J=1,MPC
      K=J+IJ
      M=J+IL
      DO 791 L=1,IT
  791 FMAT(L,K)=FMAT(L,M)
      IJ=IJ+MPC
      GO TO 797
C
  792 DO 794 I=1,KB
      J=KB12(I)+IL
      DO 794 K=1,IT
  794 SFM(I,K)=FMAT(K,J)
C
      DO 796 I=1,MBCOL
      M=I+IJ
      K=INDB(I)+IL
      DO 796 J=1,IT
      FMAT(J,M)=FMAT(J,K)
      DO 796 L=1,KB
  796 FMAT(J,M)=FMAT(J,M)+SFM(L,J)*B(L,I)
      IJ=IJ+MBCOL
  797 IL=IL+MPC
  798 CONTINUE
      GO TO 801
```

```
  800 IT=NDIAPH*MPC
      DO 802 I=1,NDIAPH
  802 KTEM(I)=(I-1)*MPC
      KTEM(NDIAPH+1)=IT
C
C     SAVE INFORMATION ON TAPE 1
C
  801 REWIND 1
      WRITE(1) ((FMAT(I,J),I=1,IT),J=1,IT),(DINP(I),I=1,IT),KB12,B,KB
      RETURN
      END
```

```
      OVERLAY(MASTER,3,0)
      PROGRAM    FRAME
C
C*****************************************************************************
C     ANALYZE EACH TYPE OF FRAME BENTS BY DIRECT STIFFNESS METHOD. STORE
C     THE FLEXIBILITY MATRICES AND ELEMENT INFORMATION ON TAPES.
C*****************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12)
      COMMON/PARAM/NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(8)
     1 ,NUSPRG(8),NPT(8),NPR(80)
      COMMON/FBENT/EFM(10),G(10),
     1 LM(6),SA(6,6),ASA(6,6),T(3,3),          S(6,6),RF(6),JK(3),
     2 NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(80),
     3 COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),
     4 NPQ(80),          NFP(80),A(120,120)
      DIMENSION HHH(14400),LSIZE(8)
      EQUIVALENCE (HHH,A)
C
C     READ AND PRINT CONTROL DATA
C
      WRITE(6,900)
      REWIND 4
      REWIND 7
      REWIND 9
      DO 290 MCOUNT=1,NBT
    1 READ  (5,1000) NFT,NUMEL,NUMNP,NUMMAT,NUMETP,NUMSPR
      WRITE (6,2000) NFT,NUMEL,NUMNP,NUMMAT,NUMETP,NUMSPR
C
C     READ AND PRINT MATERIAL PROPERTY DATA
C
      WRITE (6,2001)
      DO 10 I=1,NUMMAT
      READ (5,1001)N,EFM(N),G(N)
      WRITE(6,2002)N,EFM(N),G(N)
   10 G(N)=0.5*EFM(N)/(1.0+G(N))
C
C     READ AND PRINT STIFFNESS OF ELASTIC SUPPORTS
C
      IF(NUMSPR .EQ. 0) GO TO 50
      WRITE (6,2007)
      DO 40 I=1,NUMSPR
      READ  (5,1003) N,(SP(N,J),J=1,3)
   40 WRITE (6,2008) N,(SP(N,J),J=1,3)
   50 CONTINUE
C
C     READ AND PRINT GEOMETRIC PROPERTIES OF COMMON ELEMENTS.
C
```

```
      WRITE (6,2003)
      DO 30 I=1,NUMETP
      READ  (5,1002) N,COAX(N),COAY(N),COAAZ(N)
      IF((COAX(N).NE.0.0).AND. (COAAZ(N).NE.0.0)) GO TO 20
      WRITE (6,2013)
      CALL EXIT
   20 WRITE (6,2004) N,COAX(N),COAY(N),COAAZ(N)
   30 CONTINUE
C
C     READ AND PRINT NODAL POINT DATA
C
      WRITE (6,2005)
   60 READ(5,1004)(N,KODE(N),X(N),Y(N),NPSTP(N),NFP(N),I=1,NUMNP)
      WRITE(6,2006)(N,KODE(N),X(N),Y(N),NPSTP(N),NFP(N),N=1,NUMNP)
C
C     SET UP NPQ AND NPR ARRAYS
C
      INK=NUMNP+1
      INM=0
      DO 80 N=1,NUMNP
      IF(NFP(N).EQ.0) GO TO 79
      INM=INM+1
      NPQ(INM)=N
      GO TO 80
   79 INK=INK-1
      NPQ(INK)=N
   80 CONTINUE
      DO 84 N=2,INM
      NN1=N-1
      DO 83 MM=1,NN1
      M=N-MM
      M1=M+1
      NA=NPQ(M1)
      NB=NPQ(M)
      IF(NFP(NA).GT.NFP(NB))GO TO 84
      NPQ(M1)=NB
      NPQ(M)=NA
   83 CONTINUE
   84 CONTINUE
      DO 85 I=1,NUMNP
      J=NPQ(I)
      NPR(J)=I
   85 CONTINUE
C
C     SET UP ID ARRAY(ROW NO. OF DEGREES OF FREEDOM ELIMINATED)
C
      NP=0
      DO 87 N=1,INM
      NA=NPQ(N)
      NB=NFP(NA)
      NN1=N-1
      DO 87 M=1,3
      IF(JFOR(M,NB).EQ.0) GO TO 87
      NP=NP+1
```

```
      ID(NP)=3*NN1+M
   87 CONTINUE
      INM1=INM+1
      DO 90 N=INM1,NUMNP
      NN1=N-1
      DO 90 M=1,3
      NP=NP+1
      ID(NP)=3*NN1+M
   90 CONTINUE
C
C     FORM STIFFNESS FOR EACH ELEMENT
C
      REWIND 2
      CALL ELSTIF
C
C     ADD ELEMENT STIFFNESS TO STRUCTURE STIFFNESS
C
      CALL STIFF (A,120)
C
C     STATIC CONDENSATION
C
      CALL STACON (A,ID,IQ,NEQ,120,NP)
C
C     STORE ELASTIC SUPPORT DATA ON TAPE 4
C
      IF (NUMSPR.EQ.0) GO TO 210
      WRITE(4)(NPSTP(I),I=1,NUMNP)
      WRITE(4)((SP(I,J),I=1,NUMSPR),J=1,3)
C
C     INVERSE THE STIFFNESS MATRIX
C
  210 NMAX=NEQ-NP
      CALL SYMINV (A,NMAX,120)
C
C     STORE THE FLEXIBILITY MATRIX ON TAPE 9
C
  266 WRITE(9)((A(I,J),J=1,NMAX),I=1,NMAX)
      NUMELT(NFT)=NUMEL
      NUMNPT(NFT)=NUMNP
      NEQN(NFT)=NEQ
      NUSPRG(NFT)=NUMSPR
      NPT(NFT)=NP
  290 CONTINUE
C
C     STORE INFORMATION ACCORDING TO THE SEQUENCE OF THE BENT
C
      REWIND 2
      REWIND 7
      DO 410 I=1,NBT
      NUMEL=NUMELT(I)
      DO 400 J=1,NUMEL
      K1=1+(J-1)*87
      K2=K1+86
  400 READ(7)(HHH(K),K=K1,K2)
```

```
      K3=NUMEL*90
      WRITE(2)(HHH(K),K=1,K3)
  410 CONTINUE
      REWIND 7
      DO 415 I=1,NDIAPH
      IF(KODIA(I).NE.3) GO TO 415
      REWIND 2
      IN=KDTP(I)
      IF(IN.EQ.1) GO TO 413
      DO 412 J=2,IN
  412 READ(2) HH
  413 NUMEL=NUMELT(IN)
      K3=NUMEL*87
      READ(2)(HHH(K),K=1,K3)
      DO 414 L=1,NUMEL
      K1=1+(L-1)*87
      K2=K1+86
  414 WRITE(7)(HHH(K),K=K1,K2)
  415 CONTINUE
      REWIND 2
      REWIND 4
      DO 500 I=1,NBT
      NEQ=NEQN(I)
      NUMNP=NUMNPT(I)
      NP=NPT(I)
      NUMSPR=NUSPRG(I)
      READ(4)(HHH(J),J=1,NEQ)
      L=NEQ+1
      L1=NEQ-NP
      L2=NEQ
      DO 490 M=1,NP
      L2=L2+L1
      READ(4)(HHH(J),J=L,L2)
      L=L2+1
      L1=L1+1
  490 CONTINUE
      IF(NUMSPR.EQ.0) GO TO 495
      L2=L+NUMNP-1
      READ(4)(HHH(J),J=L,L2)
      L=L2+1
      L2=L+3*NUMSPR-1
      READ(4)(HHH(J),J=L,L2)
  495 WRITE(2)(HHH(J),J=1,L2)
      LSIZE(I)=L2
  500 CONTINUE
      REWIND 4
      DO 520 I=1,NDIAPH
      IF(KODIA(I).NE.3) GO TO 520
      REWIND 2
      IN=KDTP(I)
      IF(IN.EQ.1) GO TO 513
      DO 512 J=2,IN
  512 READ(2) HH
  513 CONTINUE
```

```
      ISIZE=LSIZE(I)
      READ(2)(HHH(J),J=1,ISIZE)
      NEQ=NEQN(IN)
      NP=NPT(IN)
      NUMNP=NUMNPT(IN)
      NUMSPR=NUSPRG(IN)
      WRITE(4)(HHH(J),J=1,NEQ)
      L=NEQ+1
      L1=NEQ-NP
      L2=NEQ
      DO 515 M=1,NP
      L2=L2+L1
      WRITE(4)(HHH(J),J=L,L2)
      L=L2+1
  515 L1=L1+1
      IF(NUMSPR.EQ.0) GO TO 520
      L2=L+NUMNP-1
      WRITE(4)(HHH(J),J=L,L2)
      L=L2+1
      L2=L+3*NUMSPR-1
      WRITE(4)(HHH(J),J=L,L2)
  520 CONTINUE
      REWIND 2
      DO 550 I=1,NDIAPH
      IF(KODIA(I).NE.3) GO TO 550
      REWIND 9
      IN=KDTP(I)
      IF(IN.EQ.1) GO TO 546
      DO 545 J=2,IN
  545 READ(9) HH
  546 NMAX=NEQN(IN)-NPT(IN)
      N=NMAX*NMAX
      READ(9)(HHH(J),J=1,N)
      NN1=1
      NN2=NMAX
      DO 547 L=1,NMAX
      WRITE(2)(HHH(J),J=NN1,NN2)
 2017 FORMAT (6E20.8)
      NN1=NN1+NMAX
  547 NN2=NN2+NMAX
  550 CONTINUE
      RETURN
C
  900 FORMAT(37H1FRAME BENT PROGRAM IS TO BE EXECUTED/19H INPUT DATA FOL
     1LOWS)
 1000 FORMAT(6I5)
 1001 FORMAT(I5,E10.0,F10.0)
 1002 FORMAT(I5,3F10.0)
 1003 FORMAT(I5,3F10.0)
 1004 FORMAT(2I5,2F10.0,2I5)
 2000 FORMAT(34H2FRAME BENT TYPE NUMBER               =I6/
     1 34H NUMBER OF ELEMENTS               =I6/
     2 34H NUMBER OF NODAL POINTS           =I6/
     3 34H NUMBER OF MATERIALS              =I6/
```

```
    4 34H NUMBER OF ELEMENT TYPES          =I6/
    5 34H NUMBER OF ELASTIC SUPPORT TYPES =I6////)
2001 FORMAT(50H1MATERIAL   YOUNG S     POISSON S
    1      /50H            MODULUS       RATIO                          )
2002 FORMAT(1H ,I5,3X,E13.4,F14.5)
2003 FORMAT(1H1/
    1  60H ELEMENT        AXIAL        SHEAR    MOMENT OF
    2 /60H  TYPE          AREA         AREA     INERTIA                 )
2004 FORMAT(1H ,I5,3X,3F12.3)
2005 FORMAT(1H1,
    1  39H FRAME              NODAL COORDINATES
    2  54H       ELASTIC SUPPORT     CORRESPONDING NODE            /
    3  10H NODE CODE,7X,1HX,11X,1HY,20X,4HTYPE,14X,15HIN FOLDED PLATE)
2006 FORMAT(1H ,I4,I5,2F12.3,2I20)
2007 FORMAT(1H1/
    1  60H              SPRING CONSTANTS OF ELASTIC SUPPORTS            /
    2 /60H            LINEAR            LINEAR         ROTATIONAL       /
    3  60H  TYPE  STIFFNESS  X    STIFFNESS  Y    STIFFNESS  Z          )
2008 FORMAT(1H ,I4,3F16.3)
2009 FORMAT(26H0NODAL POINT CARD ERROR N= I5)
2012 FORMAT (50H0PROBLEMS COMPLETED OR CONTROL CARD ERROR               )
2013 FORMAT(1H0/
    1  60H AXIAL AREA OR FLEXURAL INERTIA CANNOT BE SPECIFIED AS ZERO.)
2014 FORMAT (10I5)
     END
```

```
      SUBROUTINE ELSTIF
C
C***********************************************************************
C     FORM ELEMENT STIFFNESS FOR ONE DIMENSIONAL ELEMENT
C***********************************************************************
C
      COMMON/PARAM/NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(8)
     1 ,NUSPRG(8),NPT(8),NPR(80)
      COMMON/FBENT/EFM(10),G(10),
     1 LM(6),SA(6,6),ASA(6,6),T(3,3),           S(6,6),RF(6),JK(3),
     2 NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(80),
     3 COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),
     4 NPQ(80),           NFP(80),A(120,120)
C
C     INITIALIZATION
C
      NEQ=3*NUMNP
      DO 10 I=1,6
      S(I,1)=0.0
      S(4,I)=0.0
   10 S(I,4)=0.0
      T(3,3)= 1.0
      DO 20 I=1,2
      T(3,I)=0.0
   20 T(I,3)=0.0
C
C     READ AND PRINT ELEMENT DATA
C
      WRITE (6,4000)
  400 READ (5,3000) NEL,NI,NJ,MATTYP,MELTYP,NELKOD
      SIJ=4.0
      SJI=4.0
      CIJ=0.5
      WRITE (6,4001) NEL,NI,NJ,MATTYP,MELTYP,NELKOD
C
   78  AX= COAX(MELTYP)
       AY= COAY(MELTYP)
      AAZ=COAAZ(MELTYP)
C
      DX=X(NJ)-X(NI)
      DY=Y(NJ)-Y(NI)
      DL=SQRT(DX*DX+DY*DY)
      IF(DL) 75,75,76
   75 WRITE (6,4005) NEL
      CALL EXIT
   76 COSA=DX/DL
      SINA=DY/DL
C
C     DETERMINE IF SHEAR DEFORMATIONS ARE TO BE INCLUDED.
C
      SHF=0.0
      IF(AY.NE.0.0)SHF=6.*EFM(MATTYP)*AAZ/(G(MATTYP)*AY*DL*DL)
      COMM=EFM(MATTYP)*AAZ/DL
```

```
      SHEF=0.5*(2.+SHF)/(1.+2.*SHF)
      COMM=COMM*SHEF
      SIJ=SIJ*COMM
      SJI=SJI*COMM
      CIJ=(CIJ-0.5*SHF)/(1.+0.5*SHF)
      CJI=CIJ*SIJ/SJI
C
C
C     FORM GLOBAL TO LOCAL COORDINATE TRANSFORMATION.
C
      T(1,1)= COSA
      T(1,2)=-SINA
      T(2,1)= SINA
      T(2,2)= COSA
C
C     FORM ELEMENT STIFFNESS IN LOCAL COORDINATES
C
      S(1,1)=AX*EFM(MATTYP)/DL
      S(4,1)=-S(1,1)
      S(3,2)=-SIJ*(1.+CIJ)/DL
      S(6,2)=-SJI*(1.+CJI)/DL
      S(2,2)=-(S(3,2)+S(6,2))/DL
      S(5,2)=-S(2,2)
      S(3,3)= SIJ
      S(6,3)= CIJ*SIJ
      S(5,3)= (S(3,3)+S(6,3))/DL
      S(4,4)= S(1,1)
      S(5,5)=-S(5,2)
      S(6,5)=-S(6,2)
      S(6,6)= SJI
      DO 110 I=1,5
      M=I+1
      DO 110 J=M,6
  110 S(I,J)=S(J,I)
C
C     MODIFY ELEMENT STIFFNESS FOR KNOWN ZERO MEMBER END FORCES
C
      IF(NELKOD .EQ. 0) GO TO 145
      KK=NELKOD
      KD=100000
      DO 140 I=1,6
      IF(KK-KD) 140,120,120
  120 SII=S(I,I)
      DO 125 N=1,6
  125 SA(1,N)=S(I,N)
      DO 130 M=1,6
      COF=S(M,I)/SII
      DO 130 N=1,6
  130 S(M,N)=S(M,N)-COF*SA(1,N)
      KK=KK-KD
  140 KD=KD/10
C
C     OBTAIN SA(6,6) RELATING ELEMENT END FORCES (LOCAL) AND JOINT
C     DISPLACEMENTS (GLOBAL).
```

```
C
  145 DO 150 I=1,6
      DO 150 J=1,3
      SA(I,J)  =0.0
      SA(I,J+3)=0.0
      DO 150 K=1,3
      IF(T(K,J) .EQ. 0.0) GO TO 150
      SA(I,J)  =SA(I,J)  +S(I,K)   *T(K,J)
      SA(I,J+3)=SA(I,J+3)+S(I,K+3)*T(K,J)
  150 CONTINUE
C
C     OBTAIN ELEMENT STIFFNESS ASA(6,6) IN GLOBAL COORDINATES
C
      DO 160 I=1,3
      DO 160 J=1,6
      ASA(I,J)  =0.0
      ASA(I+3,J)=0.0
      DO 160 K=1,3
      IF(T(K,I) .EQ. 0.0) GO TO 160
      ASA(I+3,J)=ASA(I+3,J)+T(K,I)*SA(K+3,J)
      ASA(I,J)  =ASA(I,J)  +T(K,I)*SA(K,J)
  160 CONTINUE
C
C     FORM LOCAL LOCATION MATRIX FOR ELEMENT
C
      NMI=NPR(NI)
      NMJ=NPR(NJ)
      DO 170 M=1,3
      J=M-3
      LM(M)=3*NMI+J
  170 LM(M+3)=3*NMJ+J
C
C     MODIFY GLOBAL STIFFNESS AND BOUNDARY CONDITIONS FOR KNOWN JOINT
C     DISPLACEMENTS
C
      JK(1)=KODE(NI)
      JK(2)=KODE(NJ)
      DO 240 N=1,2
      KD=100
      KK=JK(N)
      DO 240 M=1,3
      I=3*(N-1)+M
      II=LM(I)
      IF (KK-KD) 240,190,190
  190 DO 230 K=1,6
      ASA(I,K)=0.0
  230 ASA(K,I)=0.0
      ASA(I,I)=1.0
      KK=KK-KD
  240 KD=KD/10
C
C     STORE ELEMENT INFORMATION ON TAPE 2
C
      WRITE (2) (LM(I),I=1,87)
```

```
C
      WRITE(7)(LM(I),I=1,87)
      IF (NUMEL-NEL) 402,500,400
  402 WRITE (6,4003) NEL
      CALL EXIT
  500 RETURN
C
 3000 FORMAT(5I5,I10)
 4000 FORMAT(1H1/
     1  60H ELEMENT   NODE   NODE  MATERIAL   ELEMENT   ELEMENT
     2 /60H             I      J     TYPE       TYPE      CODE          )
 4001 FORMAT(1H ,I5,I7,I6,I8,I10,I11)
 4003 FORMAT(36H0ELEMENT CARD ERROR, ELEMENT NUMBER= I6)
 4004 FORMAT(1H ,31HNODAL POINT NUMBERS FOR ELEMENT,I5,36HARE IDENTICAL.
     1 EXECUTION TERMINATED.)
 4005 FORMAT(8H0ELEMENT,I5,39H HAS ZERO LENGTH. EXECUTION TERMINATED.)
      END
```

```
      SUBROUTINE STIFF (A,ND)
C
C***********************************************************************
C     ASSEMBLE THE TOTAL FRAME BENT STIFFNESS MATRIX
C***********************************************************************
C
      COMMON/PARAM/NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(8)
     1 ,NUSPRG(8),NPT(8),NPR(80)
      COMMON/FBENT/EFM(10),G(10),
     1 LM(6),SA(6,6),ASA(6,6),T(3,3),          S(6,6),RF(6),JK(3),
     2 NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(80),
     3 COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),
     4 NPQ(80),         NFP(80)
      DIMENSION A(ND,ND)
C
C     INITIALIZATION
C
      DO 10 I=1,NEQ
      DO 10 J=1,NEQ
   10 A(I,J)=0.0
C
C     ADD ELEMENT STIFFNESS TO STRUCTURE STIFFNESS
C
      REWIND 2
      DO 30 N=1,NUMEL
      READ (2) (LM(I),I=1,87)
      DO 20 I=1,6
      II=LM(I)
      DO 20 J=1,6
      JJ=LM(J)
      IF( JJ .LE. 0 ) GO TO 20
      A(II,JJ)=A(II,JJ)+ASA(I,J)
   20 CONTINUE
   30 CONTINUE
C
C     ADD STIFFNESS OF ELASTIC FOUNDATION TO STRUCTURE STIFFNESS
C
      IF ( NUMSPR .EQ. 0 ) GO TO  37
      DO 36 J=1,NUMNP
      MSPR=NPSTP(J)
      IF (MSPR .EQ. 0)  GO TO 36
      DO 35 K=1,3
      KJ=3*(J-1)+K
   35 A(KJ,1)=A(KJ,1)+SP(MSPR,K)
   36 CONTINUE
   37 RETURN
      END
```

```
      SUBROUTINE STACON (A,ID,IQ,N,ND,NP)
C
C*****************************************************************************
C     STATIC CONDENSATION ROUTINE TO ELIMINATE CERTAIN DEGREES OF
C              FREEDOM FROM A SYMMETRIC SYSTEM OF EQUATIONS
C
C                              -  INPUT  -
C     N    - NUMBER OF EQUATIONS
C     NP   - NUMBER OF DEGREES OF FREEDOM TO BE ELIMINATED
C     ND   - NUMBER OF ROWS IN DIMENSION STATEMENT OF MATRIX  A
C     A    - COEFFICIENT MATRIX OF ORDER N
C     B    - LOAD VECTOR OF ORDER N
C     ID   - ARRAY CONTAINING ROW NUMBERS OF DEGREES OF FREEDOM
C            TO BE ELIMINATED
C
C                              -  OUTPUT  -
C
C     A    - REDUCED COEFFICIENT MATRIX OF ORDER N-NP
C     B    - REDUCED LOAD VECTOR OF ORDER N-NP
C     IQ   - ARRAY CONTAINING SEQUENCE OF UNKNOWNS IN REDUCED SYSTEM
C            OF EQUATIONS
C*****************************************************************************
C
      DIMENSION A(ND,N),ID(NP),IQ(N)
C
C     SET UP  IQ-ARRAY
C
      DO 5 I=1,N
    5 IQ(I)=I
C
C     INTERCHANGE ROWS
C
      DO 30 I=1,NP
      II=NP-I+1
      IJ=ID(II)
      KI=N-I+1
      IF(KI.EQ.IJ) GO TO 30
      MKI=KI-1
      DO 10 J=1,N
      X=A(IJ,J)
      DO 6 M=IJ,MKI
      ML=M+1
    6 A(M,J)=A(ML,J)
   10 A(KI,J)=X
C
C     INTERCHANGE COLUMNS
C
      DO 20 J=1,N
      X=A(J,IJ)
      DO 19 M=IJ,MKI
      ML=M+1
   19 A(J,M)=A(J,ML)
   20 A(J,KI)=X
```

```
      IX=IQ(IJ)
      DO 21 M=IJ,MKI
      ML=M+1
   21 IQ(M)=IQ(ML)
      IQ(KI)=IX
   30 CONTINUE
C
C     STORE IQ ON TAPE 4
C
      WRITE(4)(IQ(I),I=1,N)
C
C     STATIC CONDENSATION
C
      DO 50 M=1,NP
      K=N-M
      L=K+1
      DO 40 I=1,K
      A(L,I)=A(L,I)/A(L,L)
      DO 40 J=I,K
      A(J,I)=A(J,I)-A(L,I)*A(J,L)
   40 A(I,J)=A(J,I)
   50 CONTINUE
C
C     STORE STIFFNESS COEFF. OF ELIMINATED DEG. OF FREEDOM ON TAPE 4
C
      K=N-NP+1
      DO 60 I=K,N
      L=I-1
   60 WRITE(4)(A(I,J),J=1,L)
C
      RETURN
      END
```

```
      SUBROUTINE SYMINV (A,NMAX,NSIZE)
C
C*****************************************************************************
C     INVERSE A SYMMETRIC MATRIX
C*****************************************************************************
C
      DIMENSION A(NSIZE,NSIZE)
C
      DO 5 N=1,NMAX
    5 A(N,1)=A(1,N)
C
   20 DO 160 N=1,NMAX
   30 PIVOT=A(N,N)
   40 A(N,N)=-1.
   50 DO 60 J=1,NMAX
   60 A(N,J)=A(N,J)/PIVOT
   80 DO 145 I=1,NMAX
   90 IF(N-I) 95,145,95
   95 IF(A(I,N)) 100,145,100
  100 DO 140 J=I,NMAX
  110 IF(N-J) 120,140,120
  120 A(I,J)=A(I,J)-A(I,N)*A(N,J)
  130 A(J,I)=A(I,J)
  140 CONTINUE
  145 CONTINUE
  150 DO 160 I=1,NMAX
  160 A(I,N)=A(N,I)
C
  163 DO 165 I=1,NMAX
  164 DO 165 J=1,NMAX
  165 A(I,J)=-A(I,J)
  250 RETURN
      END
```

```
      OVERLAY(MASTER,4,0)
      PROGRAM    FLEXD
C
C*************************************************************************
C     ANALYZE EACH TYPE OF THE FLEXIBLE MOVABLE DIAPHRAGMS BY FORCE
C     METHOD. STORE THE FLEXIBILITY MATRICES ON TAPES.
C*************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60)
      COMMON/FXDM/IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),
     1 XDOD(120),BF(3,120)
      DIMENSION FE(3,3),FLE(120,120),TB(3),D1(8),D2(8),D3(8),HHH(14400)
      EQUIVALENCE(FLE,HHH)
   10 FORMAT(2I4)
   12 FORMAT(46H1PROPERTIES OF THE FLEXIBLE MOVABLE DIAPHRAGMS)
   13 FORMAT(33H3FLEXIBLE MOVABLE DIAPHRAGM TYPE ,I3)
   15 FORMAT(6F10.0)
   20 FORMAT (1H0,8X,9HTHICKNESS,11X,5HDEPTH,13X,12HNEUTRAL AXIS,11X,1HE
     1,16X,1HV/4E20.8,F10.3)
   30 FORMAT(20H0  MOMENT OF INERTIA,10X,4HAREA,13X,10HSHEAR AREA,10X,12
     1HNEUTRAL AXIS, 13X,1HE,14X,1HV/5E20.8,F10.3)
C
C     READ DIAPHRAGM PROPERTIES
C
      PRINT 12
      DO 90 I=1,NFMD
      READ 10,IN,MOP
      PRINT 13,IN
      GO TO(60,70),MOP
   60 READ 15,DITH,DIDP,CODE,DIE,DINU
      CC=0.5*CODE*DIDP
      PRINT 20,DITH,DIDP,CC,DIE,DINU
      DIPHA=DITH*DIDP
      DIPHI=DIPHA*DIDP*DIDP/12.
      DIAS=DIPHA/1.2
      GO TO 80
   70 READ 15,DIPHI,DIPHA,DIAS,CC,DIE,DINU
      PRINT 30,DIPHI,DIPHA,DIAS,CC,DIE,DINU
      DIDP=SQRT(12.*DIPHI/DIPHA)
C
C     CALCULATE CONSTANTS
C
   80 D1(I)=1./(DIPHA*DIE)
      D3(I)=1./(12.*DIE*DIPHI)
      IF(DIAS.EQ.0.) GO TO 85
      D2(I)=24.*(1.+DINU)*DIPHI/DIAS
      GO TO 90
   85 D2(I)=0.
```

```
   90 CONTINUE
C
C      GENERATE COORDINATES OF THE BEAM ELEMENTS
C
  100 K=0
      DO 150 L=1,NEL
      I=NPI(L)/4+1
      J=NPJ(L)/4+1
      IF(JFOR(1,I)*JFOR(2,I)*JFOR(3,I).NE.0) GO TO 110
      K=K+1
      XDOD(K)=XORD(I)
  110 IF(JFOR(1,J)*JFOR(2,J)*JFOR(3,J).NE.0) GO TO 150
      K=K+1
      XDOD(K)=XORD(J)
  150 CONTINUE
      EPSI=0.01*DIDP
      HGH=-99999.
      IBM=0
      DO 200 I=1,K
      G=XDOD(I)
      N=I
      J=I+1
      IF (J.GT.K) GO TO 180
      DO 170 M=J,K
      IF (XDOD(M).GE.G) GO TO 170
      G=XDOD(M)
      N=M
  170 CONTINUE
      XDOD(N)=XDOD(I)
  180 IF((G-HGH).LE.EPSI) GO TO 200
      IBM=IBM+1
      XDOD(IBM)=G
      HGH=G
  200 CONTINUE
C
C      TO FORM FORCE TRANSFORMATION MATRIX
C
      REWIND 9
      DO 210 I=1,MBCOL
      DO 210 J=1,MBCOL
  210 FLE(I,J)=0.
      DO 215 L=1,NFMD
  215 WRITE(9)((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
      IF(JN2)220,220,230
  220 C1=XORD(JN1)
      C2=C1
      C4=YORD(JN1)
      GO TO 270
  230 IF(IC(1,1).EQ.1) GO TO 250
      C4=YORD(JN2)
      IF (XORD(JN2).GT.XORD(JN1)) GO TO 240
      IFTYPE=1
      C1=XORD(JN2)
      C2=XORD(JN1)
```

```
      GO TO 270
  240 IFTYPE=2
      C1=XORD(JN1)
      C2=XORD(JN2)
      GO TO 270
  250 C4=YORD(JN1)
      IF (XORD(JN1).GT.XORD(JN2)) GO TO 260
      IFTYPE=1
      C1=XORD(JN1)
      C2=XORD(JN2)
      GO TO 270
  260 IFTYPE=2
      C1=XORD(JN2)
      C2=XORD(JN1)
  270 EPSI=0.5*EPSI
      IBM1=IBM-1
      KTAPE=-1
      DO 610 JK=1,IBM1
      KTAPE=-KTAPE
      X1=XDOD(JK)-C1
      X2=XDOD(JK+1)-C1
      I=0
      IF (X1.LE.-EPSI) GO TO 370
      C3=C2-C1
      IF (X1.GE.(C3-EPSI)) GO TO 340
      GO TO (280,310),IFTYPE
  280 IMTYPE=3
      DO 300 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      YY=YORD(I)-C4
      IF (XX.LE.(X1+EPSI)) GO TO 290
      BF(1,J)=1.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=CC-C4-(YY*X1/C3)
      BF(2,J1)=(1.-XX/C3)*X1
      BF(2,J2)=X1/C3
      BF(3,J)=CC-C4-YY*X2/C3
      BF(3,J1)=(1.-XX/C3)*X2
      BF(3,J2)=X2/C3
      GO TO 300
  290 BF(1,J)=0.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=(C3-X1)*YY/C3
      BF(2,J1)=(C3-X1)*XX/C3
      BF(2,J2)=(X1-C3)/C3
      BF(3,J)=(C3-X2)*YY/C3
      BF(3,J1)=(C3-X2)*XX/C3
      BF(3,J2)=(X2-C3)/C3
  300 CONTINUE
```

```
      GO TO 410
 310  IMTYPE=4
      DO 330 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      YY=YORD(I)-C4
      IF (XX.LE.(X1+EPSI)) GO TO 320
      BF(1,J)=0.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=-YY*X1/C3
      BF(2,J1)=(1.-XX/C3)*X1
      BF(2,J2)=X1/C3
      BF(3,J)=-YY*X2/C3
      BF(3,J1)=(1.-XX/C3)*X2
      BF(3,J2)=X2/C3
      GO TO 330
 320  BF(1,J)=-1.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=-CC+C4+YY*(1.-X1/C3)
      BF(2,J1)=XX*(1.-X1/C3)
      BF(2,J2)=-1.+X1/C3
      BF(3,J)=-CC+C4+YY*(1.-X2/C3)
      BF(3,J1)=XX*(1.-X2/C3)
      BF(3,J2)=-1.+X2/C3
 330  CONTINUE
      GO TO 410
 340  IMTYPE=2
      DO 360 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      IF (XX.GE.(X2-EPSI)) GO TO 350
      DO 345 L=1,3
      BF(L,J)=0.
      BF(L,J1)=0.
      BF(L,J2)=0.
 345  CONTINUE
      GO TO 360
 350  BF(1,J)=1.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=CC-YORD(I)
      BF(2,J1)=X1-XX
      BF(2,J2)=1.
      BF(3,J)=BF(2,J)
      BF(3,J1)=X2-XX
      BF(3,J2)=1.
 360  CONTINUE
      GO TO 410
```

```
  370 IMTYPE=1
      DO 400 J=1,MX,4
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      IF (XX.LE.(X1+EPSI)) GO TO 390
      DO 380 L=1,3
      BF(L,J)=0.
      BF(L,J1)=0.
      BF(L,J2)=0.
  380 CONTINUE
      GO TO 400
  390 BF(1,J)=-1.
      BF(1,J1)=0.
      BF(1,J2)=0.
      BF(2,J)=YORD(I)-CC
      BF(2,J1)=XX-X1
      BF(2,J2)=-1.
      BF(3,J)=BF(2,J)
      BF(3,J1)=XX-X2
      BF(3,J2)=-1.
  400 CONTINUE
C
  410 DO 420 I=1,MPCOL
      J=INDMP(I)
      DO 420 K=1,3
  420 BF(K,I)=BF(K,J)
C
  570 DO 580 I=1,MBCOL
      J=INDB(I)
      DO 580 K=1,3
  580 BF(K,I)=BF(K,J)
C
C     FIND AND SUM UP B TRANSPOSE * F * B
C
      S=XDOD(JK+1)-XDOD(JK)
      REWIND 8
      REWIND 9
      IF (KTAPE.LT.0) GO TO 584
      MTAPE=9
      NTAPE=8
      GO TO 585
  584 MTAPE=8
      NTAPE=9
  585 DO 610 L=1,NFMD
      FE(1,1)=S*D1(L)
      FE(1,2)=0.
      FE(1,3)=0.
      FE(2,1)=0.
      PHI=D2(L)/S
      FE(2,2)=(4.*S+PHI)*D3(L)
      FE(2,3)=(2.*S-PHI)*D3(L)
      FE(3,1)=0.
```

```
      FE(3,2)=FE(2,3)
      FE(3,3)=FE(2,2)
      READ(MTAPE)((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
      DO 600 I=1,MBCOL
      DO 590 J=1,3
      TB(J)=0.
      DO 590 K=1,3
  590 TB(J)=TB(J)+BF(K,I)*FE(K,J)
      DO 600 J=1,MBCOL
      DO 600 K=1,3
  600 FLE(I,J)=FLE(I,J)+TB(K)*BF(K,J)
      WRITE(NTAPE)((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
  610 CONTINUE
C
      IF(NTAPE.EQ.9) GO TO 620
      REWIND 8
      REWIND 9
      DO 615 L=1,NFMD
      READ(8)((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
  615 WRITE(9)((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
C
C     STORE FLEXIBILITY MATRICES ON TAPE 8
C
  620 REWIND 8
      DO 650 I=1,NDIAPH
      IF(KODIA(I).NE.4) GO TO 650
      REWIND 9
      IN=KDTP(I)
      N=MBCOL*MBCOL
      IF(IN.EQ.1) GO TO 646
      DO 645 J=2,IN
  645 READ(9) HH
  646 READ(9)(HHH(J),J=1,N)
      NN1=1
      NN2=MBCOL
      DO 647 L=1,MBCOL
      WRITE(8)(HHH(J),J=NN1,NN2)
      NN1=NN1+MBCOL
  647 NN2=NN2+MBCOL
  650 CONTINUE
      RETURN
      END
```

```
      OVERLAY(MASTER,5,0)
      PROGRAM    CORF2
C
C*****************************************************************************
C     SUM UP THE FLEXIBILITY MATRICES OF THE FOLDED PLATES, THE FLEXIBLE
C     BENTS AND THE FLEXIBLE MOVABLE DIAPHRAGMS. SOLVE FOR THE CORREC-
C     TIVE FORCES.
C*****************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60),CF(120)
      COMMON/FOLD/FMAT(120,120),DINP(120),L1,L2,DISP(80,81)
      COMMON/FXDM/IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),
     1 XDOD(120),BF(3,120),IT
      DIMENSION RB(120),ERASE(120),DD1(80),T(120),FRAM(120),DD(4,20)
     1 ,KB12(3),B(3,120)
      EQUIVALENCE (FRAM,CF),(DD,DD1)
C
   44 FORMAT (I5,3E20.8)
   60 FORMAT (27H1OVERFLOW WHEN SOLVING FMAT)
   61 FORMAT (17H1FMAT IS SINGULAR)
   70 FORMAT (64H1CHECK ACCURACY OF SOLVING EQUATIONS, TO COMPARE -DISPL
     1 WITH F*R //17X,7H -DISPL 14X,6H F * R )
   72 FORMAT (I4,2E20.6)
   73 FORMAT (40H1FINAL CORRECTIVE JOINT FORCES           )
   74 FORMAT (////14H DIAPHRAGM NO. I4, 8X,4H X = F10.4, 8X,12H THICKNES
     1S = F10.6//6H JOINT 11X,8H H-FORCE 12X,8H V-FORCE 13X,7H MOMENT)
C
C     RESTORE INFORMATION SAVED ON TAPE 1
C
      REWIND 1
      READ(1)((FMAT(I,J),I=1,IT),J=1,IT),(DINP(I),I=1,IT),KB12,B,KB
C
C     SUM UP THE FLESIBILITIES OF THE FOLDED PLATE AND THE FLEXIBLE BENT
C
      REWIND 2
      REWIND 8
      DO 300 K=1,NDIAPH
      IK=KODIA(K)
      GO TO (300,300,180,210),IK
  180 KMK=KTEM(K)
      DO 200 I=1,MPC
      READ(2)(FRAM(J),J=1,MPC)
      IXYZ=KMK+I
      DO 200 J=1,MPC
      JXYZ=KMK+J
  200 FMAT(IXYZ,JXYZ)=FMAT(IXYZ,JXYZ)+FRAM(J)
      GO TO 300
C
```

```
C      ADD THE FLEXIBILITY OF THE FLEXIBLE MOVABLE DIAPHRAGM
C
  210 KMK=KTEM(K)
      DO 250 I=1,MBCOL
      READ(8) (FRAM(J),J=1,MBCOL)
      IXYZ=KMK+I
      DO 250 J=1,MBCOL
      JXYZ=KMK+J
  250 FMAT(IXYZ,JXYZ)=FMAT(IXYZ,JXYZ)+FRAM(J)
  300 CONTINUE
C
C      SOLVE FOR CORRECTIVE FORCES
C
  801 REWIND 1
      WRITE (1) ((FMAT(I,J),I=1,IT),J=1,IT)
      DO 805 J=1,IT
  805 RB(J)=DINP(J)
      C=0.
      L=ISIMEQ(120,IT,1,FMAT,RB,C,ERASE)
      GO TO (820,810,811),L
  810 PRINT 60
      STOP
  811 PRINT 61
      STOP
  820 DO 825 J=1,IT
C
C      PRINT DINP AND FMAT*RB FOR CHECK
C
  825 RB(J)=FMAT(J,1)
      REWIND 1
      READ (1) ((FMAT(I,J),I=1,IT),J=1,IT)
      PRINT 70
      DO 850 J=1,IT
      ERASE(J)=0.
      DO 850 K=1,IT
  850 ERASE(J)=ERASE(J)+FMAT(J,K)*RB(K)
      PRINT 72, (L,DINP(L),ERASE(L),L=1,IT)
C
C      STORE INTERACTION FORCES ON TAPE 9
C
      REWIND 9
      DO 860 M=1,NDIAPH
      II=KTEM(M)+1
      IJ=KTEM(M+1)
  860 WRITE(9)(RB(J),J=II,IJ)
C
C      PRINT CORRECTIVE JOINT FORCES
C
      PRINT 73
      DO 900 I=1,MX
  900 DD1(I)=0.
      DO 950 M=1,NDIAPH
      PRINT 74, M,DIAPHX(M),DIADEL(M)
      II=KTEM(M)
```

```
      IJ=KTEM(M+1)
      IF (IJ-II-MPC) 915,910,915
  910 DO 911 I=1,MPC
      J=I+II
  911 ERASE(I)=RB(J)
      GO TO 920
  915 DO 916 I=1,MBCOL
      K=I+II
      J=INDB(I)
      T(I)=RB(K)
  916 ERASE(J)=T(I)
      DO 918 I=1,KB
      J=KB12(I)
      C=0.
      DO 917 K=1,MBCOL
  917 C=C+B(I,K)*T(K)
  918 ERASE(J)=C
  920 DO 921 I=1,MPCOL
      J=INDMP(I)
  921 DD1(J)=ERASE(I)
      PRINT 44, (I,(DD(J,I),J=1,3),I=1,NJT)
C
  925 DO 926 I=1,MPCOL
      K=I+(M-1)*MPCOL
  926 CF(K)=ERASE(I)
  950 CONTINUE
C
      RETURN
      END
```

```
      FUNCTION   ISIMEQ(MAX,NN,LL,A,B,SCALE,ID)
C
C*****************************************************************************
C     SOLVE SYMMETRICAL SIMULTANEOUS EQUATIONS WITH PIVOTING
C*****************************************************************************
C
      DIMENSION A(MAX,MAX),B(MAX,1),ID(1)
C
C     SET I.D. ARRAY
C
      DO 50 N=1,NN
   50 ID(N)=N
C
      DO 475 N=1,NN
      N1=N+1
C
C     LOCATE LARGEST ELEMENT
C
      D=0.0
      DO 100 I=N,NN
      DO 100 J=N,NN
      IF (ABS(A(I,J))-D) 100,90,90
   90 D=ABS(A(I,J))
      II=I
      JJ=J
  100 CONTINUE
C
C     INTERCHANGE COLUMNS
C
      DO 110 I=1,NN
      D=A(I,N)
      A(I,N)=A(I,JJ)
  110 A(I,JJ)=D
C
C     RECORD COLUMN INTERCHANGE
C
      I=ID(N)
      ID(N)=ID(JJ)
      ID(JJ)=I
C
C     INTERCHANGE ROWS
C
      DO 120 J=N,NN
      D=A(N,J)
      A(N,J)=A(II,J)
  120 A(II,J)=D
C
      DO 130 L=1,LL
      D=B(N,L)
      B(N,L)=B(II,L)
  130 B(II,L)=D
C
C     FORM D(N,L)
```

```
C
      DO 150 L=1,LL
  150 B(N,L)=B(N,L)/A(N,N)
C
C     CHECK FOR LAST EQUATION
C
      IF (N-NN) 200,500,200
C
  200 DO 450 J=N1,NN
C
C     FORM H(N,J)
C
      IF (A(N,J)) 250,350,250
  250 A(N,J)=A(N,J)/A(N,N)
C
C     MODIFY A(I,J)
C
      DO 300 I=N1,NN
  300 A(I,J)=A(I,J)-A(I,N)*A(N,J)
C
C     MODIFY B(I,L)
C
  350 DO 400 L=1,LL
  400 B(J,L)=B(J,L)-A(J,N)*B(N,L)
  450 CONTINUE
  475 CONTINUE
C
C     BACK-SUBSTITUTION
C
  500 N1=N
      N=N-1
      IF (N) 700,700,550
C
  550 DO 600 L=1,LL
      DO 600 J=N1,NN
  600 B(N,L)=B(N,L)-A(N,J)*B(J,L)
C
      GO TO 500
C
C     REORDER UNKNOWNS
C
  700 DO 950 N=1,NN
      DO 900 I=N,NN
      IF (ID(I)-N) 900,750,900
  750 DO 800 L=1,LL
      D=B(N,L)
      B(N,L)=B(I,L)
  800 B(I,L)=D
      GO TO 950
  900 CONTINUE
  950 ID(I)=ID(N)
C
      ISIMEQ=1
C
```

```
C     PUT ANSWERS IN A ARRAY
C
      DO 960 L=1,LL
      DO 960 I=1,NN
  960 A(I,L)=B(I,L)
C
      RETURN
C
      END
```

```
      OVERLAY(MASTER,6,0)
      PROGRAM    EDGDIS
C
C*****************************************************************************
C     CALCULATE AND PRINT FINAL JOINT DISPLACEMENTS FOR THE FOLDED
C     PLATE STRUCTURE
C*****************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60),CF(120)
      COMMON/PERM/NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
      COMMON/EDGE/SIND(100,12),
     1  RJDIS(80,14),DISP(80),EDP(240),DI(80,81),LIND(80),D(12),
     2 P(80),ISW(30),ZZ(5206),SINKX(100,14),COSKX(100,14)
C
   40 FORMAT (14H1FINAL RESULTS/26H1FINAL JOINT DISPLACEMENTS////10X,25H
     1 HORIZONTAL DISPLACEMENTS)
   41 FORMAT (////10X,23H VERTICAL DISPLACEMENTS)
   42 FORMAT (////10X,10H ROTATIONS)
   43 FORMAT (////10X,27H LONGITUDINAL DISPLACEMENTS)
   58 FORMAT(1H1,38H MOMENTS TAKEN BY EACH GIRDER AT  X = , F10.3///,
     1 58H GIRDER NO.    MOMENT    PERCENTAGE    TENSION    COMPRESSION//)
   59 FORMAT(I6,E16.6,F9.2,2E16.6)
   61 FORMAT(//6H TOTAL,E16.6,F9.2,2E16.6)
C
C     INITIATION
C
      DO 10 J=1,NXP
      DO 10 I=1,MX
   10 RJDIS(I,J)=0.
      REWIND 1
      REWIND 3
C
C     CYCLE FOR EACH HARMONIC
C
      MM=0
      DO 700 NN=N1,MHARM,N2
      MM=MM+1
      FN=NN
      FK=FN*PI/SPAN
C
C     READ DISPLACEMENT MATRIX FROM TAPE 3
C
      READ (3) ((DI(I,J),I=1,MX),J=1,MPC1)
      IF (NDIAPH) 30,30,45
   30 DO 31 I=1,MX
   31 DISP(I)=DI(I,1)
      GO TO 500
```

```
C
C     FOURIER MULTIPLIERS ARE COMPUTED
C
   45 DO 100 I=1,NDIAPH
      XX=FK*DIAPHX(I)
      S=SIN(XX)
      IF (DIADEL(I)) 60,60,50
   50 XX=FK*DIADEL(I)/2.
      C=SIN(XX)
      D(I)=2./(XX*SPAN)*C*S
      SIND(MM,I)=1./DIADEL(I)*C*S
      GO TO 100
   60 D(I)=2./SPAN*S
      SIND(MM,I)=0.5*FK*S
  100 CONTINUE
C
C     FIND FINAL JOINT DISPLACEMENTS (DISP)
C
  200 DO 210 I=1,MPCOL
      P(I)=0.
      DO 210 J=1,NDIAPH
      K=I+(J-1)*MPCOL
  210 P(I)=P(I)+CF(K)*D(J)
      DO 220 I=1,MX
      C=0.
      DO 215 J=1,MPCOL
  215 C=C+DI(I,J)*P(J)
  220 DISP(I)=C+DI(I,MPC1)
C
C     CALCULATE AND SUM UP JOINT DISPLACEMENTS AT DIFFERENT POINTS
C
  500 DO 510 II=1,NXP
      XX=FK*XP(II)
      C=COS(XX)
      S=SIN(XX)
      COSKX(MM,II)=C
      SINKX(MM,II)=S
      DO 510 L=4,MX,4
      I=L-3
      J=L-1
      DO 505 K=I,J
  505 RJDIS(K,II)=RJDIS(K,II)+DISP(K)*S
  510 RJDIS(L,II)=RJDIS(L,II)+DISP(L)*C
C
C     CALCULATE EDGE DISPLACEMENTS FOR EACH ELEMENT AND STORE ON TAPE 1
C
      N=0
      DO 600 L=1,NEL
      K=KPL(L)
      I=NPI(L)
      J=NPJ(L)
      C=H(K)
      S=V(K)
      EDP(N+1)=DISP(I+3)
```

```
      EDP(N+2)=DISP(J+3)
      EDP(N+3)=+S*DISP(I+1)+C*DISP(I+2)
      EDP(N+4)= S*DISP(J+1)+C*DISP(J+2)
      EDP(N+5)=-DISP(I+4)
      EDP(N+6)=-DISP(J+4)
      EDP(N+7)=-C*DISP(I+1)+S*DISP(I+2)
      EDP(N+8)=-C*DISP(J+1)+S*DISP(J+2)
C     THE SIGNS OF EDP(3,5,6,8) HAVE BEEN CHANGED IN ORDER TO AGREE WITH
C     GOLDBERG'S SIGN CONVENTION
  600 N=N+8
      WRITE (1) (EDP(I),I=1,N)
C
  700 CONTINUE
C
C     PRINT RESULTS FOR JOINT DISPLACEMENTS
C
      DO 710 I=1,NJT
      J=4*I
      LIND(J)=I
      LIND(J-1)=I
      LIND(J-2)=I
  710 LIND(J-3)=I
      IF (NXP-7) 720,720,721
  720 II=NXP
      IL=1
      GO TO 730
  721 II=7
      IJ=NXP
      IL=2
  730 PRINT 40
      CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,1)
      PRINT 41
      CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,2)
      PRINT 42
      CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,3)
      PRINT 43
      CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,4)
C
  750 CALL PLFOR (MM,II,IJ,IL)
C
      IF (MCHECK.EQ.0) GO TO 781
      DO 760 I=1,NOXMP
      PP = 0.0
      TOT = 0.0
      TOTEN=0.
      TOCOM=0.
      DO 745 J=1,NBOX
      TOTEN=TOTEN+TENS(I,J)
      TOCOM=TOCOM+COMP(I,J)
  745 TOT = TOT + BOXMOM(I,J)
      IF (TOT.EQ.0.) GO TO 760
      PRINT 58,XMP(I)
      DO 746 J=1,NBOX
      PC = BOXMOM(I,J)/TOT*100.
```

```
      PP = PP + PC
  746 PRINT 59,J,BOXMOM(I,J),PC,TENS(I,J),COMP(I,J)
      PRINT 61,TOT,PP,TOTEN,TOCOM
  760 CONTINUE
  781 RETURN
      END
```

```
      SUBROUTINE PLFOR (MM,II,IJ,IL)
C
C***********************************************************************
C     CALCULATE AND PRINT FINAL INTERNAL FORCES FOR EACH PLATE ELEMENT
C***********************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12),INDMP(60),CF(120)
      COMMON/EDGE/SIND(100,12),
     1 A(8,1500),CONT(13,100),            SKX(14),CKX(14),SINKX(100,14),
     2 COSKX(100,14)
      COMMON/PLATE/ XYM(14,13),XQ(14,13),YQ(14,13),XN(14,13),YN(14,13),
     1 XYN(14,13),WD(14,13),UD(14,13),VD(14,13)
      COMMON/PERM/NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
C
      DIMENSION XM(14,13),YM(14,13),DI(240),DIS(8,30),CON(13)
C
      EQUIVALENCE (DI,DIS,XM),
     1 (FKT,CON(1)),(FKC,CON(2)),(SC1,CON(3)),(SC2,CON(4)),(SC3,CON(5)),
     2 (FL1,CON(6)),(FL2,CON(7)),(FL3,CON(8)),(FL4,CON(9)),(FL5,CON(10))
     3,(FL6,CON(11)),(FL7,CON(12)),(FL8,CON(13))
C
      NELINC=12000/(MM*8)-1
      NOFPL=0
      NEL2=0
C
C     READ EDGE DISPLACEMENTS FROM TAPE 1
C
   30 NEL1=NEL2+1
      IF (NEL1-NEL) 31,31,100
   31 NEL2=MIN0((NEL1+NELINC),NEL)
      NDI=NEL2*8
      REWIND 1
      L=0
      DO 35 I=1,MM
      READ (1) (DI(J),J=1,NDI)
      DO 35 J=NEL1,NEL2
      L=L+1
      DO 35 K=1,8
   35 A(K,L)=DIS(K,J)
C
C     FOR EACH ELEMENT
C
      NDI=NEL2-NEL1+1
      DO 99 IE=NEL1,NEL2
      FN=NSEC(IE)
      IF (FN) 99,99,38
   38 NUMY=NSEC(IE)+1
```

```
      IEPL=KPL(IE)
      ISW=1
   26 DO 40 J=1,NUMY
      DO 40 K=1,NXP
      WD(K,J)=0.0
      UD(K,J)=0.0
      VD(K,J)=0.0
      XM(K,J)=0.0
      YM(K,J)=0.0
      XYM(K,J)=0.0
      XQ(K,J)=0.0
      YQ(K,J)=0.0
      XN(K,J)=0.0
      YN(K,J)=0.0
   40 XYN(K,J)=0.0
      IF (IEPL-NOFPL) 41,45,41
   41 U=FNU(IEPL)
      B=PWTH(IEPL)
      D=E(IEPL)*TH(IEPL)**3/(12.*(1.-U**2))
      D1=D*(1.-U)/2.
      D2=E(IEPL)*TH(IEPL)/(2.*(1.+U))
      U1=2./(1.-U)
      U2=U1*U
      U3=(1.+U)/(1.-U)
      U5=2./(1.+U)
      U4=U5*U
      U6=(1.-U)/(1.+U)
      U7=(3.+U)/(1.+U)
      UV=(3.-U)/(1.+U)
   45 DIFY=B/FN
C
C        FOR EACH HARMONIC
C
      N=0
      DO 80 NN=N1,MHARM,N2
      N=N+1
      N3=(-1)**NN
      IF (IEPL-NOFPL) 49,47,49
   47 DO 48 I=1,13
   48 CON(I)=CONT(I,N)
      GO TO 51
   49 FM=NN
      SC1=FM*PI/SPAN
      SC2=SC1**2
      SC3=SC1**3
      G=SC1*B
      EG=EXP(-G)
      EG2=EG*EG
      T1=1.+EG
      T2=1.-EG
      S=G/2.
      FKT=T2/T1
      FKC=S/FKT
      FKT=S*FKT
```

```
      S=2.*G*EG
      C=1.-EG2
      T3=S+C
      T4=S-C
      FL1=T1/T3
      FL2=T2/T4
      FL3=T2/T3
      FL4=T1/T4
      C=C*UV
      T3=S+C
      T4=S-C
      FL5=T1/T4
      FL6=T2/T3
      FL7=T2/T4
      FL8=T1/T3
      DO 50 I=1,13
   50 CONT(I,N)=CON(I)
   51 I=NDI*(N-1)+(IE-NEL1+1)
      DISP1=A(1,I)
      DISP2=A(2,I)
      DISP3=A(3,I)
      DISP4=A(4,I)
      DISP5=A(5,I)
      DISP6=A(6,I)
      DISP7=A(7,I)
      DISP8=A(8,I)
      DO 52 J=1,NXP
      CKX(J)=COSKX(N,J)
   52 SKX(J)=SINKX(N,J)
C
C     FIND ZLOAD, YLOAD, ZTRIL, YTRIL FOR THIS HARMONIC
C
      IF (N3) 53,54,54
   53 ZLOAD=VL(IE)
      YLOAD=HL(IE)
      GO TO 55
   54 ZLOAD=0.0
      YLOAD=0.0
   55 IF (NSURL) 63,63,56
   56 DO 62 I=1,NSURL
      IF (LEL(I)-IE) 62,57,62
   57 IF (SURDEL(I)) 58,59,58
   58 T1=SIN(SC1*SURXI(I))*SIN(SC1*SURDEL(I)/2.)
      GO TO 60
   59 T1=SIN(SC1*SURXI(I))*SC1/2.
   60 ZLOAD=ZLOAD+SURVL(I)*T1
      YLOAD=YLOAD+SURHL(I)*T1
   62 CONTINUE
C
   63 YTRIL=0.
      ZTRIL=0.
   70 TOTLD=ABS(ZLOAD)+ABS(YLOAD)
C
C         FOR EACH TRANSVERSE SECTION
```

```
C
   71 D1SC1=D1*SC1
      DSC2=D*SC2
      D1SC2=D1*SC2
      DSC3=D*SC3
      D2SC1=D2*SC1
      DO 80 IY=1,NUMY
      IJK=(IY-1)*(IY-NUMY)
      FI=IY-1
      FI=FI*DIFY
      Y=B/2.-FI
      T1=SC1*FI
      T2=(B-FI)*SC1
      T1=EXP(-T1)
      T2=EXP(-T2)
      SY=T1-T2
      CY=T1+T2
      GY=SC1*Y
      SY1=GY*SY
      CY1=GY*CY
C
C        TO FIND MAX. INTERNAL FORCES DUE TO EDGE DISPLACEMENTS
C
      T1=FL1*(SY1-FKT*CY)
      T2=FL2*(CY1-FKC*SY)
      FWD=(DISP1*(T1-T2)-DISP2*(T1+T2))/SC1
      T1=FL1*(SY1+(U1-FKT)*CY)
      T2=FL2*(CY1+(U1-FKC)*SY)
      FMY=D1SC1*(DISP1*(-T1+T2)+DISP2*(T1+T2))
      T1=FL1*(SY1-(U2+FKT)*CY)
      T2=FL2*(CY1-(U2+FKC)*SY)
      FMX=D1SC1*(DISP1*(T1-T2)-DISP2*(T1+T2))
      T1=FL1*SY
      T2=FL2*CY
      QY=DSC2*(DISP1*(-T1+T2)+DISP2*(T1+T2))
      T1=FL1*CY
      T2=FL2*SY
      QX=DSC2*(DISP1*(-T1+T2)+DISP2*(T1+T2))
      T1=FL1*(CY1+(1.-FKT)*SY)
      T2=FL2*(SY1+(1.-FKC)*CY)
      FMXY=D1SC1*(DISP1*(-T1+T2)+DISP2*(T1+T2))
      T1=FL3*(SY1-(1.+FKC)*CY)
      T2=FL4*(CY1-(1.+FKT)*SY)
      FWD=0.5*((DISP3*(T2-T1)-DISP4*(T1+T2))+FWD)
      T1=FL3*(SY1+(U3-FKC)*CY)
      T2=FL4*(CY1+(U3-FKT)*SY)
      FMY=D1SC2*(DISP3*(T1-T2)+DISP4*(T1+T2))+FMY
      T1=FL3*(SY1-(U3+FKC)*CY)
      T2=FL4*(CY1-(U3+FKT)*SY)
      FMX=D1SC2*(DISP3*(-T1+T2)-DISP4*(T1+T2))+FMX
      T1=FL3*SY
      T2=FL4*CY
      QY=DSC3*(DISP3*(T1-T2)+DISP4*(T1+T2))+QY
      T1=FL3*CY
```

```
      T2=FL4*SY
      QX=DSC3*(DISP3*(T1-T2)+DISP4*(T1+T2))+QX
      T1=FL3*(CY1-FKC*SY)
      T2=FL4*(SY1-FKT*CY)
      FMXY=DISC2*(DISP3*(T1-T2)+DISP4*(T1+T2))+FMXY
      T1=FL5*(SY1-FKT*CY)
      T2=FL6*(CY1-FKC*SY)
      FUD=DISP7*(T1-T2)-DISP8*(T1+T2)
      T1=FL5*(CY1-(UV+FKT)*SY)
      T2=FL6*(SY1-(UV+FKC)*CY)
      FVD=DISP7*(T1-T2)-DISP8*(T1+T2)
      T1=FL5*(SY1+(U4-FKT)*CY)
      T2=FL6*(CY1+(U4-FKC)*SY)
      FNX=DISP7*(-T1+T2)+DISP8*(T1+T2)
      T1=FL5*(SY1-(U5+FKT)*CY)
      T2=FL6*(CY1-(U5+FKC)*SY)
      FNY=DISP7*(T1-T2)-DISP8*(T1+T2)
      T1=FL5*(CY1-(U6+FKT)*SY)
      T2=FL6*(SY1-(U6+FKC)*CY)
      FNXY=DISP7*(T1-T2)-DISP8*(T1+T2)
      T1=FL7*(SY1+(UV-FKC)*CY)
      T2=FL8*(CY1+(UV-FKT)*SY)
      FUD=0.5*((DISP5*(T2-T1)-DISP6*(T1+T2))+FUD)
      T1=FL7*(CY1-FKC*SY)
      T2=FL8*(SY1-FKT*CY)
      FVD=0.5*((DISP5*(T2-T1)-DISP6*(T1+T2))+FVD)
      T1=FL7*(SY1+(U7-FKC)*CY)
      T2=FL8*(CY1+(U7-FKT)*SY)
      FNX=D2SC1*((DISP5*(T1-T2)+DISP6*(T1+T2))+FNX)
      T1=FL7*(SY1+(U6-FKC)*CY)
      T2=FL8*(CY1+(U6-FKT)*SY)
      FNY=D2SC1*((DISP5*(-T1+T2)-DISP6*(T1+T2))+FNY)
      T1=FL7*(CY1+(U5-FKC)*SY)
      T2=FL8*(SY1+(U5-FKT)*CY)
      FNXY=D2SC1*((DISP5*(T2-T1)-DISP6*(T1+T2))+FNXY)
C
C        INTERNAL FORCES DUE TO SURFACE LOADS AND CORRECTIVE PLATE FORCE
C
      IF (TOTLD) 72,78,72
   72 T1=4.*ZLOAD*(1.-U)/(SC3*SPAN)
      T2=FKC
      FMY=-T1*(FL3*(SY1+(U3-T2)*CY)-U2*0.5)+FMY
      FMX= T1*(FL3*(SY1-(U3+T2)*CY)+U1*0.5)+FMX
      FMXY=-T1*FL3*(CY1-T2*SY)+FMXY
      T1=-8.*ZLOAD/(SC2*SPAN)
      QY=T1*SY*FL3+QY
      QX=0.5*T1*(2.*CY*FL3-1.)+QX
      T1=8.*YLOAD/(SC2*SPAN)
      FNY = T1*FL6*(CY1-(T2+U5)*SY)+FNY
      FNX =-T1*FL6*(CY1-(T2-U4)*SY)+FNX
      FNXY= 0.5*T1*(2.*FL6*(SY1-(T2+U6)*CY)+1.)+FNXY
      IF (IJK) 200,210,200
  200 T1=T1/(2.*D2SC1)
      FUD=T1*FL6*(CY1-T2*SY)+FUD
```

```
      FVD=T1*(FL6*(SY1-(UV+T2)*CY)+1.)+FVD
      T1=4.*ZLOAD/(DSC3*SC2*SPAN)
      FWD=T1*(FL3*(SY1-(1.+T2)*CY)+1.)+FWD
  210 CONTINUE
C
C     SUM UP INTERNAL FORCES
C
   78 DO 79 I=1,NXP
      T1=SKX(I)
      T2=CKX(I)
      WD(I,IY)=WD(I,IY)+FWD*T1
      UD(I,IY)=UD(I,IY)+FUD*T2
      VD(I,IY)=VD(I,IY)+FVD*T1
      XM(I,IY)=XM(I,IY)+FMX*T1
      YM(I,IY)=YM(I,IY)+FMY*T1
      XYM(I,IY)=XYM(I,IY)+FMXY*T2
      XQ(I,IY)=XQ(I,IY)+QX*T2
      YQ(I,IY)=YQ(I,IY)+QY*T1
      XN(I,IY)=XN(I,IY)+FNX*T1
      YN(I,IY)=YN(I,IY)+FNY*T1
   79 XYN(I,IY)=XYN(I,IY)+FNXY*T2
   80 CONTINUE
C
C     PRINT INTERNAL FORCES FOR EACH ELEMENT
C
   10 FORMAT (76H1INTERNAL FORCES PER UNIT LENGTH AND INTERNAL DISPLACEM
     1ENTS FOR ELEMENT NO. I4,17H  BETWEEN JOINTS I3,5H AND I3)
   11 FORMAT (////10X,5H M(X))
   12 FORMAT (////10X,5H M(Y))
   13 FORMAT (////10X,6H M(XY))
   14 FORMAT (////10X,5H Q(X))
   15 FORMAT (////10X,5H Q(Y))
   16 FORMAT (////10X,5H N(X))
   17 FORMAT (////10X,5H N(Y))
   18 FORMAT (////10X,6H N(XY))
   19 FORMAT (////10X,2H U)
   20 FORMAT (////10X,2H V)
   21 FORMAT (////10X,2H W)
C
      I=NPI(IE)/4+1
      J=NPJ(IE)/4+1
      PRINT 10, IE,I,J
      PRINT 11
      CALL OPRINT  (XM,14,13,XP,NUMY,II,IJ,IL)
      PRINT 12
      CALL OPRINT  (YM,14,13,XP,NUMY,II,IJ,IL)
      PRINT 13
      CALL OPRINT (XYM,14,13,XP,NUMY,II,IJ,IL)
      PRINT 14
      CALL OPRINT  (XQ,14,13,XP,NUMY,II,IJ,IL)
      PRINT 15
      CALL OPRINT  (YQ,14,13,XP,NUMY,II,IJ,IL)
      PRINT 16
      CALL OPRINT  (XN,14,13,XP,NUMY,II,IJ,IL)
```

```
      PRINT 17
      CALL OPRINT  (YN,14,13,XP,NUMY,II,IJ,IL)
      PRINT 18
      CALL OPRINT (XYN,14,13,XP,NUMY,II,IJ,IL)
      PRINT 19
      CALL OPRINT  (UD,14,13,XP,NUMY,II,IJ,IL)
      PRINT 20
      CALL OPRINT  (VD,14,13,XP,NUMY,II,IJ,IL)
      PRINT 21
      CALL OPRINT  (WD,14,13,XP,NUMY,II,IJ,IL)
      IF (MCHECK.EQ.0) GO TO 90
      KIE = KPL(IE)
      PLW = PWTH(KIE)
      CALL MOMPER(XN,XM,PLW,IE,NUMY)
   90 CONTINUE
      NOFPL=IEPL
   99 CONTINUE
      GO TO 30
  100 RETURN
      END
```

```
      SUBROUTINE PINVAL (IND,D,M,N,X,MX,K1,K2,NCYC,L)
C
C***************************************************************************
C     PRINT FINAL JOINT DISPLACEMENTS AT SPECIFIED LOCATIONS
C***************************************************************************
C
      DIMENSION IND(M),D(M,N),X(N),N1(2),N2(2)
    1 FORMAT (I6,1P7E16.7)
    2 FORMAT (6HOJOINT,7(6H    X =F10.3))
      DATA N1(1),N1(2)/1,8/
      N2(1)=K1
      N2(2)=K2
      DO 10 K=1,NCYC
      J1=N1(K)
      J2=N2(K)
      PRINT 2, (X(I),I=J1,J2)
      DO 10 I=L,MX,4
   10 PRINT 1, (IND(I),(D(I,J),J=J1,J2))
      RETURN
      END
```

```
      SUBROUTINE OPRINT (A,M,N,X,NY,K1,K2,NCYC)
C
C***********************************************************************
C     PRINT FINAL PLATE INTERNAL FORCES OR DISPLACEMENTS AT SPECIFIED
C     LOCATIONS
C***********************************************************************
C
      DIMENSION A(M,N),X(M),N1(2),N2(2)
    1 FORMAT (I6,1P7E16.7)
    2 FORMAT (6H0SECT.,7(6H    X =F10.3))
      DATA N1(1),N1(2)/1,8/
      N2(1)=K1
      N2(2)=K2
      DO 10 K=1,NCYC
      J1=N1(K)
      J2=N2(K)
      PRINT 2, (X(I),I=J1,J2)
      DO 10 I=1,NY
   10 PRINT 1, (I,(A(J,I),J=J1,J2))
      RETURN
      END
```

```
      SUBROUTINE MOMPER(XN,XM,W,I,NY)
C
C*************************************************************************
C     FIND THE GIRDER MOMENTS BY INTEGRATING THE MEMBRANE STRESSES AND
C     PLATE BENDING MOMENTS IN EACH GIRDER
C*************************************************************************
C
      COMMON/PERM/NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
      DIMENSION XN(14,13),XM(14,13),X(14)
      EQUIVALENCE (XMP,X)
      DO 100 J=1,NOXMP
      N1=NGIEL(I,1)
      N2=NGIEL(I,2)
      IX=MOPX(J)
      NSC=NY-1
      SC=NSC
      DEL=W/SC
      DEV=(DNAJ(I)-DNAI(I))/SC
      IF (DEV.EQ.0.) GO TO 8
      DEH=-DEV*HS(I)/VS(I)
      GO TO 9
    8 DEH=HS(I)/SC
    9 X1=DNAI(I)
      IF (N2.NE.0) GO TO 20
      DO 10 NN=1,NSC
      X2=X1+DEV
      CALL ADDM(J,N1,X1,X2,DEL,DEH,XN(IX,NN),XN(IX,NN+1),XM(IX,NN),XM(IX
     1 ,NN+1))
   10 X1=X2
      GO TO 100
   20 NN=1
      HH=0.
   30 HH=HH+DEH
      AHH=ABS(HH)
      AXDIV=ABS(XDIV(I))
      IF (AHH.GT.AXDIV) GO TO 40
      X2=X1+DEV
      CALL ADDM(J,N1,X1,X2,DEL,DEH,XN(IX,NN),XN(IX,NN+1),XM(IX,NN),XM(IX
     1 ,NN+1))
      X1=X2
      NN=NN+1
      GO TO 30
   40 FA=(XDIV(I)+DEH-HH)/DEH
      XL=FA*DEL
      XH=FA*DEH
      X2=X1+FA*DEV
      XN2=XN(IX,NN)+FA*(XN(IX,NN+1)-XN(IX,NN))
      XM2=XM(IX,NN)+FA*(XM(IX,NN+1)-XM(IX,NN))
      CALL ADDM(J,N1,X1,X2,XL,XH,XN(IX,NN),XN2,XM(IX,NN),XM2)
      X3=X1+DEV
      XL=DEL-XL
      XH=DEH-XH
```

```
      CALL ADDM(J,N2,X2,X3,XL,XH,XN2,XN(IX,NN+1),XM2,XM(IX,NN+1))
      X1=X3
   50 NN=NN+1
      IF (NN.GT.NSC) GO TO 100
      X2=X1+DEV
      CALL ADDM(J,N2,X1,X2,DEL,DEH,XN(IX,NN),XN(IX,NN+1),XM(IX,NN),XM(IX
     1 ,NN+1))
      X1=X2
      GO TO 50
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ADDM (J,N,X1,X2,XL,XH,XN1,XN2,XM1,XM2)
C
C***********************************************************************
C     INTEGRATE THE STRESSES BY TRAPEZOIDAL RULE
C***********************************************************************
C
      COMMON/PERM/NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30)
     1 ,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)
      F1=XN1*XL/2.
      XM=F1*(X2+2.*X1)/3.
      F2=XN2*XL/2.
      XM=XM+F2*(X1+2.*X2)/3.
      F=F1+F2
      XM=XM+0.5*(XM1+XM2)*XH
      BOXMOM(J,N)=BOXMOM(J,N)+XM
      IF (F.LT.0.) GO TO 10
      TENS(J,N)=TENS(J,N)+F
      GO TO 20
   10 COMP(J,N)=COMP(J,N)+F
   20 RETURN
      END
```

```
      OVERLAY (MASTER,7,0)
      PROGRAM    FORCE
C
C*****************************************************************************
C     CALCULATE JOINT DISPLACEMENTS AND MEMBER END FORCES FOR EACH FRAME
C     BENT
C*****************************************************************************
C
      COMMON SPAN,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,
     1 KFOR,NXBAND,MAXJTD,NSURL,PI,MX,N1,N2,MPCOL,MPC,MPC1,L3,XP(14),
     2 DIAPHX(12),DIADEL(12),H(15),V(15),TH(15),E(15),FNU(15),PWTH(15),
     3 NPI(30),NPJ(30),KPL(30),NSEC(30),HL(30),VL(30),LEL(50),SURHL(50),
     4 SURVL(50),SURXI(50),SURDEL(50),LCASE(4,20),JFOR(3,20),XORD(20),
     5 YORD(20),KODIA(12),KDTP(12)
      COMMON/PARAM/NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(8)
     1 ,NUSPRG(8),NPT(8),NPR(80)
      COMMON/FBENT/EFM(10),G(10),
     1 LM(6),SA(6,6),ASA(6,6),T(3,3),          S(6,6),RF(6),JK(3),
     2 NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(80),
     3 COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),
     4 A(120,120)
C
C
C     DETERMINE JOINT DISPLACEMENTS
C
      REWIND 2
      REWIND 4
      REWIND 7
      DO 99 IJK=1,NDIAPH
      IF(KODIA(IJK).NE.3) GO TO 99
      REWIND 9
      IF(IJK.EQ.1) GO TO 9
      DO 8 K=2,IJK
    8 READ(9) HH
    9 READ(9) (RE(I),I=1,MPC)
      IN=KDTP(IJK)
      NUMEL=NUMELT(IN)
      NUMNP=NUMNPT(IN)
      NEQ=NEQN(IN)
      NUMSPR=NUSPRG(IN)
      NP=NPT(IN)
      NMAX=NEQ-NP
      DO 10 I=1,NMAX
   10 READ(2)(A(I,J),J=1,NMAX)
      DO 30 I=1,NMAX
      B(I)=0.
      DO 20 J=1,NMAX
   20 B(I)=B(I)-A(I,J)*RE(J)
   30 CONTINUE
      N=NEQ
      READ(4)(IQ(I),I=1,N)
      L=N-NP-1
      DO 40 I=1,NP
```

```
      L=L+1
   40 READ(4)(A(I,J),J=1,L)
      L=N-NP+1
      DO 60 I=L,N
      B(I)=0.0
      K=I-1
      M=I-NMAX
      DO 50 J=1,K
   50 B(I)=B(I)-A(M,J)*B(J)
   60 CONTINUE
C
C     OUTPUT JOINT DISPLACEMENTS
C
      WRITE(6,7900) IJK
      DO 61 I=1,N
      J=IQ(I)
   61 IP(J)=I
      WRITE(6,8000)
      DO 63 I=1,NUMNP
      IL=NPR(I)
      JX=IP(3*IL-2)
      JY=IP(3*IL-1)
      JZ=IP(3*IL)
   63 WRITE(6,8001)(I,B(JX),B(JY),B(JZ))
C
C     DETERMINE MEMBER END FORCES AND PRINT
C
      DO 64 N=1,NEQ
   64 RE(N)=0.
      WRITE (6,8002)
      DO 80 N=1,NUMEL
      READ(7)(LM(I),I=1,87)
      DO 70 I=1,6
      RF(I)=0.0
      DO 65 J=1,6
      JJ=LM(J)
      JJJ=IP(JJ)
   65 RF(I)=RF(I)+SA(I,J)*B(JJJ)
   70 CONTINUE
      WRITE (6,8003) N,(RF(I),I=1,6)
C
C     OBTAIN CONTRIBUTION OF ELEMENT END FORCES TO APPLIED JOINT LOADS
C     AND STORE IN RE(NEQ)
C
      DO 80 I=1,3
      II=LM(I)
      III=LM(I+3)
      DO 80 J=1,3
      RE(II)=RE(II)+T(J,I)*RF(J)
   80 RE(III)=RE(III)+T(J,I)*RF(J+3)
C
C     DETERMINE AND PRINT ELASTIC SUPPORT REACTIONS
C
      IF (NUMSPR.EQ.0) GO TO 90
```

```
      WRITE(6,8006)
      READ(4)(NPSTP(I),I=1,NUMNP)
      READ(4)((SP(I,J),I=1,NUMSPR),J=1,3)
      DO 82 N=1,NUMNP
      MSPR=NPSTP(N)
      IF(MSPR.EQ.0) GO TO 82
      NN=NPR(N)
      DO 81 K=1,3
      KK=3*(NN-1)+K
      KKK=IP(KK)
      SPF(K)=-SP(MSPR,K)*B(KKK)
   81 RE(KK)=RE(KK)-SPF(K)
      WRITE(6,8005) N,(SPF(K),K=1,3)
   82 CONTINUE
C
C     PRINT APPLIED JOINT LOADS AND REACTIONS
C
   90 WRITE(6,8004)
      DO 95 I=1,NUMNP
      IL=NPR(I)
      JX=3*IL-2
      JY=3*IL-1
      JZ=3*IL
   95 WRITE(6,8005)I,RE(JX),RE(JY),RE(JZ)
   99 CONTINUE
 7900 FORMAT(52H1INTERNAL FORCES DISPLACEMENTS FOR DIAPHRAGM NUMBER I5)
 8000 FORMAT(1H1/20H JOINT DISPLACEMENTS//
     1  60H JOINT   X-DISPLACEMENT    Y-DISPLACEMENT        Z-ROTATION )
 8001 FORMAT(1H ,I4,3E18.5)
 8002 FORMAT(1H1/18H MEMBER END FORCES//
     1  60H                                        MEMBER END FORCES   /
     2  56H ELEMENT      AXIAL I      SHEAR I     MOMENT I      AXIAL J
     3  60H       SHEAR J    MOMENT J                                   )
 8003 FORMAT(1H ,I5,2X,6E12.4)
 8004 FORMAT(1H1/
     1  60H                    APPLIED JOINT LOADS AND REACTIONS        /
     2  60H  NODE            FORCE X           FORCE Y          MOMENT Z        )
 8005 FORMAT(1H ,I5,3E15.5)
 8006 FORMAT(1H1/
     1  60H                      ELASTIC FOUNDATION REACTIONS           /
     2  60H  NODE            FORCE X           FORCE Y          MOMENT Z        )
      RETURN
      END
```