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### **Title**

Computer Program for Curved Bridges on Flexible Bents

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**Structures and Materials Research  
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**COMPUTER PROGRAM FOR  
CURVED BRIDGES ON FLEXIBLE BENTS**

**by**

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**In cooperation with**

**State of California  
Business and Transportation Agency  
Department of Transportation  
Under Research Technical Agreement  
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**U. S. Department of Transportation  
Federal Highway Administration**

**College of Engineering  
Office of Research Services  
University of California  
Berkeley, California**

**September 1974**

ABSTRACT

A computer program is presented for the analysis of continuous prismatic folded plate structures, which are circular in plan and may have up to twelve flexible interior diaphragms or supports. The folded plate structure is considered to be an assemblage of orthotropic plate elements that may, in general, be segments of conical frustora, interconnected at longitudinal joints and simply supported at the two ends. Each plate element is idealized by a number of circumferential finite strips. The finite strip method is used to determine the strip stiffness. Interior diaphragms may be defined by flexible beams, and interior supports may be defined by two-dimensional planar frame bents. A direct stiffness harmonic analysis is used to analyze the assembled folded plate system. The interaction forces between the folded plate system and the interior diaphragms or supports are found using a force method by satisfying the required compatibility conditions. Loads and interaction forces may be approximated by up to 100 non-zero terms of the appropriate Fourier series. The final results are found by summing the solutions for the known loads and the redundant forces. Several numerical examples are presented to demonstrate the use of the program. A user's guide and a FORTRAN listing are also appended to the report.

KEY WORDS

computer program, continuous bridge, curved bridge, curved folded plate, flexible support bent, diaphragm, direct stiffness method, force method, harmonic analysis, finite strip method, shells of revolution, structural analysis.

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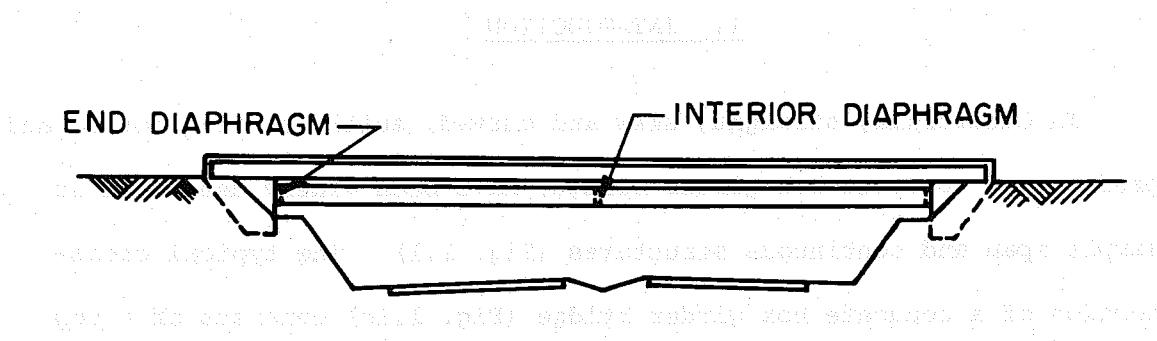
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## 1. INTRODUCTION

In California, straight, skew and curved, multi-cell reinforced and prestressed concrete box girder bridges have been widely used both as simple span and continuous structures (Fig. 1.1). The typical cross-section of a concrete box girder bridge (Fig. 1.1c) consists of a top and bottom slab connected monolithically by vertical webs to form a cellular or box-like structure. In some cases sloping or curved exterior webs are also used. Transverse diaphragms are placed at the end and interior support sections and sometimes, 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 - 19] and technical papers [20 - 32]. The analysis of curved box girder bridges forms one part of this research program.

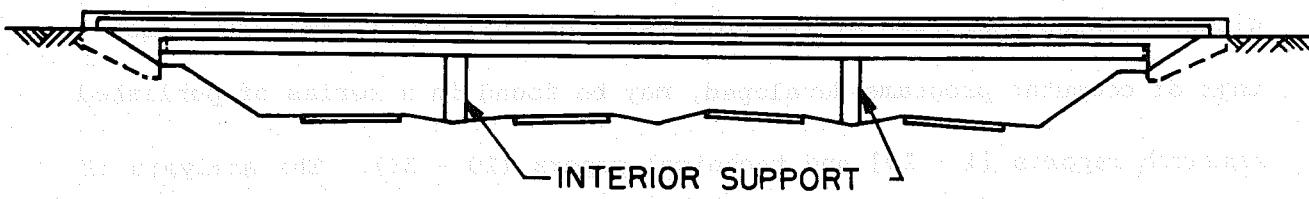
A curved prismatic box girder bridge, circular in plan (Fig. 1.2a), may be considered to be made up of segments of conical frustra (Fig. 1.2b). Because of their complexity and the lack of an available rational analysis, these bridges have been designed using simplified approximate methods. A common procedure is to ignore the curvature and analyze an equivalent straight bridge taking the curved centerline length as the effective span. When curvature is taken into account, elementary curved beam theory is used in which the entire bridge cross-section is treated as a beam section. As an alternative, the curved bridge system may be approximated by a series of short straight one-dimensional beam segments and analyzed as a three-dimensional frame using one of the standard available computer programs for this purpose.



### a) ELEVATION OF TYPICAL SIMPLE SPAN BRIDGE

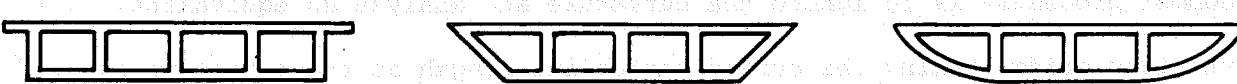
The bridge shown is a typical simple span bridge. It consists of a multi-cell box girder supported by two piers. The piers are rigidly connected to the deck at their bases. The deck is rigidly connected to the end diaphragms at both ends. The deck is rigidly connected to the interior diaphragm at its center.

The bridge is designed for lateral stability. The deck is rigidly connected to the end diaphragms at both ends.



### b) ELEVATION OF TYPICAL CONTINUOUS BRIDGE

The bridge shown is a typical continuous bridge. It consists of a multi-cell box girder supported by three piers. The piers are rigidly connected to the deck at their bases. The deck is rigidly connected to the end diaphragms at both ends. The deck is rigidly connected to the interior support at its center.

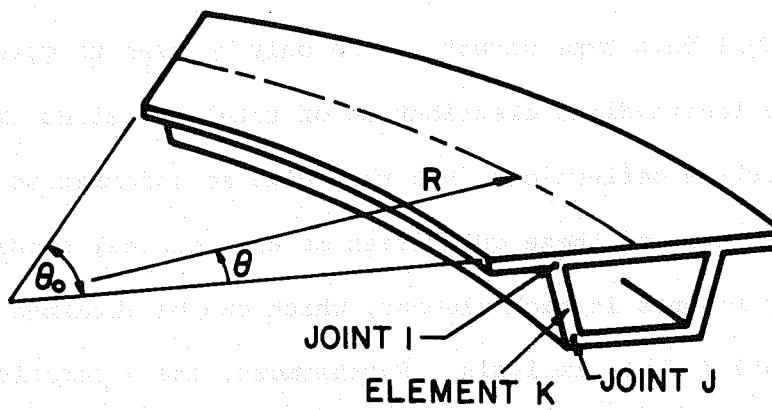


### c) TYPICAL CROSS-SECTIONS

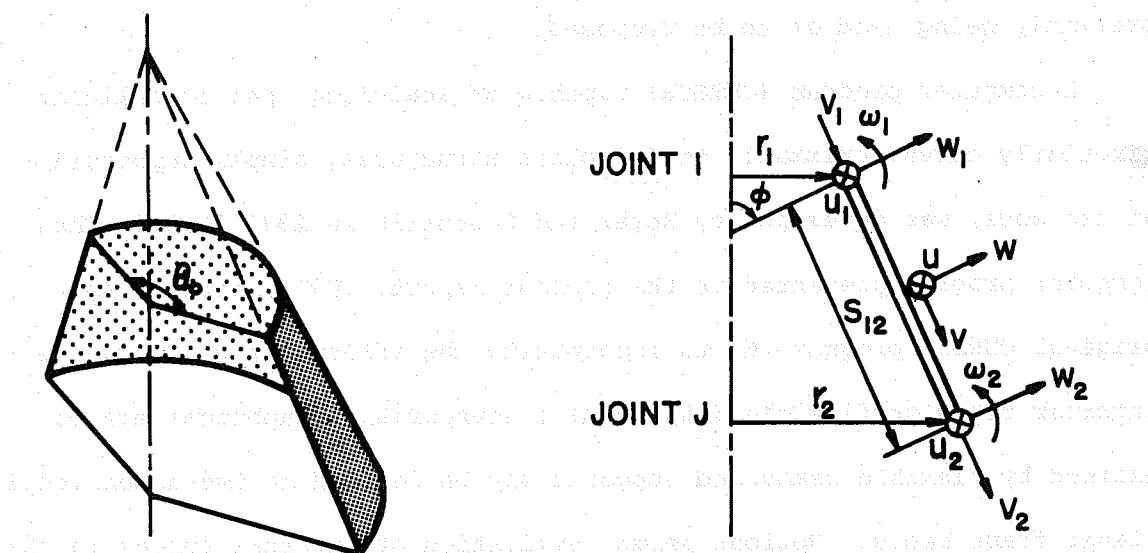
The bridge shown is a typical continuous bridge. It consists of a multi-cell box girder supported by three piers. The piers are rigidly connected to the deck at their bases. The deck is rigidly connected to the end diaphragms at both ends. The deck is rigidly connected to the interior support at its center.

**FIG. 1.1 MULTI-CELL BOX GIRDER BRIDGES**

Fig. 1.2 shows a circularly curved prismatic box girder bridge.



### a) STRUCTURAL SYSTEM



### b) TYPICAL ELEMENT

### c) ELEMENT COORDINATES AND DEGREES OF FREEDOM

The diagram illustrates the degrees of freedom (DOFs) for the typical element. At JOINT I, the DOFs are labeled  $U_I$ ,  $V_I$ ,  $W_I$ ,  $U_2$ ,  $V_2$ , and  $W_2$ . At JOINT J, the DOFs are labeled  $U_2$ ,  $V_2$ , and  $W_2$ . The angle  $\phi$  represents the rotation of the element about its longitudinal axis  $S_{I2}$ .

**FIG. 1.2 CIRCULARLY CURVED PRISMATIC BOX GIRDER BRIDGE**

It is obvious that analyses based on an idealization of the bridge as a one-dimensional beam type structure can only be used to give an indication of the longitudinal distribution of total reactions, moments, torques and centerline deflections, but they give no information on the transverse distribution of these quantities or the internal membrane forces and plate bending moments in each element, which can be obtained from a more complex folded plate analysis. Furthermore, the assumptions used in elementary beam theory of plane sections remaining plane, and no transverse distortions or warping of the cross-sections may be seriously in error for some box girder bridge types.

For the above reasons, a refined analytical method is needed to yield accurate results for design where deemed necessary. The refined method may also be used to evaluate simplified approximate methods presently being used or to be proposed.

A computer program (CURSTR) capable of analyzing open or cellular, circularly curved prismatic folded plate structures, simply supported at two ends, was developed by Meyer and Scordelis in 1970 [6,8]. The computer program presented in the present report, CURDI, extends the original CURSTR program [6] to incorporate the effects of up to twelve interior rigid or flexible diaphragms or supports. 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 bents, as well as the moments taken by each girder of the bridge cross-section. The program is restricted to the analysis of prismatic structures which may have interior supports, but must be simply supported at the extreme ends by radial diaphragms, rigid in

their own plane, but perfectly flexible normal to their own plane.

These end diaphragms are restrained against any displacement in their

own plane. The material of each plate element making up the cross-

section may either be isotropic or orthotropic and is assumed to be homogeneous and linearly elastic.

Having identified the conditions for the application, we may now proceed along

the lines of the previous analysis to obtain the resulting stress distributions

in the plates. A detailed description of the derivation of the equations

is given in the reference [1] and will not be repeated here.

Applying the boundary conditions and substituting the resulting distributions

into the already derived compatibility and equilibrium equations yields the

equations of motion for the system. These equations are nonlinear and must be solved numerically.

The numerical solution of the equations of motion is obtained by using the finite difference method. The spatial discretization is carried out by dividing the domain into a regular grid of points. The time discretization is carried out by using a implicit Euler scheme.

The resulting system of equations is solved using a direct solver. The solver is based on the LU factorization method and is able to handle sparse matrices.

The solution of the system of equations is obtained by using a time-stepping scheme. The time-stepping scheme is based on the explicit Euler scheme.

The resulting solution is then used to calculate the displacement field at each time step.

The displacement field is then used to calculate the stress distributions in the plates.

The stress distributions are then used to calculate the resulting forces and moments.

The resulting forces and moments are then used to calculate the resulting accelerations.

The resulting accelerations are then used to calculate the resulting velocities.

The resulting velocities are then used to calculate the resulting positions.

The resulting positions are then used to calculate the resulting displacements.

The resulting displacements are then used to calculate the resulting stresses.

The resulting stresses are then used to calculate the resulting forces and moments.

The resulting forces and moments are then used to calculate the resulting accelerations.

The resulting accelerations are then used to calculate the resulting velocities.

The resulting velocities are then used to calculate the resulting positions.

The resulting positions are then used to calculate the resulting displacements.

The resulting displacements are then used to calculate the resulting stresses.

## 2. METHOD OF ANALYSIS

### 2.1 General Remarks

For a curved prismatic box girder bridge (Fig. 1.2a), the problem to be solved is the determination of the internal forces and displacements in a structural system consisting of an assembly of longitudinal plate elements interconnected at joints along their longitudinal edges and simply supported at the two ends by transverse diaphragms. The known quantities input into the problem include the geometry, dimensions and material properties of the plate elements, the surface and joint loadings and the boundary conditions along the longitudinal joints. Each plate element selected is assumed to extend longitudinally over the entire span and transversely between designated joints on the cross-section. A typical element (Fig. 1.1b), in general, may be a segment of a conical frustum. The simple supports at the two end diaphragms infer that at these radial sections the plate elements experience no horizontal displacements in a radial direction, no vertical displacements and no rotations about a longitudinal axis.

An analysis for applied loads with any arbitrary circumferential distribution along the curved circular bridge may be performed using a harmonic analysis. The applied loads are first resolved into Fourier series components. An analysis is carried out for all loading components of each particular harmonic and then the final results are obtained by summing the results for all 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 method is ideally suited to the application of a digital computer.

For each harmonic, each joint has four degrees of freedom; it can displace vertically and horizontally in the plane of the cross-section; it can move longitudinally tangent to the joint; and it can rotate about an axis tangent to the joint. These directions define a global coordinate system for displacements or forces at the joint. The well known direct stiffness method can be used to perform the analysis for each harmonic.

## 2.2 Solution for a Simply Supported Curved Prismatic Folded Plate Structure

The solution is closely related to the finite strip analysis of plate type structures and also to the finite element analysis of shells of revolution under non-axisymmetric loads. This method is called the "curved strip method" and is described in detail by Meyer [8].

Provided a stiffness matrix can be derived for a typical curved strip element, which relates the generalized joint displacements and forces, it is possible to then apply the direct stiffness method to solve for the unknown generalized joint displacements.

The actual steps in the analysis procedure can be summarized as follows:

1. Replace all surface or line loads distributed across the width of a curved strip element by a set of equivalent nodal joint loads and transform their components to the global system.
2. Resolve all the loads to which the structure is subjected into Fourier series and form the loading vector by adding all load contributions for one typical harmonic of the series. The dimension  $m$  of this vector equals four times the number of joints in the structure.

3. Calculate the  $8 \times 8$  stiffness matrix of each curved strip element in the element coordinate system (Fig. 1.2c) for a typical harmonic of the Fourier series.
4. Transform each element stiffness to global coordinates, so that the structure stiffness matrix may be assembled according to the principles of the well known direct stiffness method. This  $m \times m$  matrix, in conjunction with the loading vector, constitutes the set of equilibrium equations for a typical harmonic of the Fourier series expansion.
5. Solve the system of equations for the unknown joint displacements which actually are the amplitudes of the displacement functions for the respective harmonic term.
6. Transform the joint displacements back to the element coordinates in order to determine the edge displacements to which each curved strip element is subjected.
7. For the edge displacements of this particular harmonic, calculate the internal forces in each curved strip element.
8. Repeat all of the above steps for each harmonic of the Fourier series and sum up the contributions of each term in order to obtain the final displacements and internal stress resultants throughout the structure.

For the analysis, the following assumptions are made:

1. The thickness of each curved strip element is constant and small compared with the other strip dimensions.
2. Straight lines which are perpendicular to the middle surface of the undeformed element remain straight and perpendicular to the deformed middle surface.

3. The material is homogeneous and linearly elastic, with orthotropic properties which are constant throughout any one element.

However, material property and thickness variations in the radial direction may be approximated by further subdividing each plate into curved strips and assigning different properties to each of them such as to simulate the true variation of the element properties.

### 2.2.1 Element Stiffness Matrix

The key step in the analysis is the derivation of the  $8 \times 8$  stiffness matrix for a general conical shell segment (Fig. 1.2c) in the  $n$ 'th mode of the harmonic series.

The three displacement components of a general conical shell segment (Fig. 1.1c) are assumed to vary as

$$\begin{aligned} u &= \sum_{n=1}^N u_n \cos \frac{n\pi\theta}{\theta_0} = \sum_{n=1}^N \langle \Phi_u(n) \rangle \{u_i\}_n \cos \frac{n\pi\theta}{\theta_0} \\ v &= \sum_{n=1}^N v_n \sin \frac{n\pi\theta}{\theta_0} = \sum_{n=1}^N \langle \Phi_v(n) \rangle \{v_i\}_n \sin \frac{n\pi\theta}{\theta_0} \\ w &= \sum_{n=1}^N w_n \sin \frac{n\pi\theta}{\theta_0} = \sum_{n=1}^N \langle \Phi_w(n) \rangle \{w_i\}_n \sin \frac{n\pi\theta}{\theta_0} \end{aligned} \quad (2.1)$$

where

$$\{u_i\}_n = \begin{cases} u_1 \\ u_2 \end{cases}_n \quad \{v_i\}_n = \begin{cases} v_1 \\ v_2 \end{cases}_n \quad \{w_i\}_n = \begin{cases} w_1 \\ w_2 \end{cases}_n \quad \left. \begin{array}{l} w_1 = \frac{\partial w}{\partial \eta} \\ w_2 = \frac{\partial w}{\partial \eta} \end{array} \right\} (2.2)$$

are the displacement amplitudes at the nodal joints 1 and 2 for a typical harmonic term  $n$ , and

$$\langle \Phi_u(\eta) \rangle = \langle \Phi_v(\eta) \rangle = \frac{1}{2} \langle (1-\eta) \quad (1+\eta) \rangle \quad (2.3a)$$

$$\langle \Phi_w(\eta) \rangle = \frac{1}{4} \langle (2-3\eta+\eta^3) \quad (2+3\eta-\eta^3) \quad \frac{s_{12}}{2}(1-\eta-\eta^2+\eta^3) \quad \frac{s_{12}}{2}(-1-\eta+\eta^2+\eta^3) \rangle \quad (2.3b)$$

are the displacement interpolation polynomials, with the natural coordinate  $\eta$  defined such that  $\eta = -1$  at joint 1 and  $\eta = +1$  at joint 2.

The accuracy of the analysis can be expected to increase if the linear transverse variation for the in-plane displacements  $u$  and  $v$  assumed in Eq. 2.3 is changed to vary quadratically over the width of one element, i.e., if the strip element shape functions assumed a parabolic

$$\{u_i\}_n = \begin{Bmatrix} u_1 \\ u_2 \\ u_0 \end{Bmatrix} \quad \{v_i\}_n = \begin{Bmatrix} v_1 \\ v_2 \\ v_0 \end{Bmatrix} \quad (2.4)$$

and

$$\langle \Phi_u(\eta) \rangle = \langle \Phi_v(\eta) \rangle = \langle \frac{1}{2}(1-\eta) \quad \frac{1}{2}(1+\eta) \quad (1-\eta^2) \rangle \quad (2.5)$$

where  $u_o$  and  $v_o$  are the in-plane displacement degrees of freedom associated with the joint halfway between joints 1 and 2. However, in the computer program version presented in this report, only the theory based on linear in-plane displacement functions is used.

After the displacement shape functions are assumed, the stiffness of each strip for  $n$ 'th harmonic can be obtained as described in detail by Meyer [8]. The stiffness terms are in integral form and are evaluated numerically by an 8'th order Gaussian quadrature formula.

Similarly the external loads are developed into Fourier series,

$$P = \sum_{n=1}^N p_n(\eta) \sin \frac{n\pi\theta}{\theta_0} \quad (2.6)$$

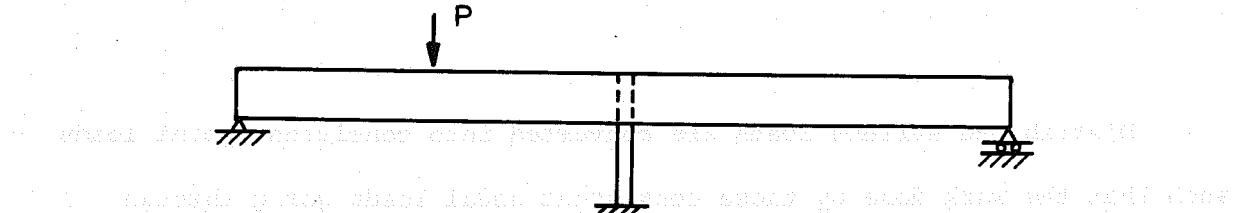
Distributed surface loads are converted into consistent joint loads such that the work done by these consistent nodal loads going through the joint displacements equals the work done by the distributed loads going through the assumed displacement field.

An important distinction should be noted between the curved strip method, which is essentially a finite element method, and the folded plate elasticity method used previously for straight bridges [1,13]. In the latter case the nodal point loads,  $R_i$ , and the element edge forces,  $S_i$ , are defined as actual forces in terms of the amplitude intensity of a particular harmonic, therefore in lb per ft or equivalent units. In the curved strip method,  $R_i$  and  $S_i$  are generalized nodal forces in lbs, which when multiplied by the nodal displacements in ft, do the same virtual work as the actual forces distributed along the longitudinal joints do in going through the joint displacement field. A nodal point displacement,  $v_i$ , is the amplitude of the harmonic displacement in ft.

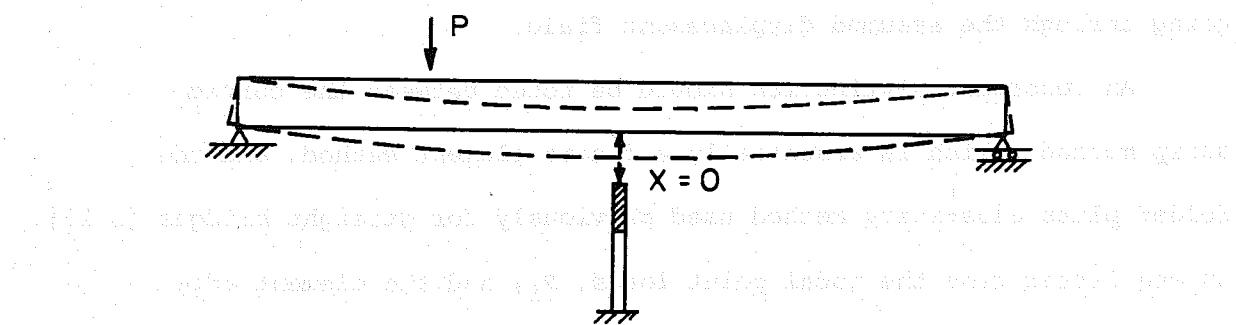
### 2.3 Solution for a Curved Prismatic Folded Plate Structure Supported by Flexible Planar Frame Bents

The method used previously for straight bridges and described in detail in an earlier report by Lin and Scordelis [13] is also employed for curved bridges. Thus, only a brief outline of the approach will be given here.

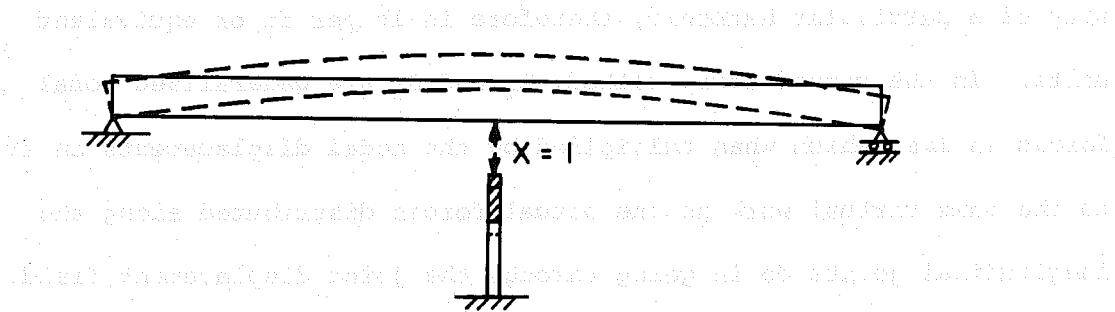
A force method is used to analyze the structure, such that compatibility between the folded plate system and the support bent (Fig. 2.1) is maintained. The interaction forces between the folded plates and the supporting frame bent are chosen as the redundants (Fig. 2.1d). Two



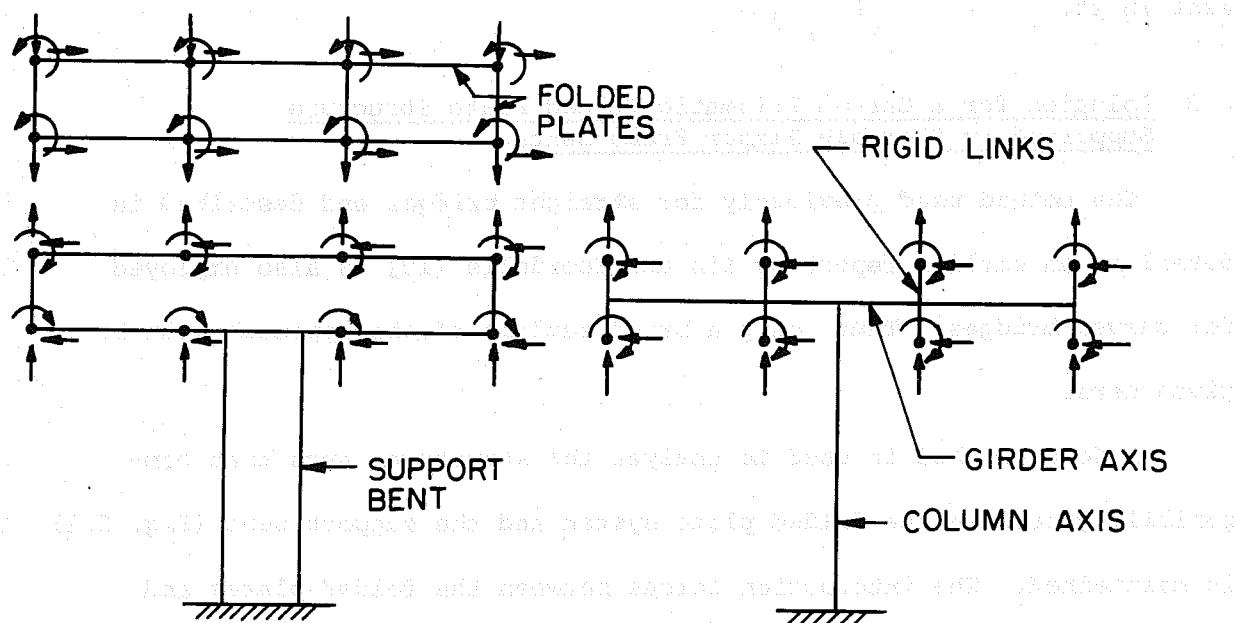
### a) ELEVATION OF THE STRUCTURE



### b) PRIMARY STRUCTURE



### c) UNDER UNIT REDUNDANT FORCE



### d) JOINT REDUNDANT FORCES

### e) IDEALIZED FRAME BENT

**FIG. 2.1 ANALYSIS OF A FOLDED PLATE STRUCTURE ON A FLEXIBLE BENT**

approximations have been made to simplify the solution procedure. First, it is assumed that the interaction forces act only at the nodes of the folded plate system, while in reality they are distributed over the contact surface between the folded plates and the bent diaphragms. Second, the longitudinal interaction forces between the folded plates and the bent system are not included. Thus, the interaction forces are represented by a set of three joint forces at each longitudinal joint (Fig. 2.1d), consisting of vertical, horizontal and rotational components in the plane of transverse cross-section.

Since the interior support bents are idealized as two-dimensional planar frames, they cannot take loads normal to their plane. The idealization of a typical support bent with a transverse girder (diaphragm) and a single column (Fig. 2.1d) is illustrated in Fig. 2.1e as a planar frame with fictitious vertical rigid links connecting the girder elastic axis to the joints of the folded plate system. In the execution of the solution, very high values of modulus of elasticity may be used for these fictitious elements to simulate rigid links.

#### **2.4 Solution of a Curved Prismatic Folded Plate Structure with Collinear Interior Flexible Diaphragms**

Once again the method used is similar to that described in detail for straight bridges in an earlier report [13]. Only a brief outline will be given here.

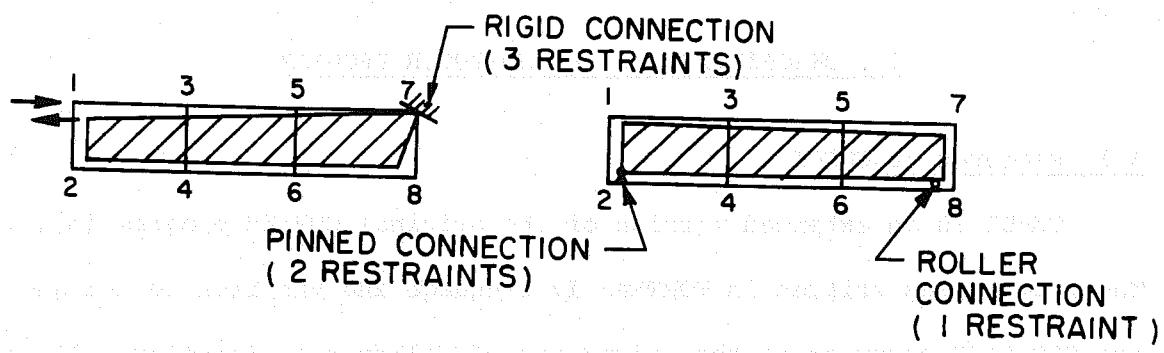
Again, a force method is used to analyse the structure, so as to maintain compatibility between the folded plate system and the diaphragms. The diaphragms are idealized as transverse beams in their own plane with zero stiffness normal to their plane. It is assumed that the diaphragms are connected to the folded plate structure at the longitudinal

joints only by three interaction forces, namely, the vertical, horizontal and rotational components in the plane of the transverse diaphragm. The joints will not allow longitudinal and rigid bending of the diaphragm (Fig. 2.3a).

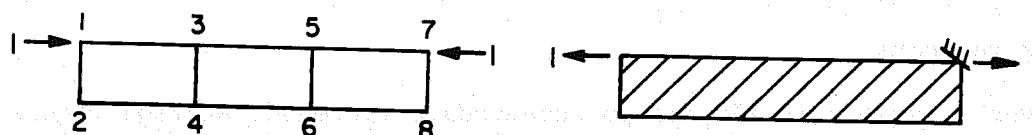
Since the diaphragms are not externally supported they undergo two kinds of displacements when subjected to the interaction forces, first, the rigid body motion of the diaphragm and second, deformations of the diaphragm itself. These conditions require that the interaction forces acting on the diaphragm must be in self-equilibrium. A system of self-equilibrating forces is generated by assuming initial connections between the diaphragm and folded plate system (Fig. 2.2).

The diaphragm may be idealized as an assemblage of one dimensional beam elements (Fig. 2.3) having boundary conditions consistent with its initial connection to the folded plate system. 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. 2.3a). A force method of analysis is used to analyze this total system such that compatibility of displacement is maintained at the interaction points between the folded plate structure and the diaphragms.

Building a folded plate structure with a peripheral diaphragm will result in a system which is more rigid than a system with a central diaphragm. This can be explained by noting that the peripheral diaphragm has a much larger area than the central diaphragm, therefore, it can resist larger loads. In addition, the peripheral diaphragm is connected to the folded plate structure at the outer edges, so it is able to transfer the applied loads to the folded plate structure more effectively. The central diaphragm, on the other hand, is connected to the folded plate structure at the center, so it is less effective in transferring the applied loads to the folded plate structure.

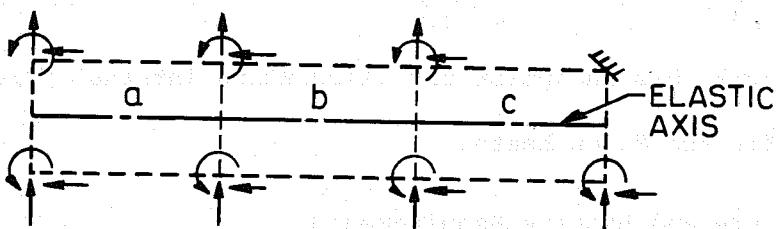


### a) TYPES OF INITIAL CONNECTIONS OF DIAPHRAGM TO FOLDED PLATE SYSTEM

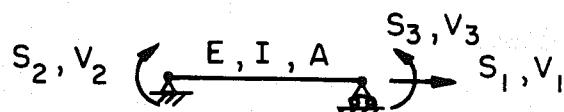


### b) INTERACTION FORCES ON FOLDED PLATES      c) INTERACTION FORCES ON DIAPHRAGM

FIG. 2.2 INTERACTION BETWEEN DIAPHRAGM AND FOLDED PLATE SYSTEM



### a) IDEALIZED FLEXIBLE DIAPHRAGM



### b) TYPICAL BEAM ELEMENT a, b OR c

FIG. 2.3 ANALYSIS OF THE FLEXIBLE DIAPHRAGM

### 3. DESCRIPTION OF THE COMPUTER PROGRAM

#### 3.1 Features of CURDI

CURDI is an extended version of the original CURSTR program [6].

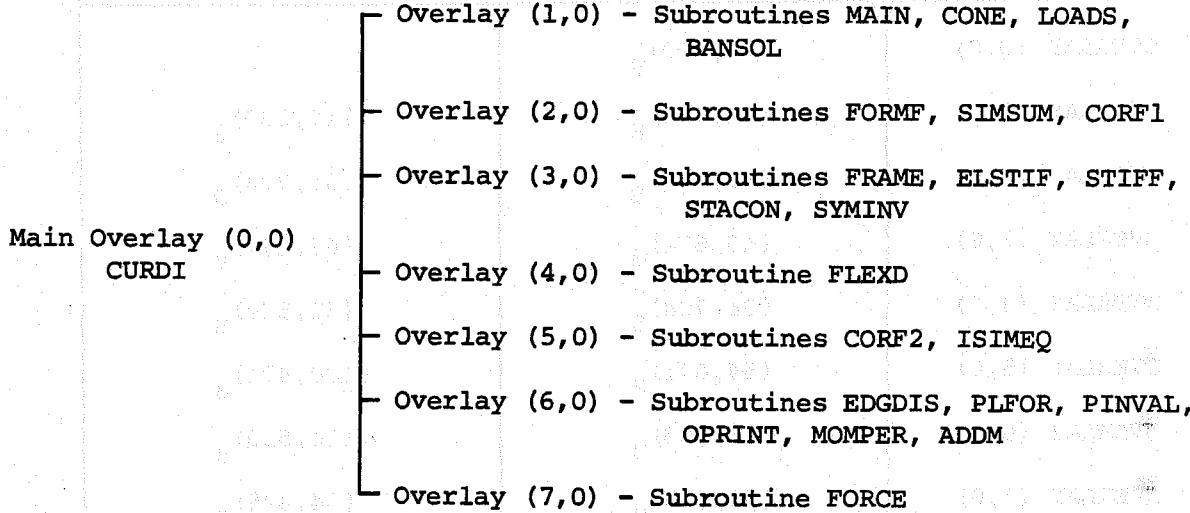
The program was written in FORTRAN IV language and has been tested on the CDC 6400 computer at the University of California, Berkeley. It provides a rapid solution for a prismatic folded plate structure simply supported at the two ends and having up to 12 interior flexible diaphragms or flexible support bents. This program differs from CURSTR in the following respects.

1. An overlay system is adopted to accommodate increased storage requirements and to make more efficient use of the storage facility.
2. The program can incorporate the effects of interior diaphragms and interior supports (maximum of 12). The diaphragms may be either rigid or flexible. Interior supports for joints of the folded plate system may be rigid or consist of a two-dimensional planar frame bent.
3. The program has an option for calculating internal forces and displacements for the frame bents.

#### 3.2 Structure and Storage Requirements

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:



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  $(130,616)_8$   $\approx (45,500)_{10}$ . The storage allocation for each overlay may be tabulated as follows

TABLE 3.1 - STORAGE REQUIREMENTS FOR CURDI PROGRAM

Overlays	Required Storage for the Overlay	Required Storage for the Execution*
OVERLAY (0,0)	(23,600) <sub>8</sub>	
OVERLAY (1,0)	(64,430) <sub>8</sub>	(110,230) <sub>8</sub>
OVERLAY (2,0)	(55,424) <sub>8</sub>	(101,224) <sub>8</sub>
OVERLAY (3,0)	(43,674) <sub>8</sub>	(67,474) <sub>8</sub>
OVERLAY (4,0)	(36,724) <sub>8</sub>	(62,524) <sub>8</sub>
OVERLAY (5,0)	(54,671) <sub>8</sub>	(100,471) <sub>8</sub>
OVERLAY (6,0)	(64,763) <sub>8</sub>	(110,563) <sub>8</sub>
OVERLAY (7,0)	(40,625) <sub>8</sub>	(64,425) <sub>8</sub>

\* 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  
 $= (130,616)_8$

### 3.3 Descriptions of Overlays and Flow Chart

Brief descriptions of each primary overlay are presented below and a condensed flow chart of the Program is given in Fig. 3.1.

OVERLAY (1,0) - Read and print input data. Resolve external load and unit interaction forces into equivalent nodal loads. Analyze the primary structure for each harmonic. Form the displacement matrix  $\delta_o$  for the external loads and the interaction forces.

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

OVERLAY (3,0) - Analyze each type of frame bent by direct stiffness

method. Form their flexibility matrices  $F_2$ .

OVERLAY (4,0) - Form the flexibility matrix  $\bar{F}_2$  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.

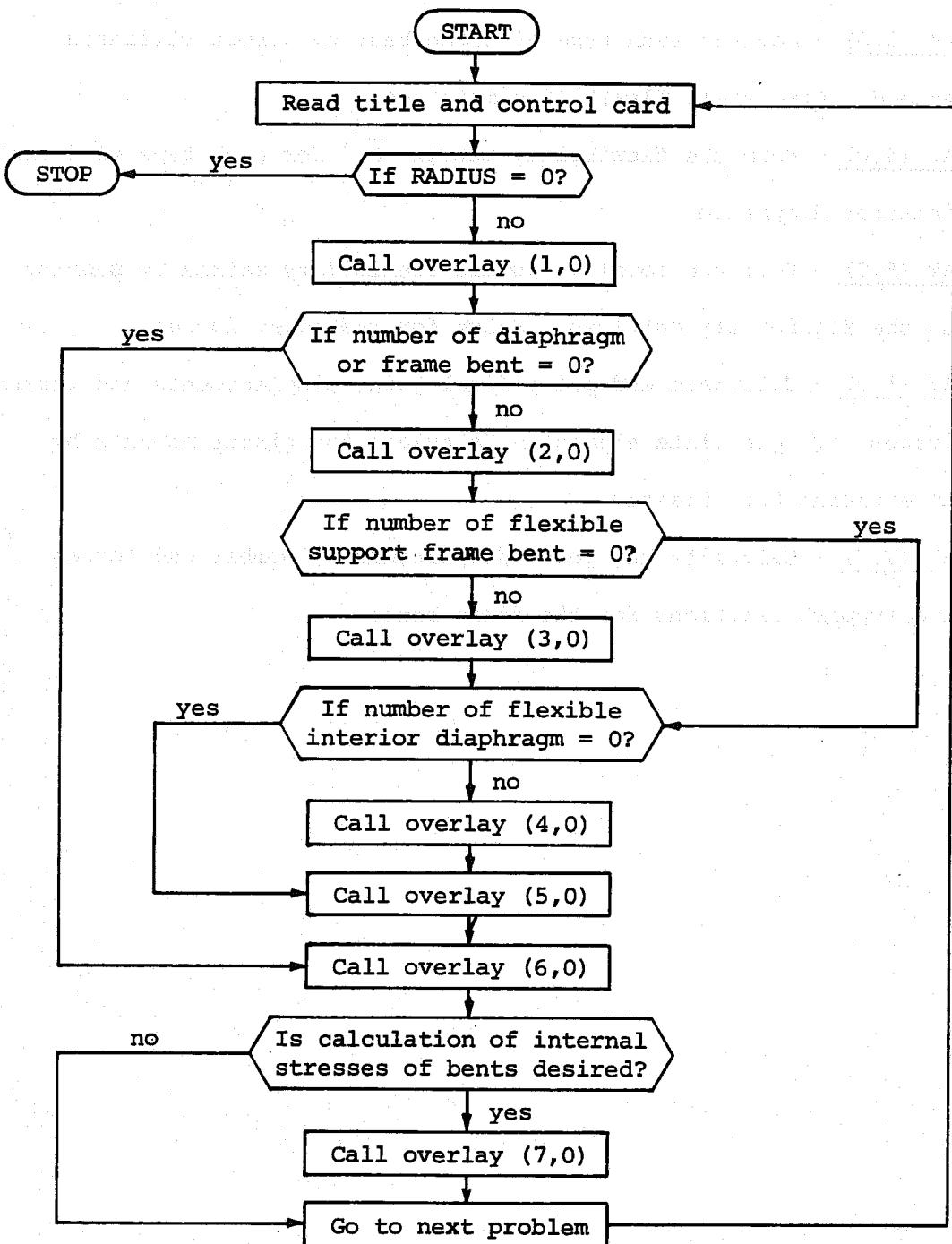


FIG. 3.1 FLOW CHART FOR CURDI

#### 4. COMPUTER PROGRAM USAGE

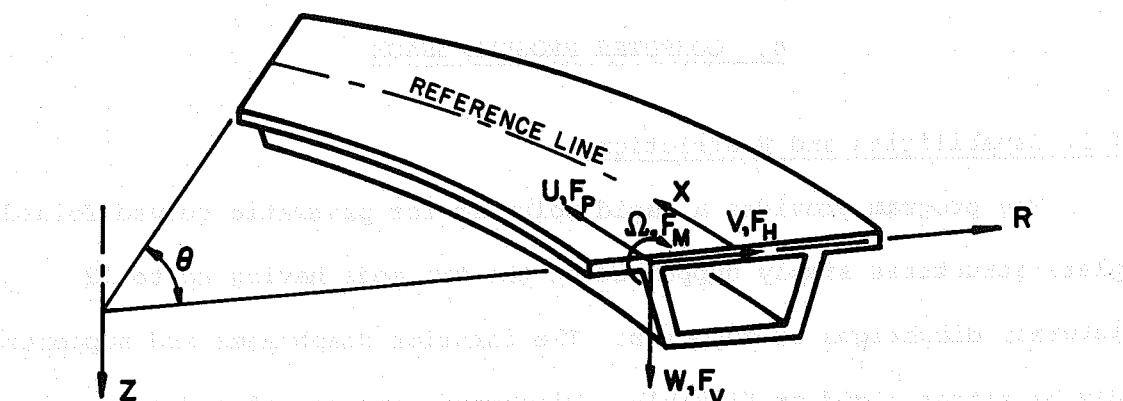
##### 4.1 Capabilities and Restrictions

The program provides a rapid solution for prismatic curved folded plate structures simply supported at the two ends having up to 12 interior diaphragms or supports. The interior 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. The two end supports are equivalent to idealized end diaphragms which do not permit any displacements within their plane but offer no resistance to displacements normal to their plane.

Uniform or partial surface loads, as well as line loads and concentrated loads, may be applied anywhere on the folded plate structure and treated as a single load case. Because of the solution technique used, which involves the summing of the results for all of the harmonics used to represent the loading for a particular load case, each new load case is treated as a new problem. Therefore, multiple load cases on a given structure cannot be analyzed simultaneously in the same problem.

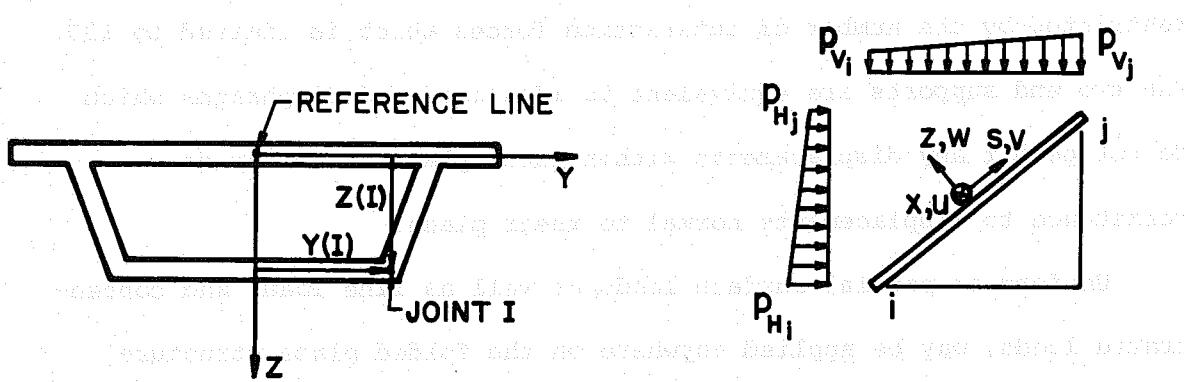
Restrictions as to the maximum number of plates, joints, diaphragms, terms of Fourier series, type of frame bents, etc., are given under user's guide in Appendix A.

The structure to be analyzed is defined by introducing a circumferential reference line, which may in general have an arbitrary location, provided its radius is nonzero (Fig. 4.1a). The cross-section is



### a) GLOBAL JOINT DISPLACEMENTS $U, V, W, \Omega$ AND JOINT LOADS

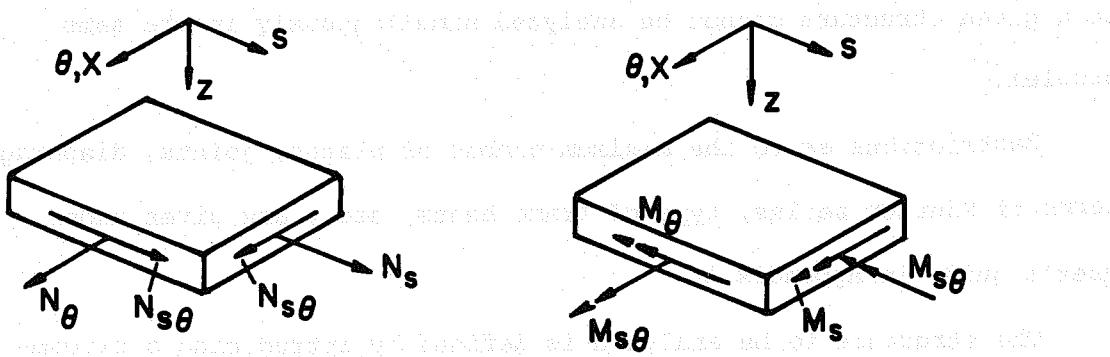
$F_P, F_H, F_V, F_M$



### b) JOINT COORDINATES

### c) SURFACE LOADS AND ELEMENT DISPLACEMENTS

Coordinate axes for the joint stiffness and force elements of truss elements are shown. Global joint coordinate system  $\theta, X, S, Z$  is defined by the reference line. Local joint coordinate system  $x, u, s, v$  is defined by the element axis.



### d) INTERNAL FORCES AND MOMENTS

Sign conventions for internal forces and moments are summarized below:

FIG. 4.1 SIGN CONVENTIONS

then defined by specifying for each nodal joint I a Y- and Z-coordinate as shown in Fig. 4.1b.

A typical element is then defined by specifying the joint numbers I and J. In general, an element is a segment of a conical frustum. The material law relating stress resultants and strains is assumed to be uniform but polar-orthotropic throughout the element.

$$\begin{Bmatrix} N_s \\ N_\theta \\ N_{s\theta} \\ M_s \\ M_\theta \\ M_{s\theta} \end{Bmatrix} = \begin{bmatrix} \frac{t^m E_s^m}{1-v_{s\theta}^m v_{\theta s}^m} & \frac{t^m E_\theta^m}{1-v_{s\theta}^m v_{\theta s}^m} & 0 & 0 & 0 & 0 \\ \frac{v_{\theta s}^m}{v_{s\theta}^m} \frac{t^m E_s^m}{1-v_{s\theta}^m v_{\theta s}^m} & \frac{v_s^m}{v_{\theta s}^m} \frac{t^m E_\theta^m}{1-v_{s\theta}^m v_{\theta s}^m} & 0 & 0 & 0 & 0 \\ 0 & 0 & t^m G^m & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{(t^b)^3 E_s^b}{12(1-v_{s\theta}^b v_{\theta s}^b)} & \frac{(t^b)^3 E_\theta^b}{12(1-v_{s\theta}^b v_{\theta s}^b)} & 0 \\ 0 & 0 & 0 & \frac{(t^b)^3 E_s^b}{12(1-v_{s\theta}^b v_{\theta s}^b)} & \frac{(t^b)^3 E_\theta^b}{12(1-v_{s\theta}^b v_{\theta s}^b)} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{(t^b)^3 G^b}{12} \end{bmatrix} \begin{Bmatrix} \epsilon_s \\ \epsilon_\theta \\ 2\epsilon_{s\theta} \\ \kappa_s \\ \kappa_\theta \\ 2\kappa_{s\theta} \end{Bmatrix} \quad (4.1)$$

or symbolically,

$$\begin{Bmatrix} N_s \\ N_\theta \\ N_{s\theta} \\ M_s \\ M_\theta \\ M_{s\theta} \end{Bmatrix} = \begin{bmatrix} d_{11} & d_{12} & 0 & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & d_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & d_{44} & d_{45} & 0 \\ 0 & 0 & 0 & d_{54} & d_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & d_{66} \end{bmatrix} \begin{Bmatrix} \epsilon_s \\ \epsilon_\theta \\ 2\epsilon_{s\theta} \\ \kappa_s \\ \kappa_\theta \\ 2\kappa_{s\theta} \end{Bmatrix} \quad (4.2)$$

where the superscript "m" denotes "membrane" or in-plane characteristics, and superscript "b" denotes "bending" properties,  $t$  is the element thickness,  $E$  and  $G$  the elastic and shear modulus, and  $\nu$  Poisson's ratio. Subscripts  $s$  and  $\theta$  indicate the radial and circumferential directions, respectively. Note that symmetry of Eq. (4.1) must be preserved so that

$$\begin{aligned} v_{s\theta}^m &= \frac{E_\theta^m}{E_s^m} v_{\theta s}^m \\ v_{s\theta}^b &= \frac{E_\theta^b}{E_s^b} v_{\theta s}^b \end{aligned} \quad (4.3)$$

and

The commonly used isotropic, homogeneous material law follows

from Eq. (4.1) by setting

$$\begin{aligned} E_s^m &= E_\theta^m = E_s^b = E_\theta^b = E \\ v_{s\theta}^m &= v_{\theta s}^m = v_{s\theta}^b = v_{\theta s}^b = \nu \\ G^m &= G^b = G = \frac{E}{2(1+\nu)}, \quad t^m = t^b = t \end{aligned}$$

## 4.2 Input and Output

The program has been written such that the material law can be input in either of two ways.

- a) Input all of the following element properties

$$t^m, t^b, E_s^m, E_s^b, E_\theta^m, E_\theta^b, G^m, G^b, v_{\theta s}^m, v_{\theta s}^b$$

for each "plate type" which is defined by a unique set of the above quantities.

- b) Input the constitutive relations directly in the form of

$$d_{11}, d_{12}, d_{22}, d_{33}, d_{44}, d_{45}, d_{55}, d_{66}$$

i.e., specify all independent elements of the constitutive matrix in

Eq. 4.2 directly, thus also completely defining a plate type. The number of different plate types is restricted to a maximum of 30.

This input option gives the user much freedom in defining his constitutive relations. Stiffeners in either direction and different amounts of reinforcement may be taken into account. In complex situations, the d-coefficients may be determined experimentally.

The structure may be subjected to surface or joint loads. Surface loads vary linearly over the width of an element and are constant over a specified portion of the circumferential length of the element. In this case they are referred to as "partial surface loads." Similarly, joint loads may also extend uniformly over the whole length of a joint or over only a fraction of it, in which case they are referred to as "partial joint loads."

The program has an option to suppress all even terms in the Fourier series whenever the applied loads are symmetric about the midspan section. Similarly, if the loads are anti-symmetric about the midspan section, as for example prestress forces applied at the end of the structure, all odd harmonics may be suppressed. If the structure is a full  $360^\circ$  axisymmetric shell subjected to axisymmetric loading, the Fourier analysis degenerates such that only the zero-th harmonic is retained, and the program has been written to incorporate this special case.

For various reasons it might be of interest to study the results not only for a specified final sum of harmonic series contributions, but also intermediate results. For this purpose, it is possible, by specifying, for example, the total number of harmonics to be used as 50, to print internal element forces and displacements also after only say

10 or 20 or 30 terms of the respective Fourier series have been accumulated, or any other combination of harmonics smaller than 50.

The question of how many Fourier terms should be used to represent the loading depends on the type of loading and on the desired output quantities. Deflections usually converge very rapidly, and 5 to 10 nonzero harmonic terms are sufficient to describe most loading types. Stresses and moments do not converge as fast, especially for concentrated loads in which case at least 40 nonzero terms may be necessary for adequate accuracy.

For input/output labelling, the user has the option to specify the circumferential coordinates either in angular degrees or in arc lengths. For strongly curved structures, the user might prefer the angle option, while for large curvature radii, the arc option will usually be more convenient. If use of the arc is made, care has to be taken that the longitudinal position of a concentrated or line load is specified along the joint where the load is acting and not along the reference line unless they coincide.

In analyzing curved bridge structures, it is often useful to know the moment that each individual girder contributes to the total statical moment at any section. In fact, the sum of these girder moments should add up to the statical moment due to the applied loads. This useful check is obtained by means of the "moment integration" option. Individual girder moments due to normal stress resultants as well as longitudinal plate bending moments may be printed out at any section for which stress and displacement output is available, together with the net compressive and tensile stress resultants within each girder.

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

The required input data includes:

- (1) The geometry and dimensions of the structure in terms of the centerline radius, angle in degrees or arc length along reference line between end supports, number of plates, joints, diaphragms, supporting frame bents, and cross-sectional dimensions.
- (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 output of final results.
- (9) Neutral axis and division of the cross-section into girders for the calculation of girder moments.

The output consists of the following:

- (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 (either in terms of arc lengths or angles in degrees) 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 Sign Conventions

The structure is defined in global cylindrical coordinates R,Z, $\theta$  as shown in Fig. 4.1a. The Z-axis is defined by the axis of revolution. It has its origin in the plane of the reference line and points downward. The R-axis points from the axis of revolution outward, and the angular  $\theta$ -coordinate points from one end of the structure towards the other end such that it describes a rotation vector in the negative Z-direction.

External vertical and horizontal loads are positive if acting in the positive Z- and R-directions, respectively. Longitudinal loads and applied moment vectors are positive if acting along a tangential X-axis which is normal to the Z-R plane such that X,R,Z form a right-handed system in that order, Fig. 4.1a.

Joint coordinates within a cross-section are measured in modified global coordinates Y and Z which are positive as shown in Fig. 4.1b.

Joint loads and displacements are positive as shown in Fig. 4.1a.

Fig. 4.1c defines positive directions of element surface loads and

element displacements, and Fig. 4.1d those of internal forces and moments.

#### 4.4 Special Considerations for the Use of CURDI

If the structure is symmetrical in the longitudinal direction about a transverse midspan 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. 4.2a), only the odd terms of the Fourier series have to be included. For anti-symmetrical loading (Fig. 4.2b), 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 only be taken in a case with only one center bent or diaphragm (Fig. 4.2a). It should be emphasized that no advantage of symmetrical loading may be taken for spans with more than one diaphragm or bent. In these cases all terms of the Fourier series must be used. Advantage of anti-symmetrical loading may be taken only in cases of simple spans with no intermediate diaphragms or bents (Fig. 4.2b).

Since forces are approximated by Fourier coefficients, a suitable number of harmonics must be used to adequately approximate the applied loads and the interaction forces. 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

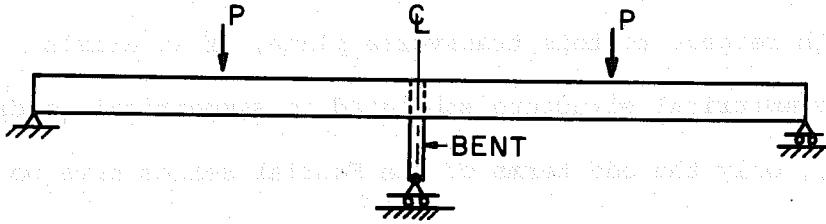
For example, a beam subjected to shear forces with different values at the ends will have a different deflection curve than one with equal shear forces at both ends.

It is important to understand the effect of loading on the deflection curve of a beam.

For example, consider a beam with a central load  $P$  and a fixed support at each end.

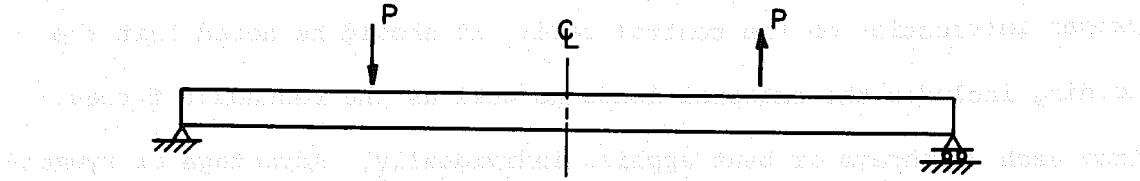
All parts of the beam experience equal bending except near the supports.

With increasing distance from the supports, the bending moment increases.



### a) SYMMETRICAL LOADING

For symmetric loading, the bending moment is zero at the supports, resulting in a parabolic deflection curve.



### b) ANTSYMMETRICAL LOADING

For antisymmetric loading, the bending moment is zero at the supports, resulting in a parabolic deflection curve.

## FIG. 4.2 LONGITUDINAL SYMMETRY AND ANTSYMMETRY

whenever detailed information is desired on internal forces and moments in the vicinity of concentrated external loads or interaction redundant forces. See references [8,13] for a further discussion of the convergence problem.

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 later in Example 4.

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. This becomes a simple determinate problem.

The output of the program is a series of tables giving the interaction forces at each node. These interaction forces are the result of the interaction between the frame bents and the folded plates. They are calculated by the computer as the sum of the reaction forces at each node due to the interaction of the frame bents and the folded plates.

The output of the program is a series of tables giving the interaction forces at each node. These interaction forces are the result of the interaction between the frame bents and the folded plates. They are calculated by the computer as the sum of the reaction forces at each node due to the interaction of the frame bents and the folded plates.

The output of the program is a series of tables giving the interaction forces at each node. These interaction forces are the result of the interaction between the frame bents and the folded plates. They are calculated by the computer as the sum of the reaction forces at each node due to the interaction of the frame bents and the folded plates.

The output of the program is a series of tables giving the interaction forces at each node. These interaction forces are the result of the interaction between the frame bents and the folded plates. They are calculated by the computer as the sum of the reaction forces at each node due to the interaction of the frame bents and the folded plates.

The output of the program is a series of tables giving the interaction forces at each node. These interaction forces are the result of the interaction between the frame bents and the folded plates. They are calculated by the computer as the sum of the reaction forces at each node due to the interaction of the frame bents and the folded plates.

## 5. EXAMPLES

### 5.1 General Remarks

Verification of the methodology required a number of comparisons and validation against other software or analytical hand solutions. Four example structures have been analyzed to verify the method of analysis used and the computer program solutions. The examples also demonstrate the capabilities as well as the limitations of the analysis using the computer program CURDI. It should be emphasized that the analysis assumes the structure to be a linear elastic system.

In Example 1, a single span, one cell, box girder bridge model with inclined webs is analyzed. The section consists of a wide concrete top slab acting compositely with a bottom steel box. Comparison of results for a curved bridge, with and without interior diaphragms, and a straight bridge of the same span without interior diaphragms are made to determine the effects of interior diaphragms and bridge curvature.

In Example 2, a straight two-span continuous T-beam bridge is analyzed. Several cases are run, and a comparison of results is made for the bridge with various types of midspan diaphragm conditions and interior support systems. The effects of the flexibility of interior diaphragms or supporting bents is demonstrated. In order to verify the results from CURDI, which is based on a curved strip method, the same cases are run using the previously developed computer program for straight bridges, MUPDI3 [13], which is based on a folded plate elasticity solution. Many previous studies have verified the accuracy of MUPDI3. The CURDI analysis is made assuming a very large radius of curvature for the straight T-beam bridge, so that for all practical purposes it becomes a straight bridge and hence a comparison with the

relations and the associated computer programs can be obtained and reliable results from MUPDI3 can be made.

In Example 3, a curved, single span, four cell, aluminum box girder bridge model having a midspan diaphragm is analyzed by CURDI. Theoretical results, thus obtained, are then compared with experimental results reported on previously [16]. This serves as an important check on the validity of the analytical model used in CURDI to represent the actual linear elastic system used in the experimental model.

In Example 4, a curved, two span, four cell, continuous concrete box girder bridge is analyzed to demonstrate the practical application of the CURDI program to a typical two lane highway overpass structure.

The structure has a single column center bent support and a diaphragm at one midspan but not at the other. The horizontal radius of curvature of the bridge was selected as being the maximum generally encountered in the California highway system.

All computer analyses were made using the CDC 6400 computer at the University of California Computer Center. The CDC 6400 carries approximately 15 significant decimal digits in its arithmetic operations. For computer systems using fewer significant figures, checks should be made with the results given for the Examples in this chapter to determine whether double precision calculations might be necessary. In Section 5.6, a summary for all examples of computer times and costs together with the number of harmonics used is given for comparison purposes. Times and costs on other computer systems will, of course, depend on the computer being used and the rate schedule.

## 5.2 Example 1 - Single Span, One Cell Box Girder Bridge

A small scale model of a typical composite concrete-steel box

girder bridge is analyzed. The cross-sectional dimensions of the model are shown in Fig. 5.1. Note the relatively thick concrete top deck supported by a thin walled steel box, which is typical of this type of construction.

Three cases were analyzed for the same pair of midspan concentrated loads consisting of 0.5 kips above each web.

**Example 1A - straight bridge without interior diaphragms**

**Example 1B - curved bridge without interior diaphragms**

**Example 1C - curved bridge with interior flexible diaphragms**

The plan dimensions of the bridges are shown in Fig. 5.3. The straight bridge had a span of 106 in., which was identical to the curved bridge spans measured along the centerline arc. Example 1A was analyzed using a large centerline radius of 10,000 in. in CURDI to closely approximate a straight bridge, while for the curved bridges of Examples 1B and 1C, the actual radius of 187.93 in. was used in CURDI.

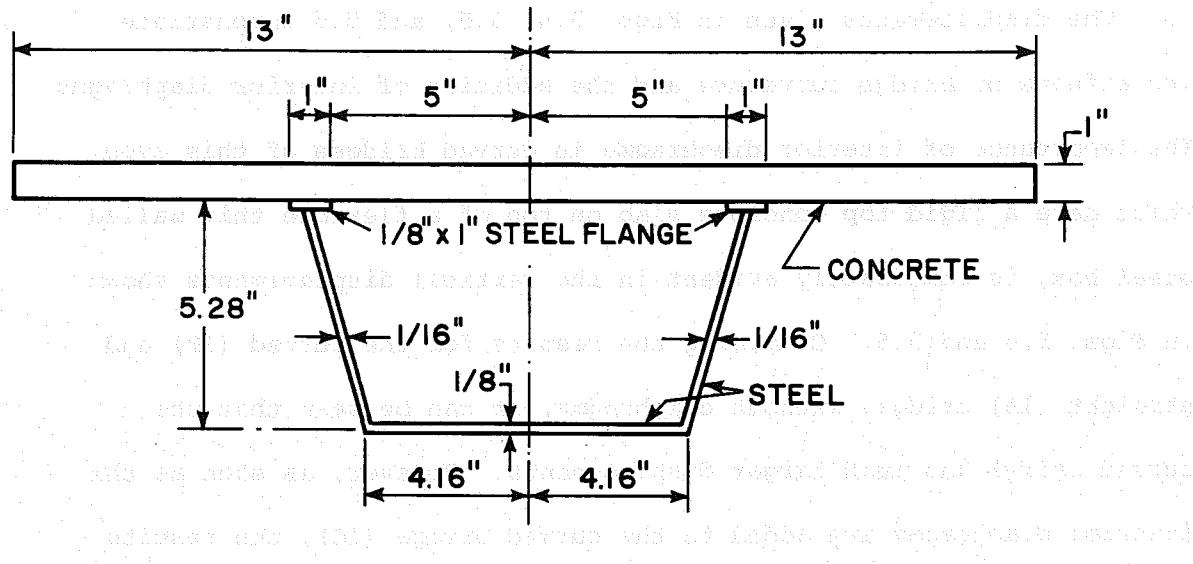
The nodal point layout and element properties are given in

Fig. 5.2. Centerline dimensions taken from Fig. 5.1 were used, and for simplicity in this study, the steel flange plates at the tops of the webs were omitted in the computer model for ease of comparison. Also indicated in Fig. 5.2 is the division of the cross-section into two girders, an inner girder 1 and an outer girder 2, with reference to the curved bridge. These are used in conjunction with the moment integration options in the computer programs.

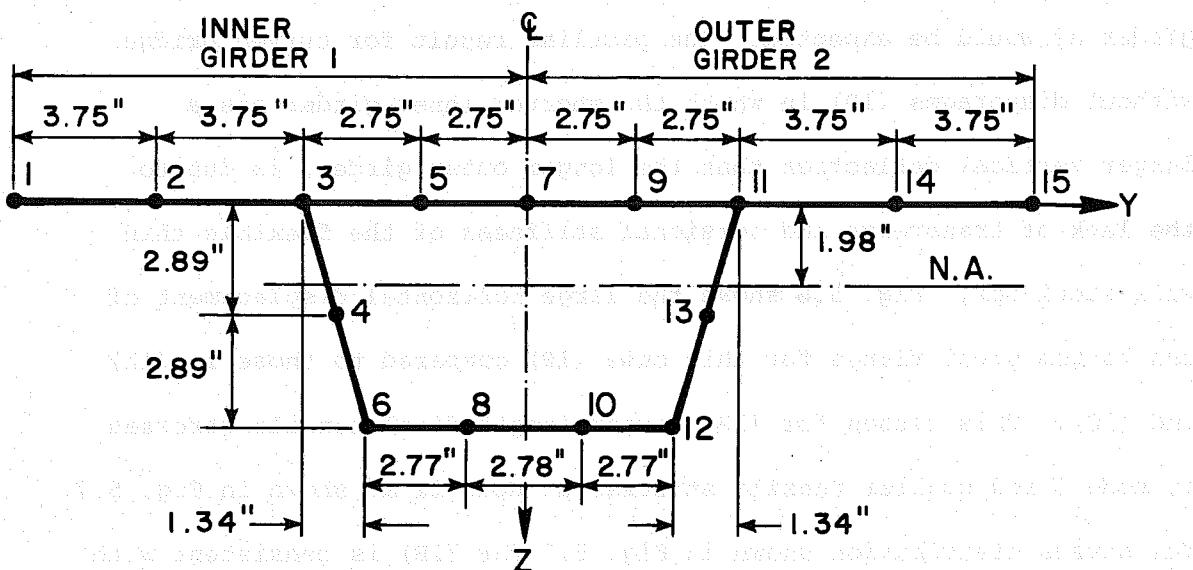
Result for displacements, internal forces and moments are presented in Figs. 5.4 to 5.10. The sign conventions for these quantities are given in Fig. 4.1.

The displacements given in Figs. 5.4, 5.5, and 5.6 demonstrate the effects of bridge curvature and the addition of interior diaphragms. The importance of interior diaphragms in curved bridges of this type, which have a rigid top concrete slab on top of a flexible thin walled steel box, is immediately evident in the vertical displacements shown in Figs. 5.4 and 5.5. Comparing the results for the curved (1B) and straight (1A) bridges without diaphragms, it can be seen that the curved bridge has much larger displacements. However, as soon as the interior diaphragms are added to the curved bridge (1C), the results become much closer to those of the straight bridge (1A), with the outer girder of the curved bridge deflecting somewhat more than the inner girder as would be expected. The peculiar result for curved bridge without diaphragms (1B), in which the shorter inner girder has a larger vertical deflection than the longer outer girder, is due to the lack of transverse and torsional stiffness of the flexible thin wall steel box. Fig. 5.6 shows the large horizontal displacement of the bottom steel flange for this case (1B) compared to those in (1A) and (1C). This causes for (1B) larger longitudinal tensile stresses at node 6 and smaller tensile stresses at node 12 as shown in Fig. 5.7. The stress distribution shown in Fig. 5.7 for (1B) is consistent with a larger vertical displacement at the inner girder than at the outer girder. It is evident that there is a complex interaction between the structural elements in bridges of this type, which cannot be predicted by simplified theories. The behavior of a similar cross-section made entirely of concrete with a thick walled, and thus stiff, concrete box on the bottom would be quite different.

The results for the longitudinal forces  $N_\theta$  (lb/in) shown in



**FIG. 5.1 EXAMPLE 1 - TYPICAL MODEL CROSS-SECTION**



#### CONCRETE

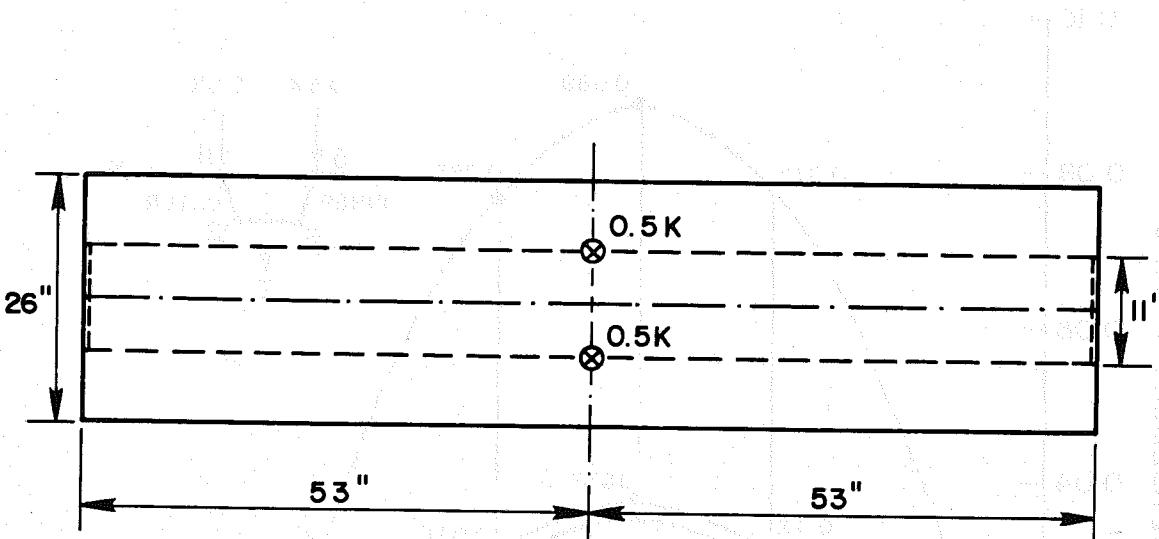
#### STEEL

$$E_c = 2,690 \text{ KSI} \quad E_s = 30,000 \text{ KSI}$$

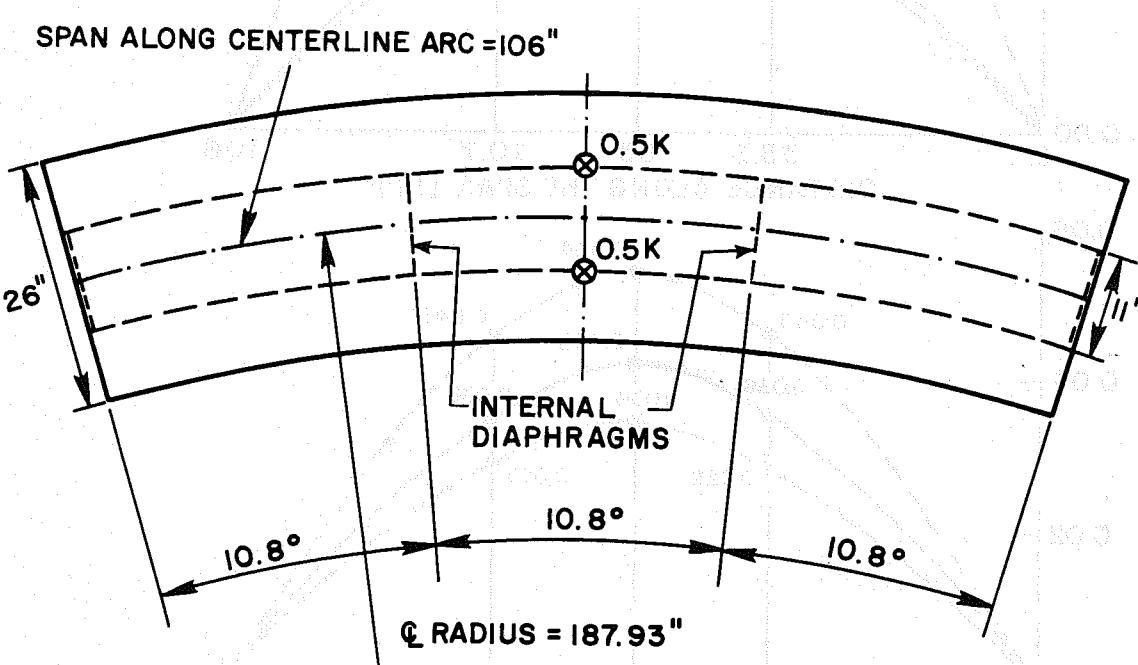
$$G_c = 1,030 \text{ KSI} \quad G_s = 11,500 \text{ KSI}$$

$$v_c = 0.157 \quad v_s = 0.30$$

**FIG. 5.2 EXAMPLE 1 - NODAL POINT LAYOUT AND MATERIAL PROPERTIES**



(a) STRAIGHT BRIDGE



(b) CURVED BRIDGE

FIG. 5.3 EXAMPLE 1 - PLAN VIEWS OF THE MODELS

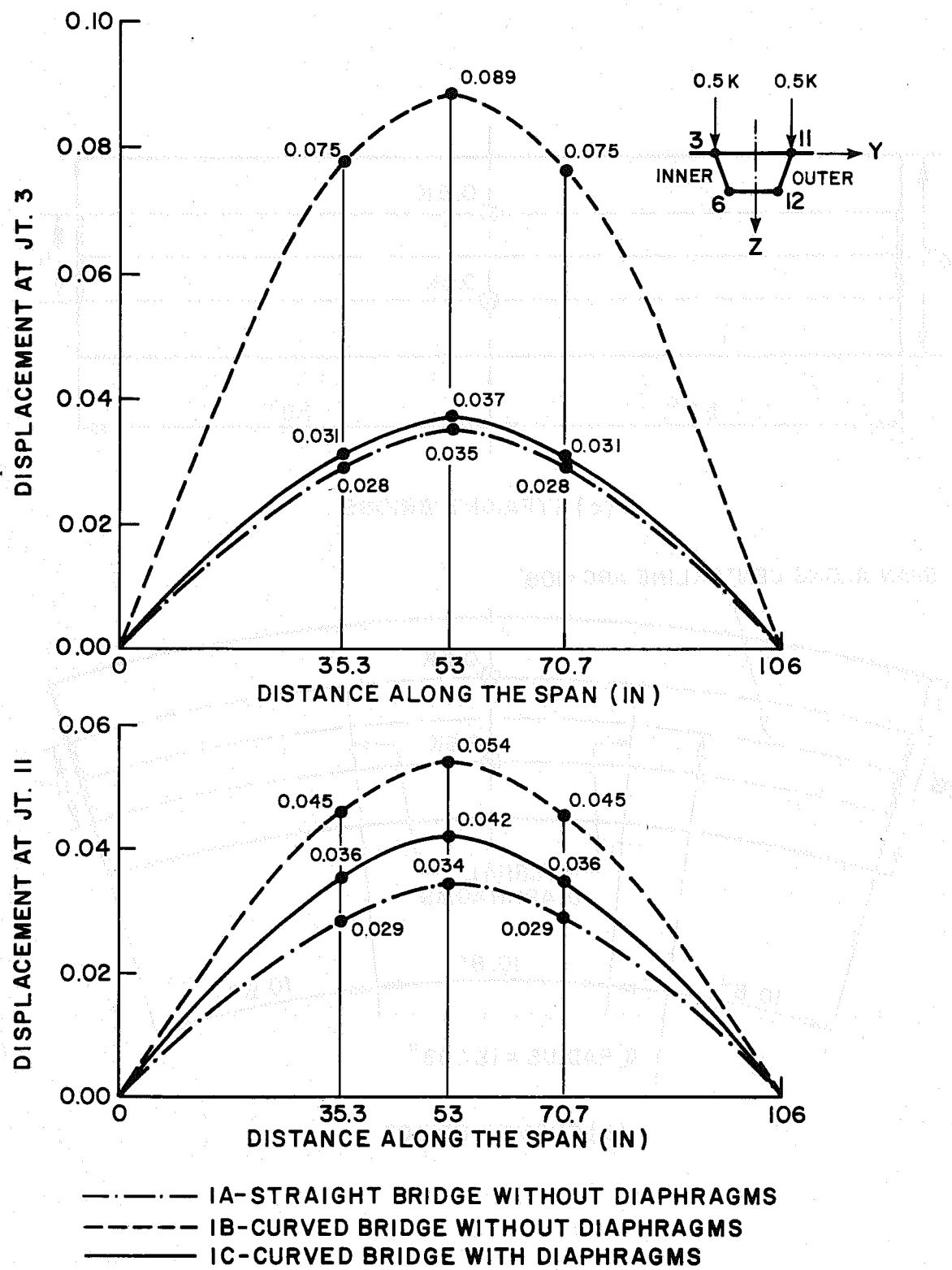
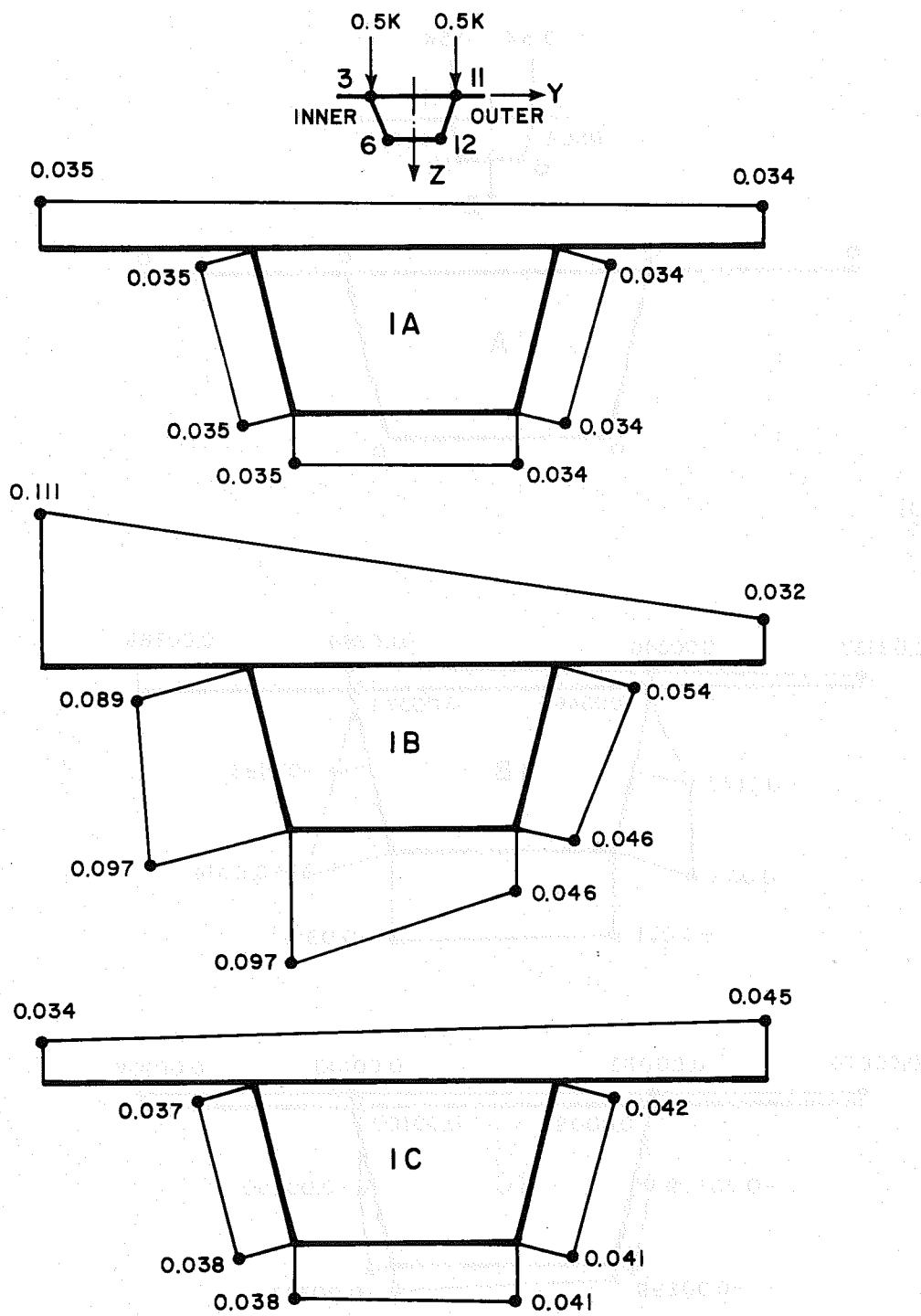


FIG. 5.4 EXAMPLE 1 – LONGITUDINAL DISTRIBUTION OF VERTICAL DEFLECTIONS (INCHES) AT THE TOPS OF THE GIRDERS WEBS

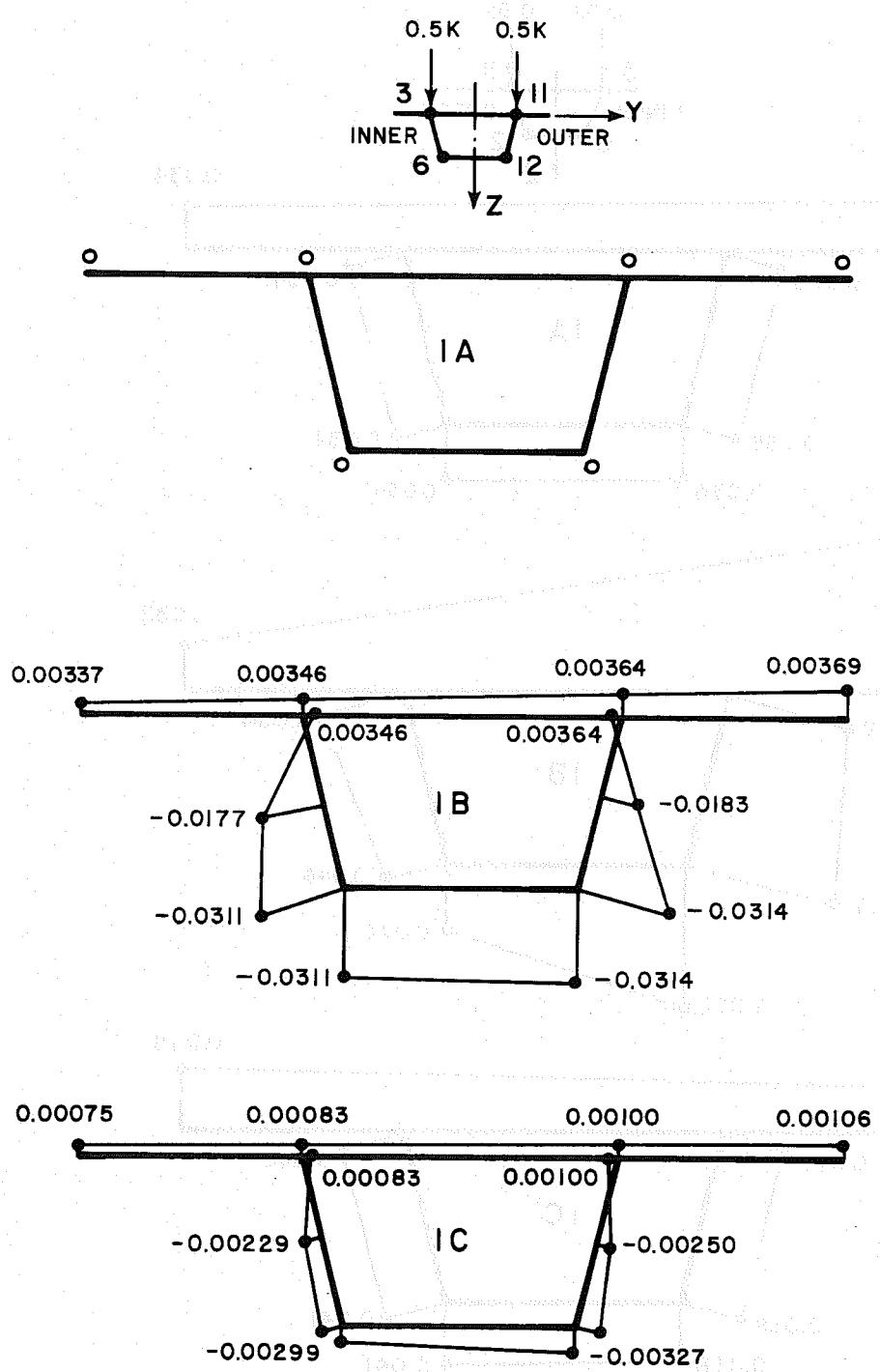


**IA - STRAIGHT BRIDGE WITHOUT DIAPHRAGMS**

**IB - CURVED BRIDGE WITHOUT DIAPHRAGMS**

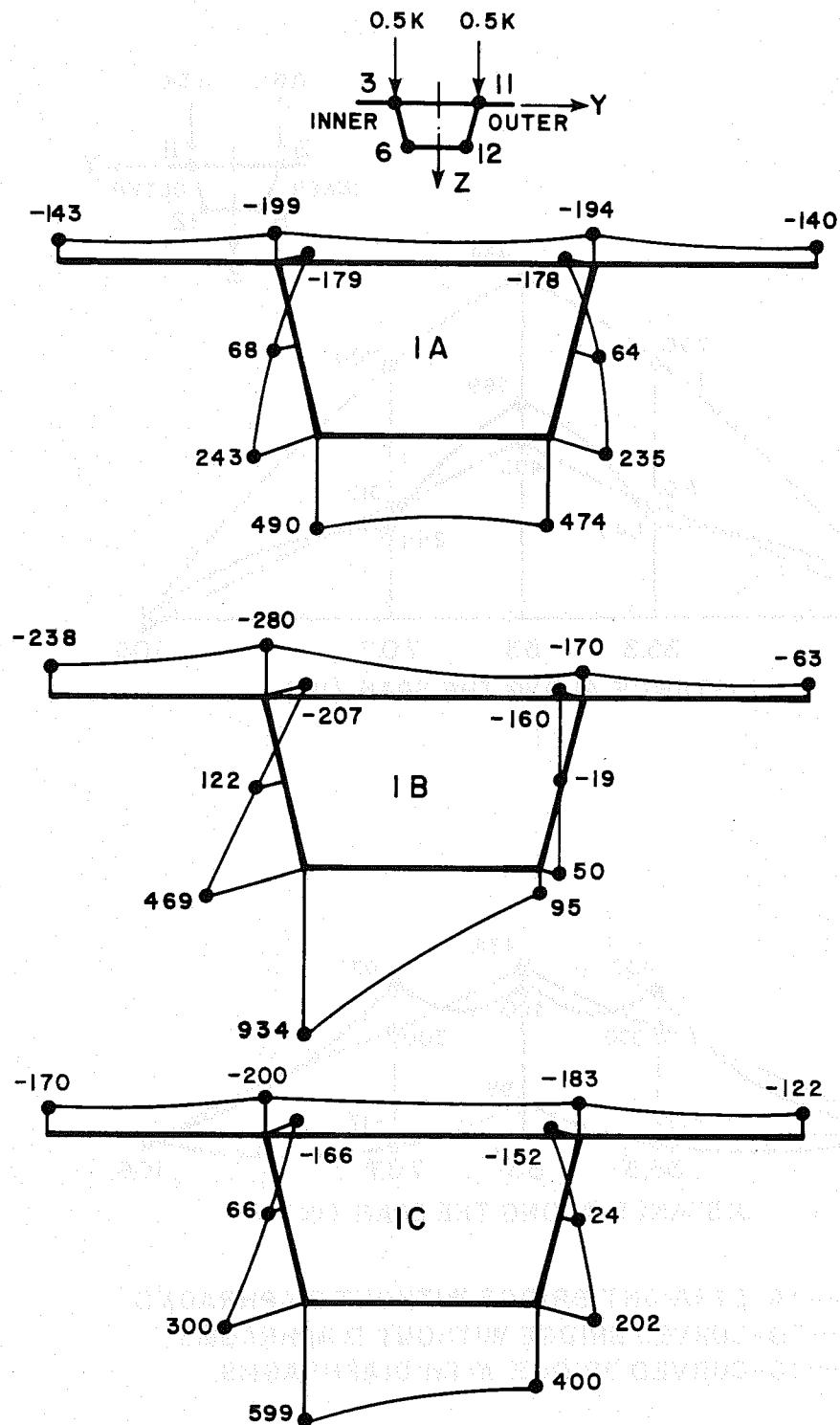
**IC - CURVED BRIDGE WITH DIAPHRAGMS**

**FIG. 5.5 EXAMPLE 1 – TRANSVERSE DISTRIBUTION OF VERTICAL DEFLECTIONS (INCHES) AT MIDSPAN SECTION**



**IA - STRAIGHT BRIDGE WITHOUT DIAPHRAGMS**  
**IB - CURVED BRIDGE WITHOUT DIAPHRAGMS**  
**IC - CURVED BRIDGE WITH DIAPHRAGMS**

**FIG. 5.6 EXAMPLE 1 – TRANSVERSE DISTRIBUTION OF HORIZONTAL DEFLECTIONS (INCHES) AT MIDSPAN SECTION**



IA - STRAIGHT BRIDGE WITHOUT DIAPHRAGMS

IB - CURVED BRIDGE WITHOUT DIAPHRAGMS

IC - CURVED BRIDGE WITH DIAPHRAGMS

FIG. 5.7 EXAMPLE 1 - TRANSVERSE DISTRIBUTION OF LONGITUDINAL FORCES  $N_{\theta}$  (LB/INCH) AT MIDSPAN SECTION

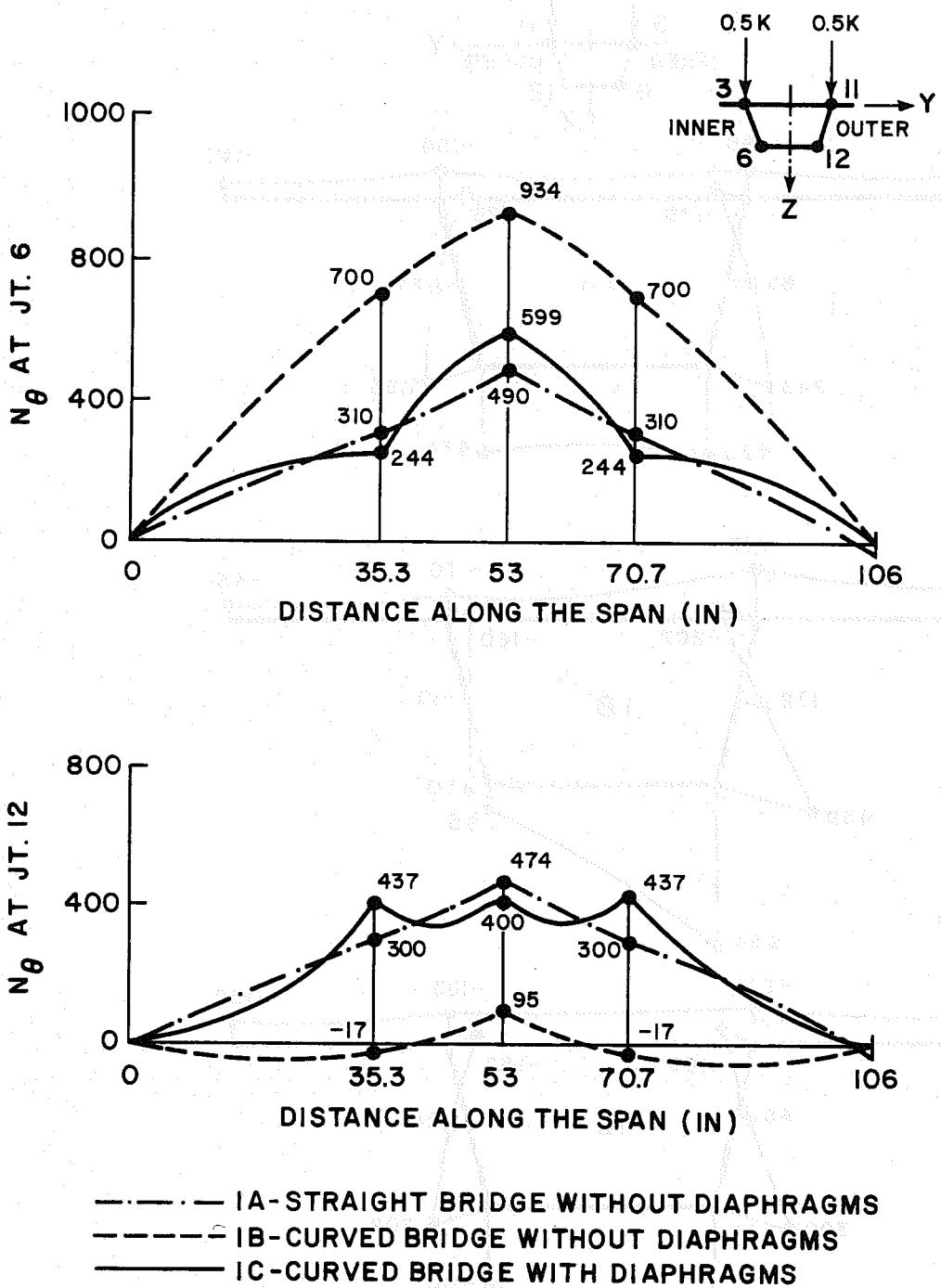
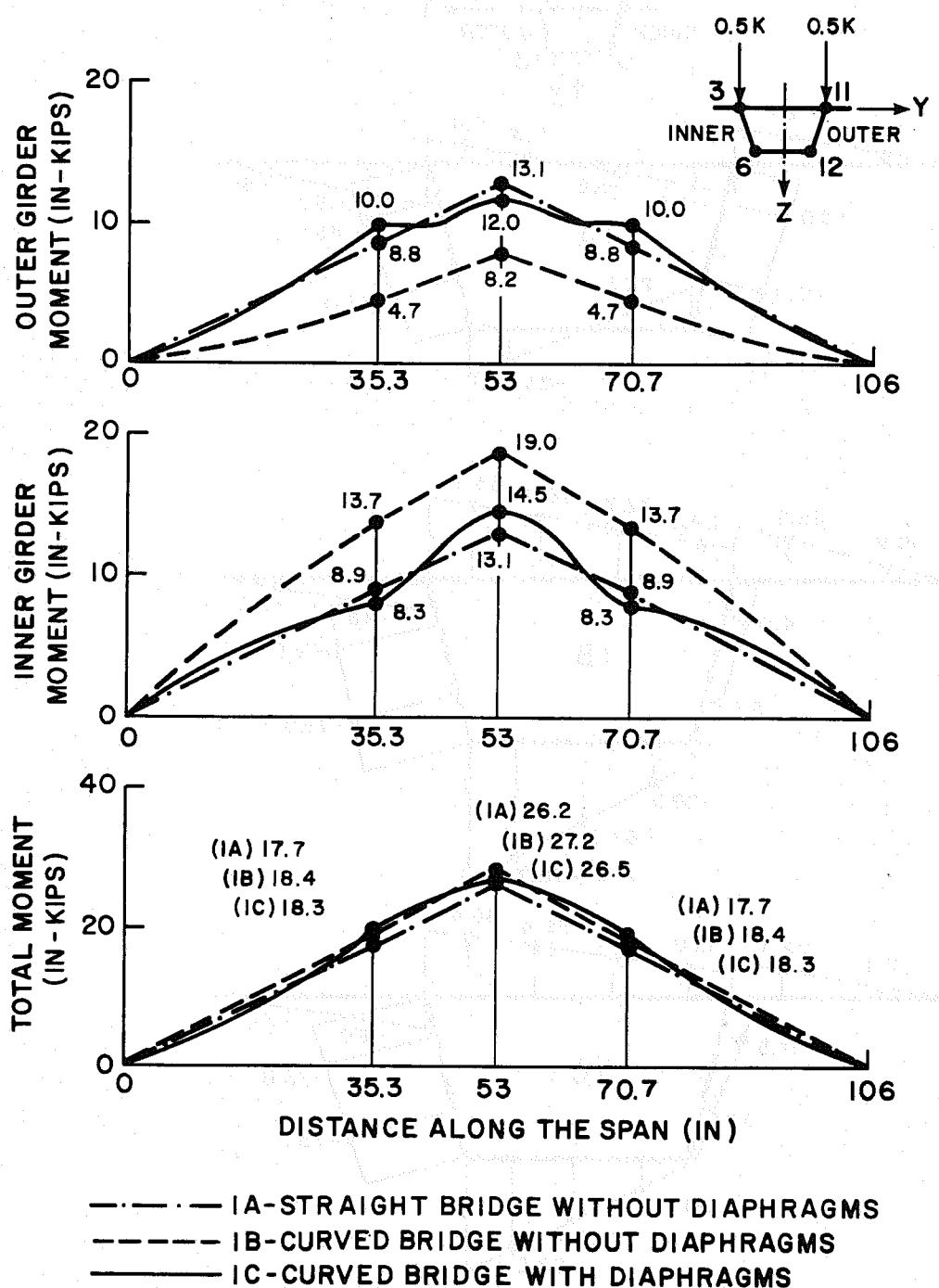
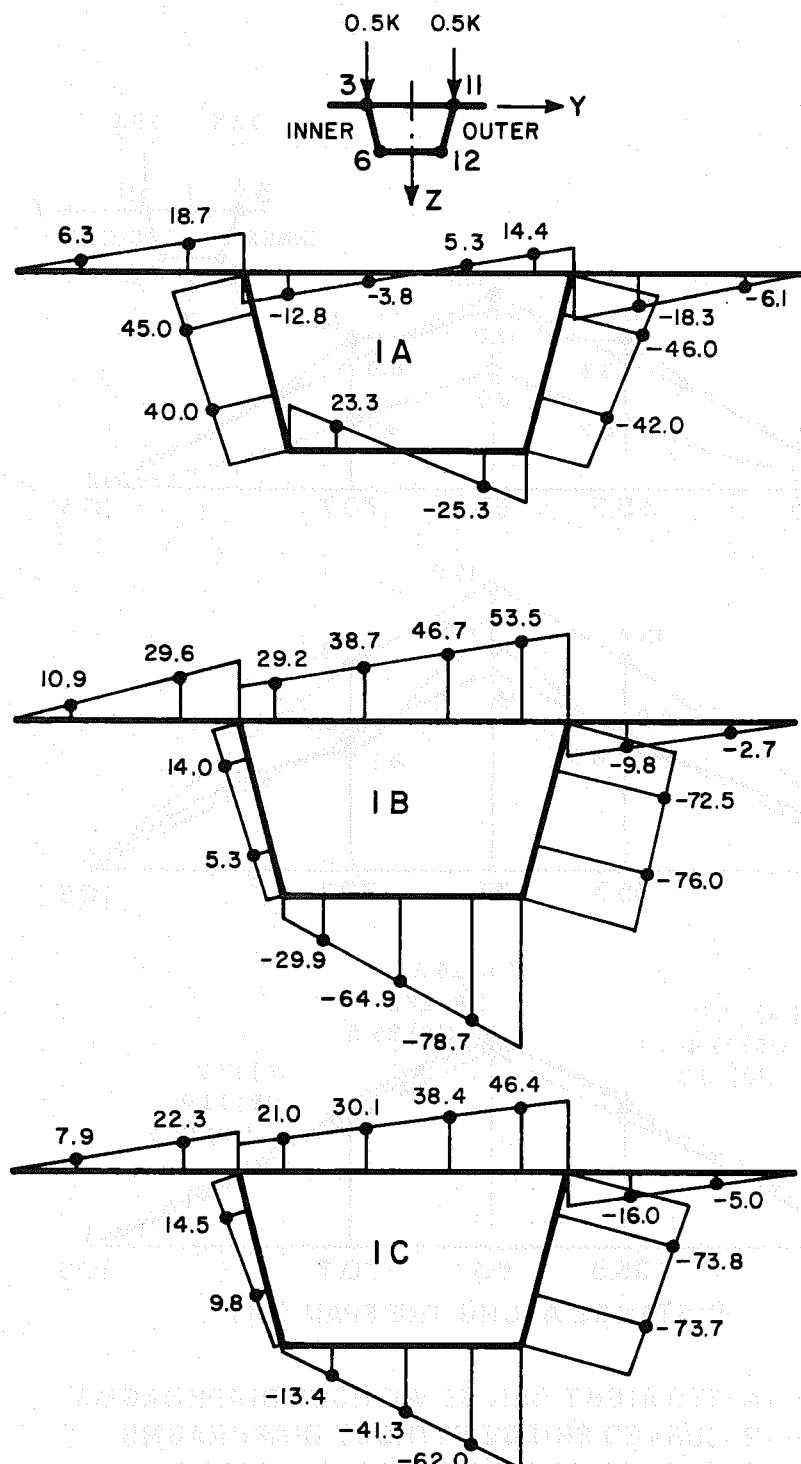


FIG. 5.8 EXAMPLE 1 - LONGITUDINAL DISTRIBUTION OF LONGITUDINAL FORCES  $N_\theta$  (LB/INCH) IN THE BOTTOM PLATE AT THE BOTTOMS OF THE GIRDERS WEBS



**FIG. 5.9 EXAMPLE 1 – LONGITUDINAL DISTRIBUTION OF GIRDER AND TOTAL MOMENTS (INCH-KIPS)**



**IA - STRAIGHT BRIDGE WITHOUT DIAPHRAGMS**

**IB - CURVED BRIDGE WITHOUT DIAPHRAGMS**

**IC - CURVED BRIDGE WITH DIAPHRAGMS**

**FIG. 5.10 EXAMPLE 1 - TRANSVERSE DISTRIBUTION OF MEMBRANE SHEAR FORCES  $N_{S\theta}$  (LB/INCH) AT END SUPPORT SECTION**

Figs. 5.7 and 5.8 again demonstrate the need for interior diaphragms to improve the load distributing properties of the curved bridge. The same thing is illustrated in Fig. 5.9, where the moment integration option has been used to evaluate the statical moment taken by the inner and outer girders and also the total of these two, which can be used as a statics check.

Finally, Fig. 5.10 presents the membrane shear forces  $N_{S\theta}$  (lb/in) at the end support. For the straight bridge (1A) the results are essentially symmetric about the section's vertical plane of symmetry, with each girder web taking one half of the total end shear. For the curved bridges (1B and 1C), since the end reactions consist of both a torque and vertical force, the membrane shears are larger in the outer web than in the inner web.

### 5.3 Example 2 - Straight Continuous T-Beam Bridge

To investigate the effects of interior diaphragms and bents, the straight, two span, continuous, concrete T-beam bridge shown in Fig. 5.11 is analyzed with various flexibilities for the midspan diaphragms and the center supporting bent. All cases were analyzed both by the previously developed program for straight bridges, MUPDI3 [13], which is based on a folded plate elasticity solution, and by CURDI, which is based on the curved strip method. For CURDI a large radius of 120,000 ft was input to give for all practical purposes a straight bridge. All cases were run with a modulus of elasticity equal to 432,000 ksf and Poisson's ratio equal to zero. The loading was identical for all cases and consisted of 1 kip midspan concentrated loads in both spans acting on girder 1 only.

and combinations of midspan and center support diaphragms. A brief account of several combinations of midspan diaphragms and center support conditions will be given and the results will be compared with those obtained by CURDI and MUPDI3.

#### **Several combinations of midspan diaphragms and center support conditions were used as follows:**

**Example 2A - Rigid diaphragm at the center support, with three different midspan diaphragm conditions.**

1. No midspan diaphragms (2A-1)
2. Normal midspan diaphragms (2A-2)
3. Rigid midspan diaphragms (2A-3)

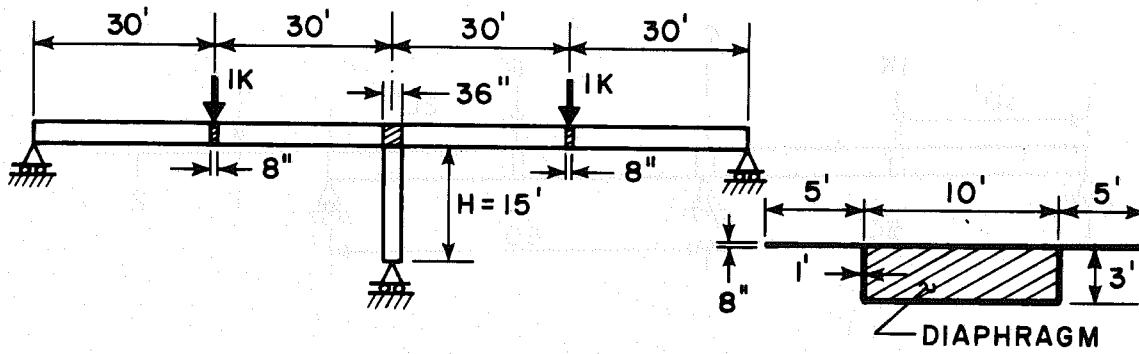
**Example 2B - Flexible center support frame bent with a 15 ft high column and normal midspan diaphragms (2B-2).**

The nodal point layout is shown in Fig. 5.11c. Normal midspan diaphragm section properties were defined by an 8 by 36 in. cross-section and flexible frame bent properties by the dimensions shown in Fig. 5.11.

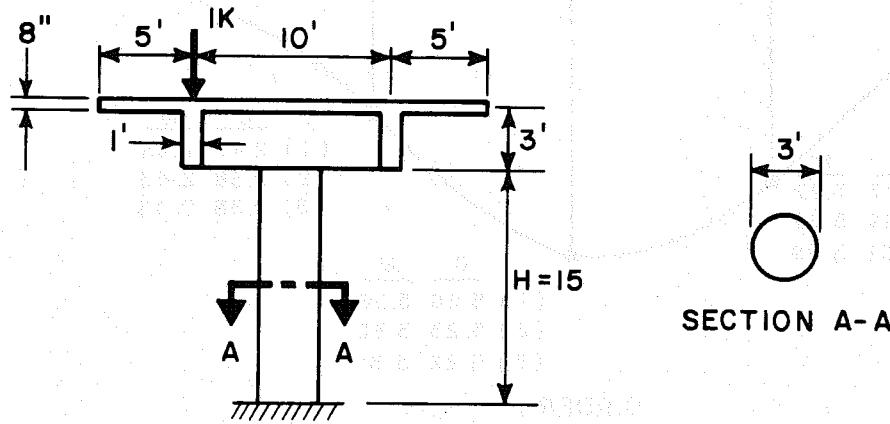
The results for girder deflections and moments are presented in Figs. 5.12 to 5.15. Close agreement between the results from CURDI and MUPDI3 is seen to exist, thus giving a good check on the CURDI program.

Comparing the results for Example 2A (Figs. 5.12 and 5.13), very little difference exists for the three types of midspan diaphragm conditions. Comparing the results for Example 2B (Figs. 5.14 and 5.15) with those of Example 2A, slightly larger deflections occur at the loaded girder for 2B due to the use of the flexible center support bent rather than a rigid support, however, the moments change very little.

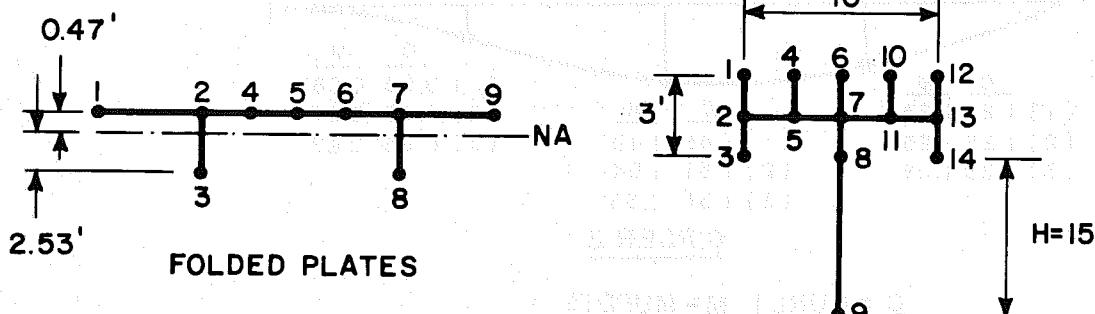
Figs. 5.16 and 5.17 show the shear-force, axial force and bending moment values found in the center support bent for Example 2B using CURDI and MUPDI3. Again the agreement between the two solutions is very good.



(a) ELEVATION AND CROSS-SECTION OF THE BRIDGE



(b) SUPPORT BENT



(c) NODAL POINT NUMBERING (E-F-E)

FIG. 5.11 EXAMPLE 2 – STRAIGHT CONTINUOUS T-BEAM BRIDGE

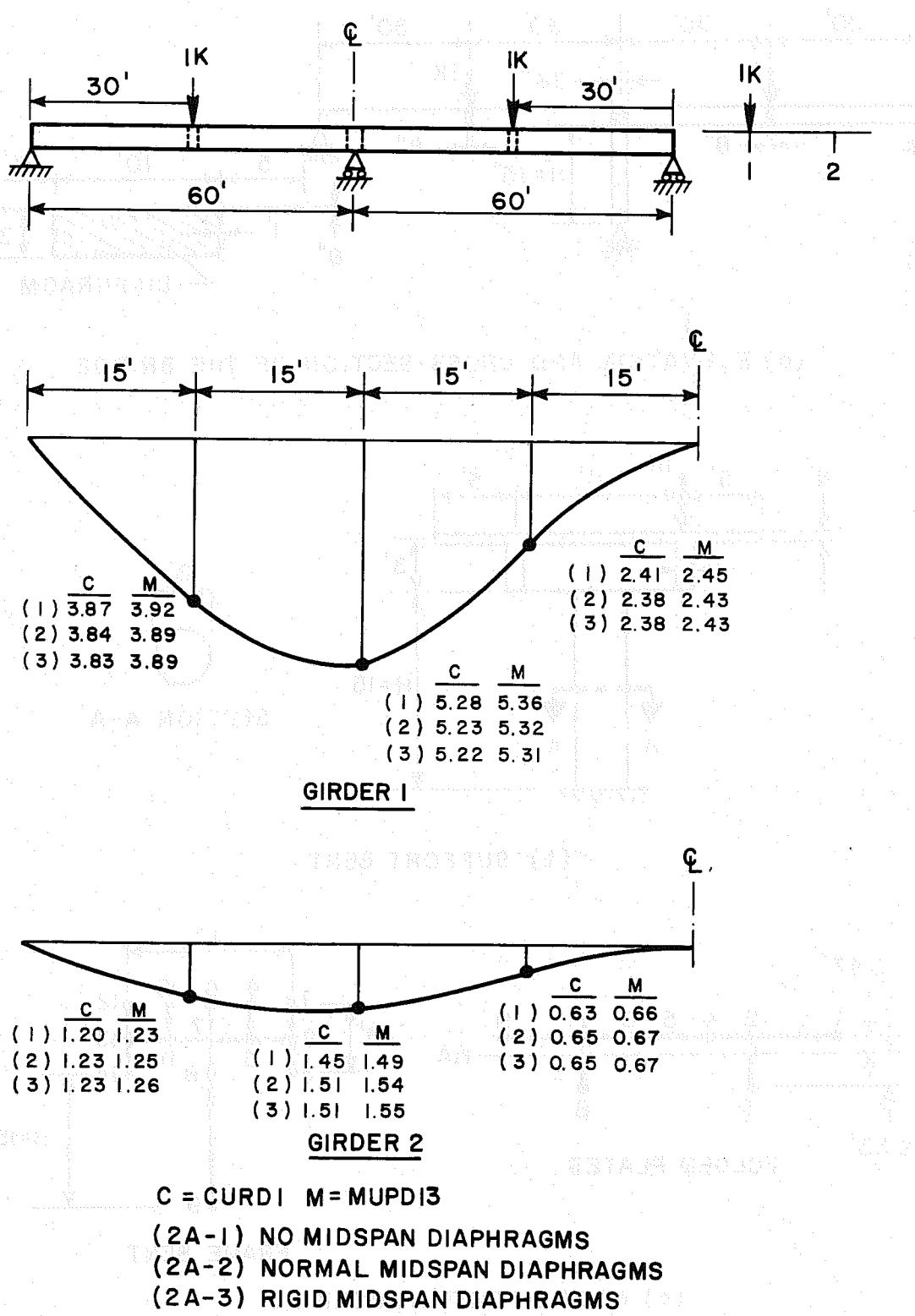
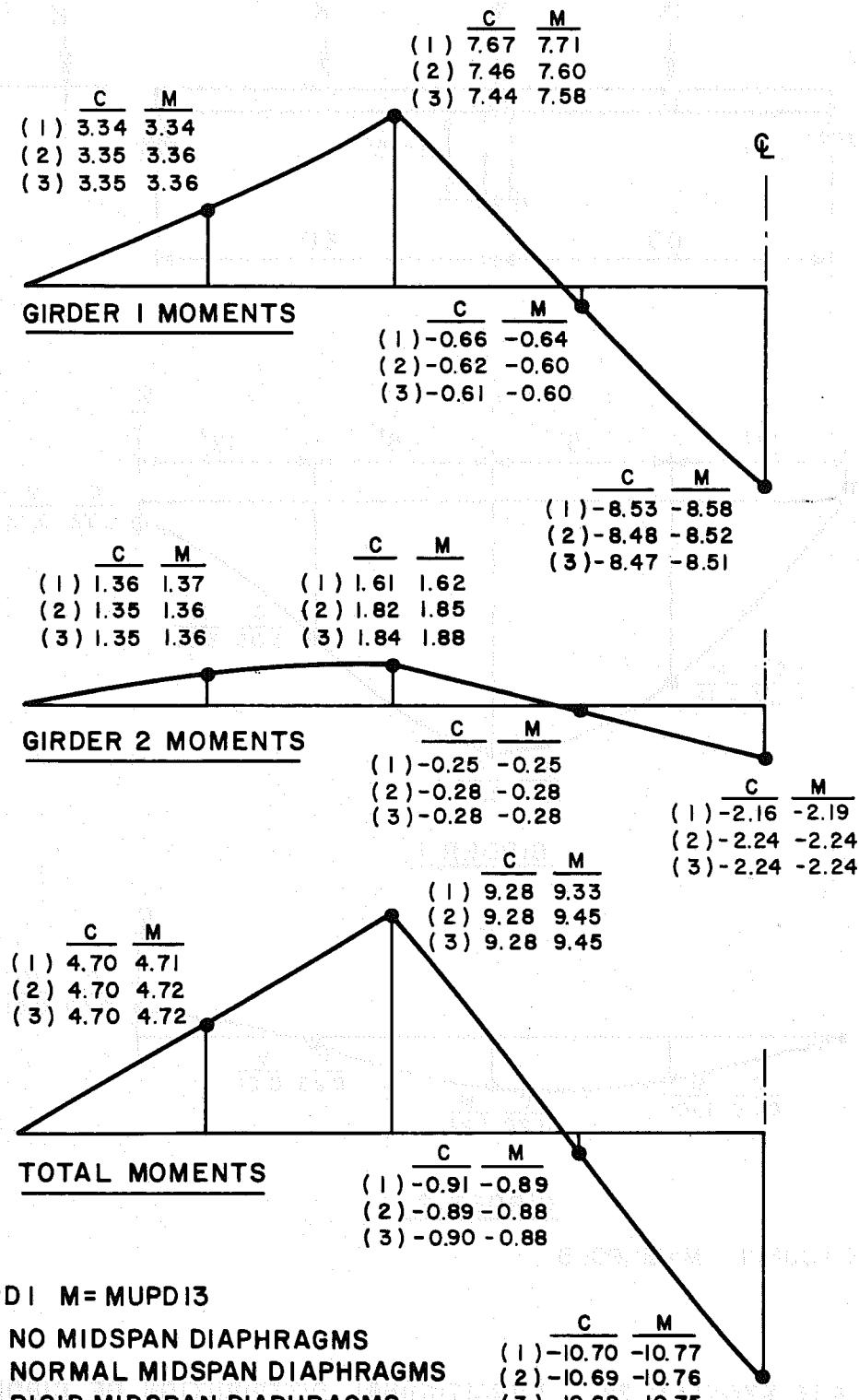


FIG. 5.12 EXAMPLE 2A – LONGITUDINAL DISTRIBUTION OF GIRDER DEFLECTIONS ( $10^{-4}$  FT) FROM MUPDI3 AND CURDI ANALYSES



**FIG. 5.13 EXAMPLE 2A – LONGITUDINAL DISTRIBUTION OF GIRDER AND TOTAL MOMENTS (FT-KIPS) FROM MUPD13 AND CURDI ANALYSES**

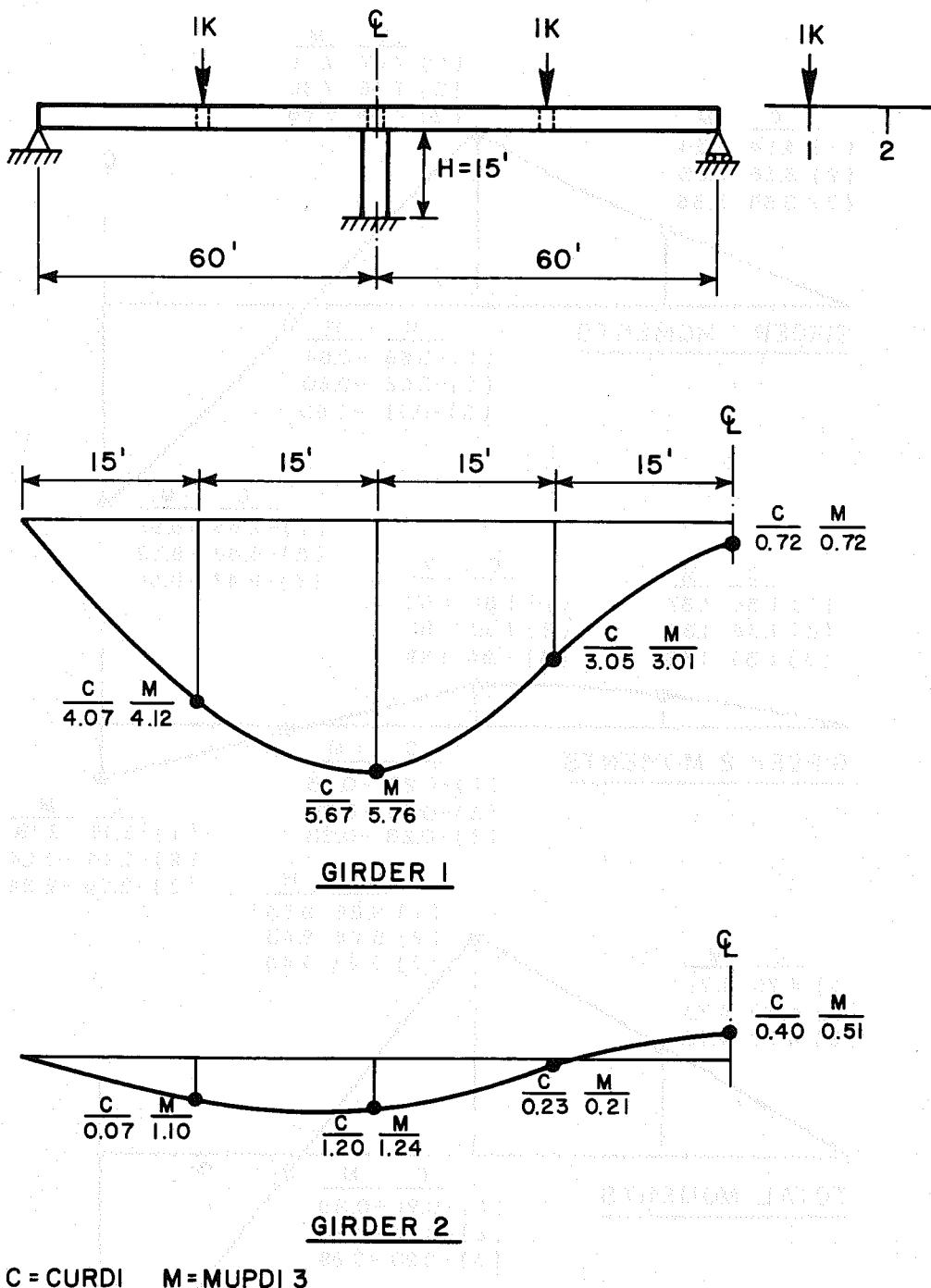


FIG. 5.14 EXAMPLE 2B - LONGITUDINAL DISTRIBUTION OF GIRDER DEFLECTIONS ( $10^{-4}$  FT) FROM MUPDI3 AND CURDI ANALYSES

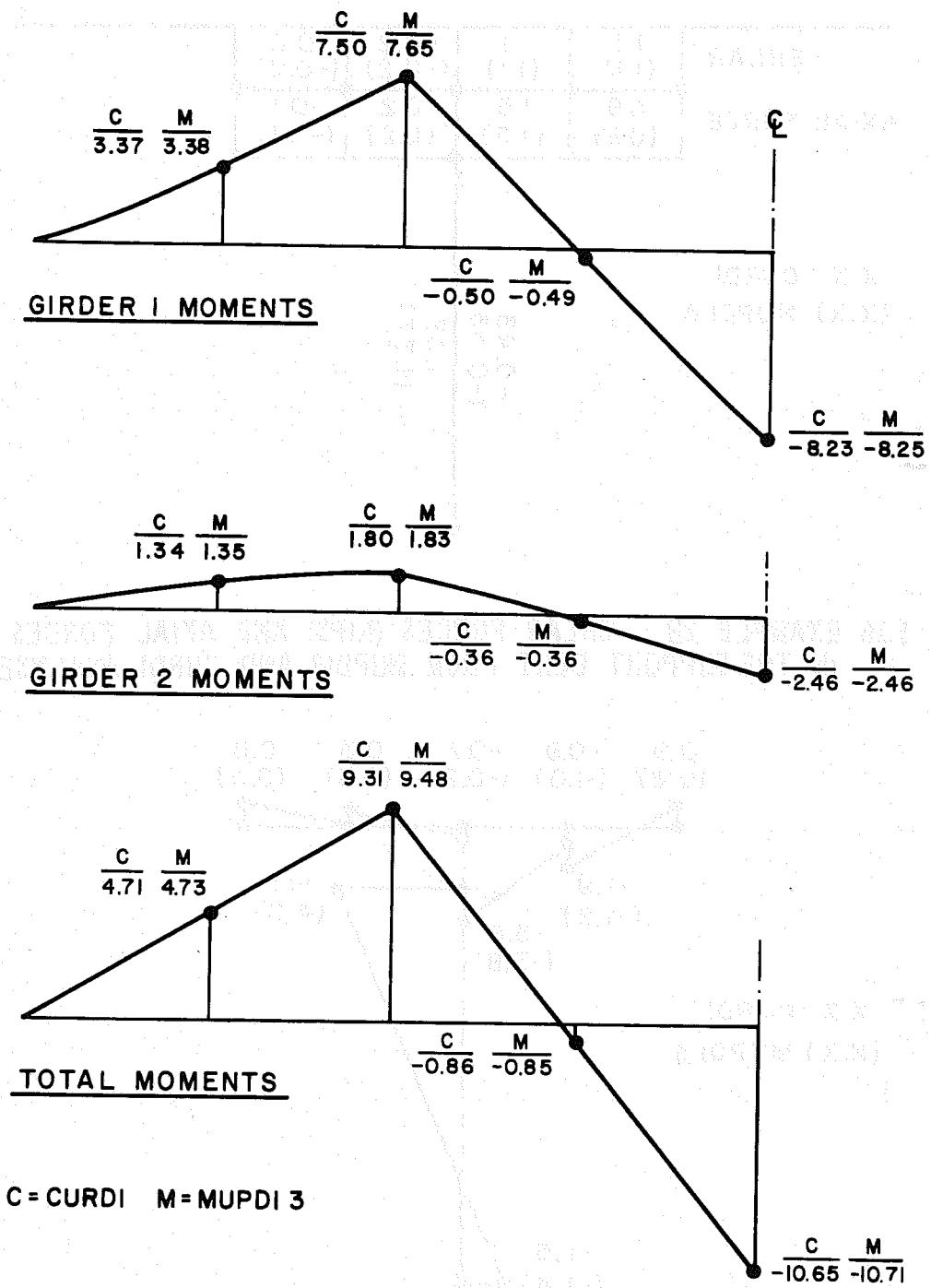


FIG. 5.15 EXAMPLE 2B – LONGITUDINAL DISTRIBUTION OF GIRDER AND TOTAL MOMENTS (FT-KIPS) FROM MUPDI3 AND CURDI ANALYSES

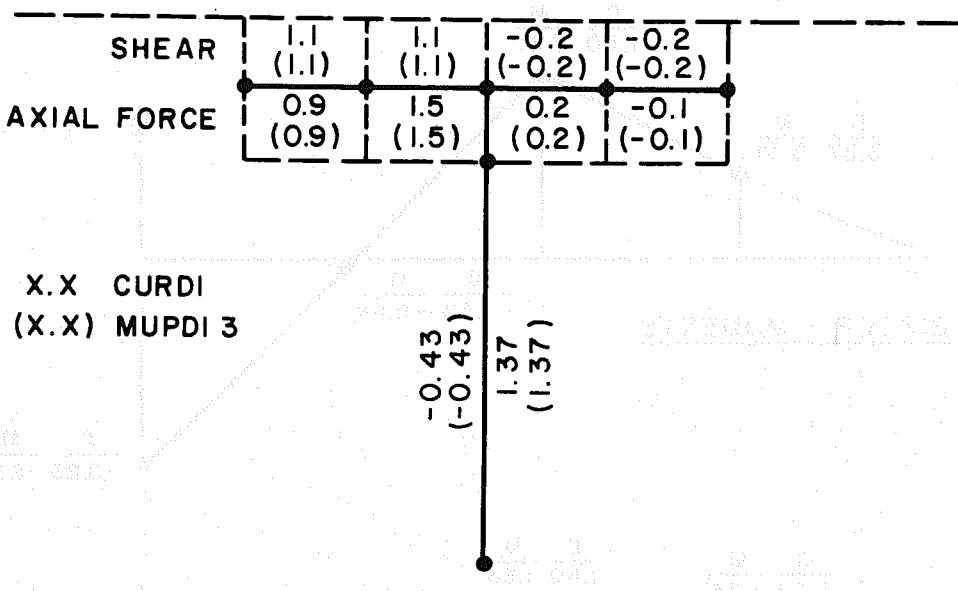


FIG. 5.16 EXAMPLE 2B – SHEAR FORCES (KIPS) AND AXIAL FORCES (KIPS)  
IN THE SUPPORT BENT FROM MUPDI3 AND CURDI ANALYSES

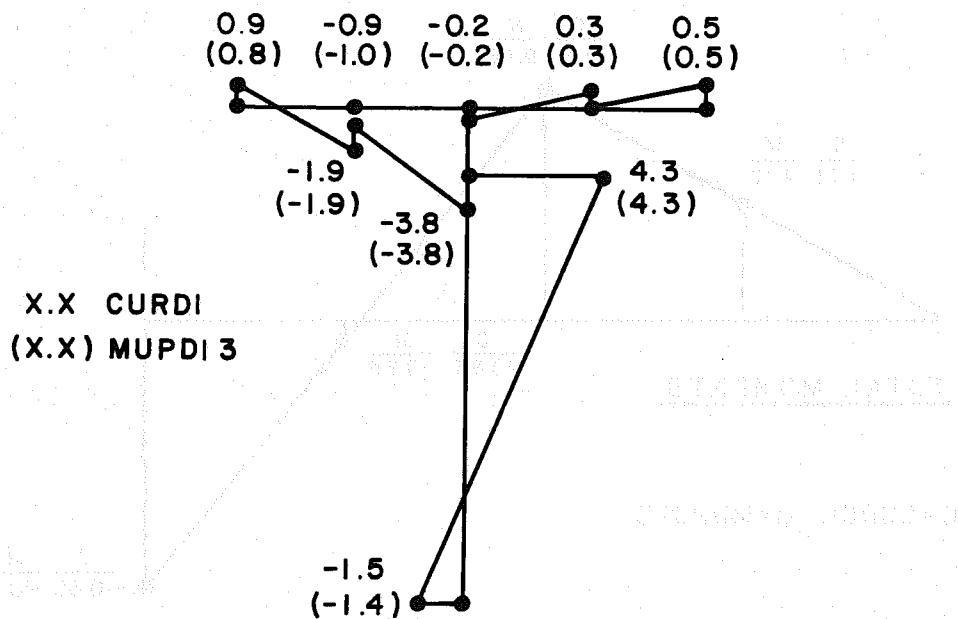


FIG. 5.17 EXAMPLE 2B – BENDING MOMENT (FT-KIPS) DIAGRAM FOR THE  
SUPPORT BENT FROM MUPDI3 AND CURDI ANALYSES

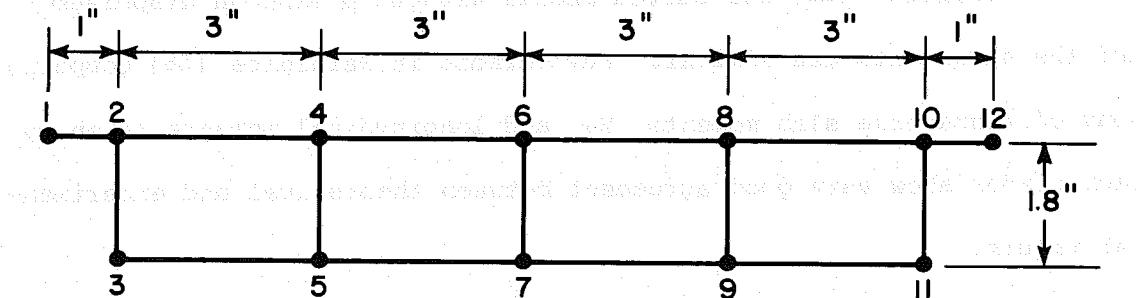
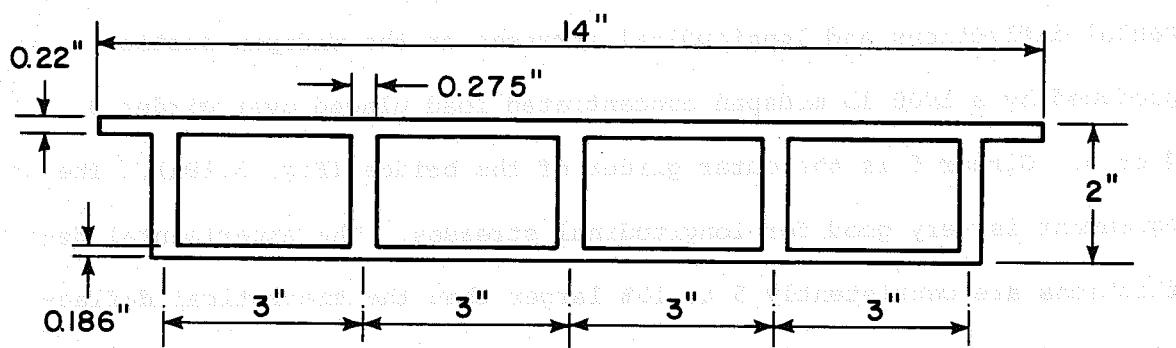
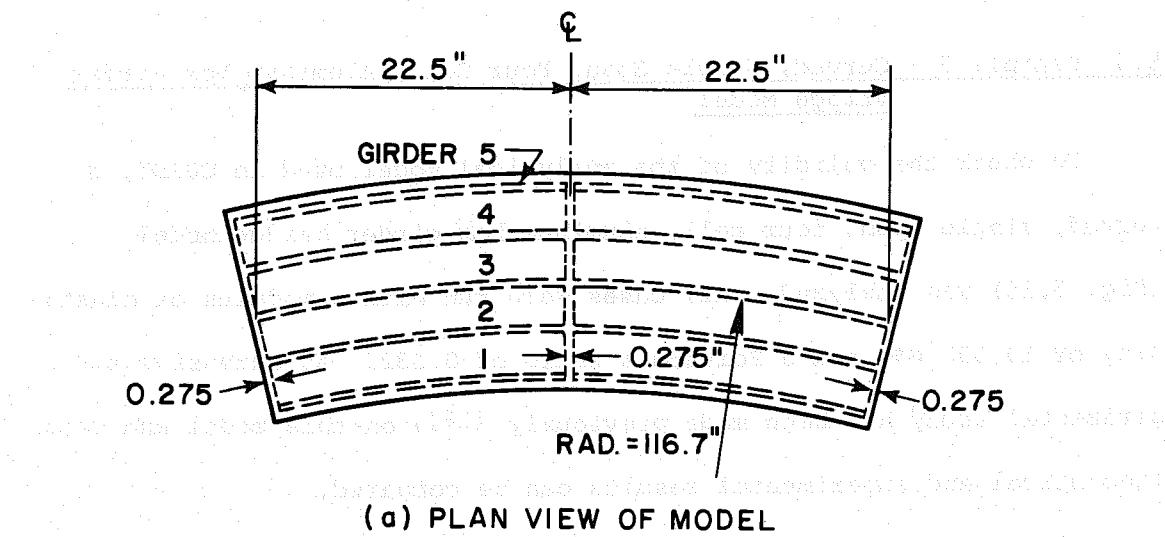
#### 5.4 Example 3 - Curved, Single Span, Four Cell, Aluminum Box Girder Bridge Model

To check the validity of the analytical model used in CURDI, a curved, single span, four cell, aluminum box girder bridge model (Fig. 5.18) was analyzed. All cases were run with a modulus of elasticity of 10,000 ksi and a Poisson's ratio of 0.332. An extensive experimental study has been made previously [16], on this model and thus theoretical and experimental results can be compared.

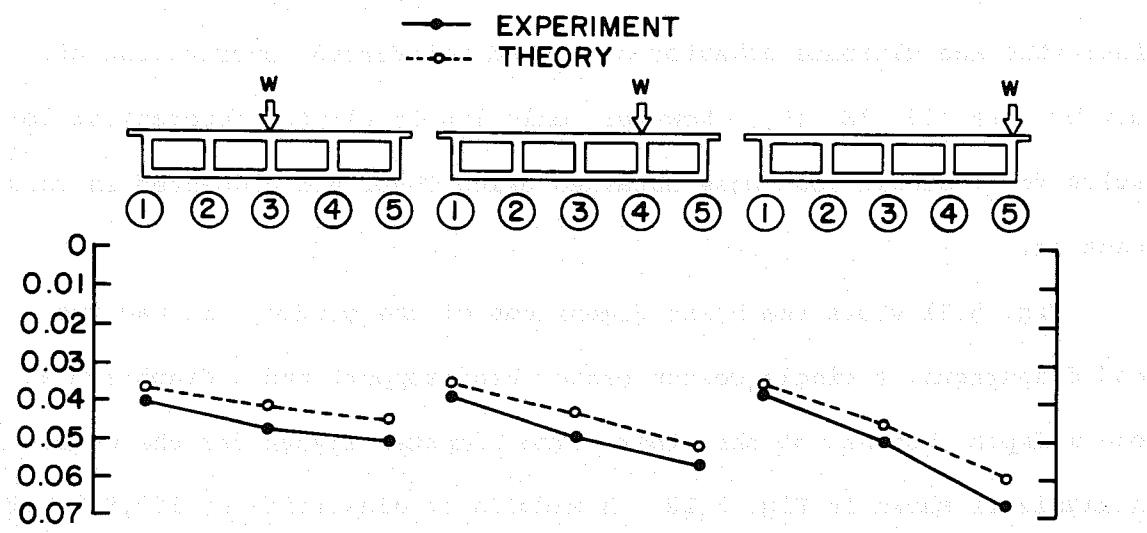
Figs. 5.19 and 5.20 give comparisons of theoretical and experimental deflections and longitudinal stresses at the midspan section produced by a 1000 lb midspan concentrated load placed over girder 3, 4 or 5. Girder 5 is the outer girder of the bridge (Fig. 5.18a). The agreement is very good for longitudinal stresses. The experimental deflections are consistently 5 to 10% larger than the theoretical deflections. This may be due to the inherent flexibilities of the joints and boundary supports of the experimental model. Further comparisons are made in Reference [16] for curved models without a midspan diaphragm and the agreements are similar. Furthermore in Reference [16] comparisons of transverse slab moments,  $M_\theta$ , and longitudinal moments taken by each girder show very good agreement between theoretical and experimental values.

#### 5.5 Example 4 - Curved, Two Span, Four Cell, Reinforced Concrete Box Girder Bridge Model

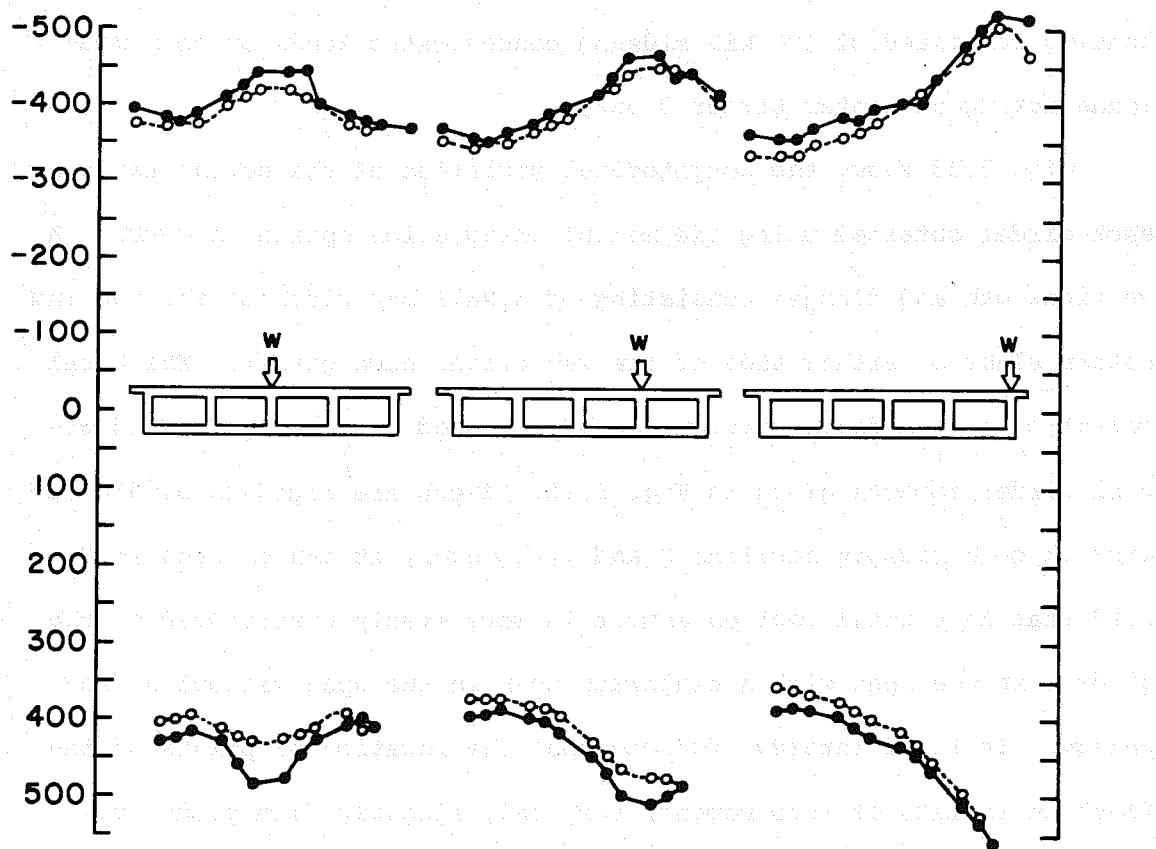
A large scale, curved, two span, four cell, reinforced concrete box girder bridge model is analyzed to demonstrate the practical application of CURDI. The model has been tested at the University of California, Berkeley as part of an extensive study of the elastic,



**FIG. 5.18 EXAMPLE 3 – MODEL DIMENSIONS AND COMPUTER MODEL LAYOUT**



**FIG. 5.19 EXAMPLE 3 – TRANSVERSE DISTRIBUTION OF THEORETICAL AND EXPERIMENTAL VERTICAL DEFLECTIONS (INCHES) AT MIDSPAN SECTION DUE TO MIDSPAN 1000 LB LOAD ON GIRDER 3, 4, OR 5**



**FIG. 5.20 EXAMPLE 3 – TRANSVERSE DISTRIBUTION OF THEORETICAL AND EXPERIMENTAL LONGITUDINAL FORCES  $N_x$  (LB/INCH) AT MIDSPAN SECTION DUE TO MIDSPAN 1000 LB LOAD ON GIRDER 3, 4 OR 5**

inelastic and ultimate behavior of curved reinforced concrete box girder bridges [17, 18, 19]. However, only linear elastic theoretical results for a single load case obtained using CURDI are presented in this section.

Fig. 5.21 shows the basic dimensions of the bridge. It had two end diaphragms, a single column center bent support and a diaphragm at one midspan, but not at the other. The computer layout for the CURDI analysis is shown in Fig. 5.22. A modulus of elasticity of 550,800 ksf was used for all top deck elements, while for the rest of the bridge including the center bent support and diaphragms a value of 432,000 ksf was used. For all elements Poisson's ratio was taken as 0.15. The loading consisted of 100 kip midspan concentrated loads at both midspans acting on center girder 3 only.

Fig. 5.23 shows the longitudinal variation of the moment taken by each girder obtained using the moment integration option in CURDI. A vertical web and flanges consisting of a half bay width of the top and bottom slabs on either side of the web define each girder. The total moment at each midspan section can be obtained by summing the individual girder moments given in Fig. 5.23. These are found to be 558 ft-kips at both midspan sections X and Y, however, it can be seen in Fig. 5.23 that this 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.

Fig. 5.24 shows a free body of the portion of the bridge structure between the inflection points on either side of the bridge bent.

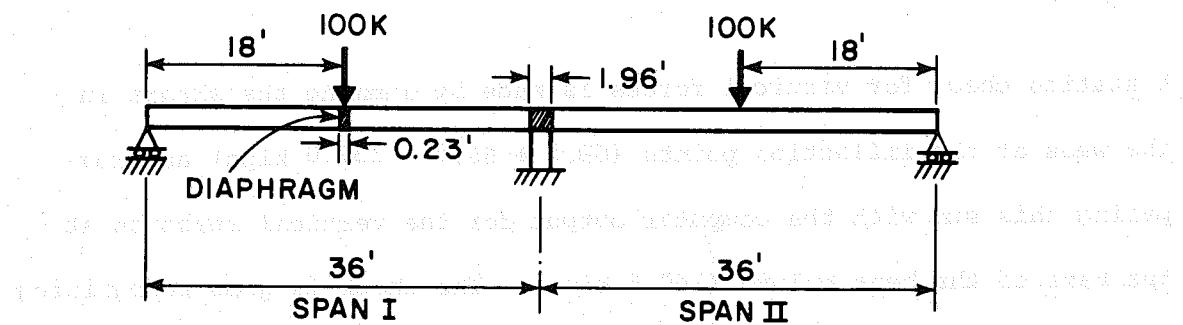
A statics check for vertical forces is made by summing the shears in the webs at the inflection points ( $68.5 + 68.5 = 137.0$  kips) and comparing this sum with the computer output for the vertical reaction at the base of the bent column (140.6 kips). The check is good recognizing that the slab transverse 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.

Fig. 5.25 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 statics 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.

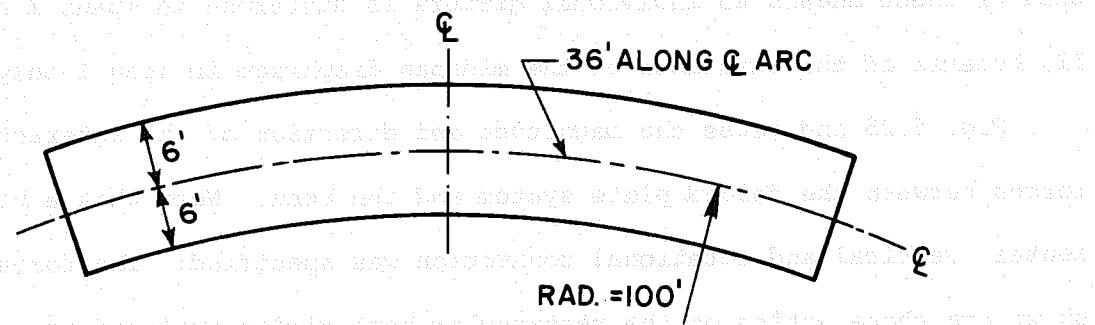
Fig. 5.26 gives the internal moments, shear forces and axial forces in the bent. Fig. 5.27 graphically illustrates that the computer output should be plotted to make a proper estimate of actual girder moments which would exist if a continuous interaction were used instead of the discretized system needed 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 transverse membrane forces in the top and bottom slab through section A-A in Fig. 5.24.

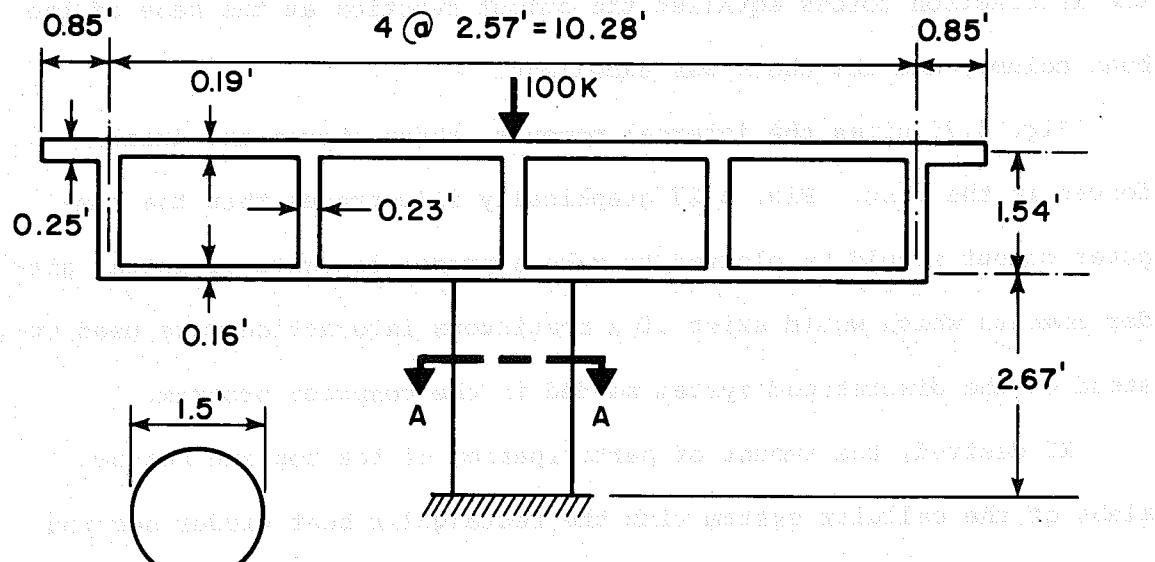
It should be emphasized that the analytical model treats the center bent as a planar frame which is incapable of taking forces



(a) ELEVATION

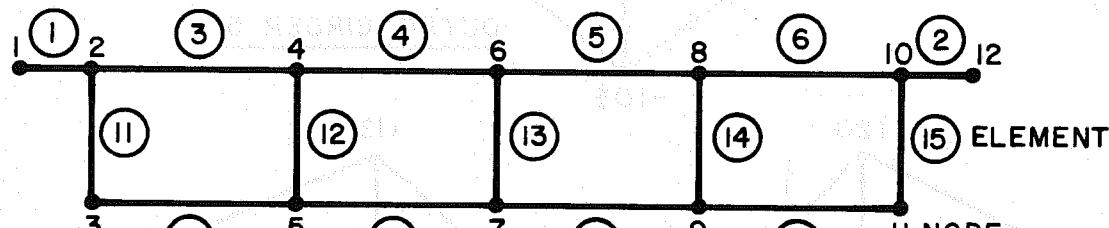


(b) PLAN

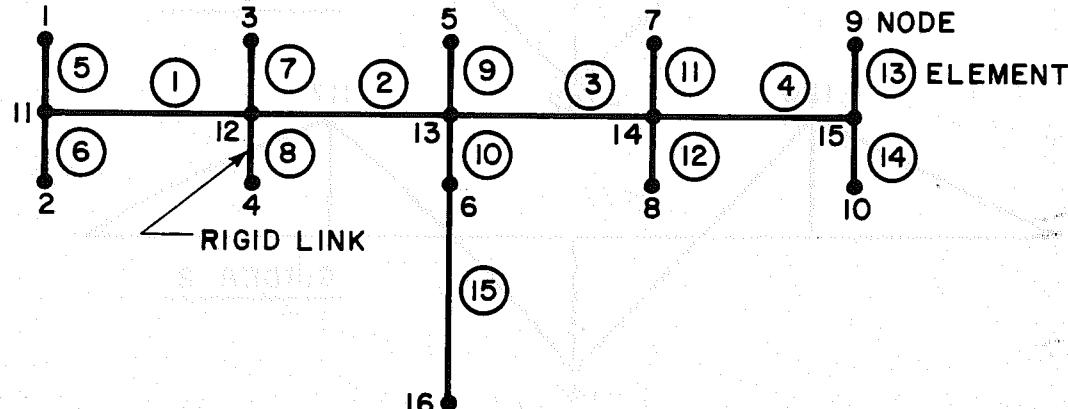


(c) CROSS-SECTION

**FIG. 5.21 EXAMPLE 4 - DIMENSIONS AND LOADING**

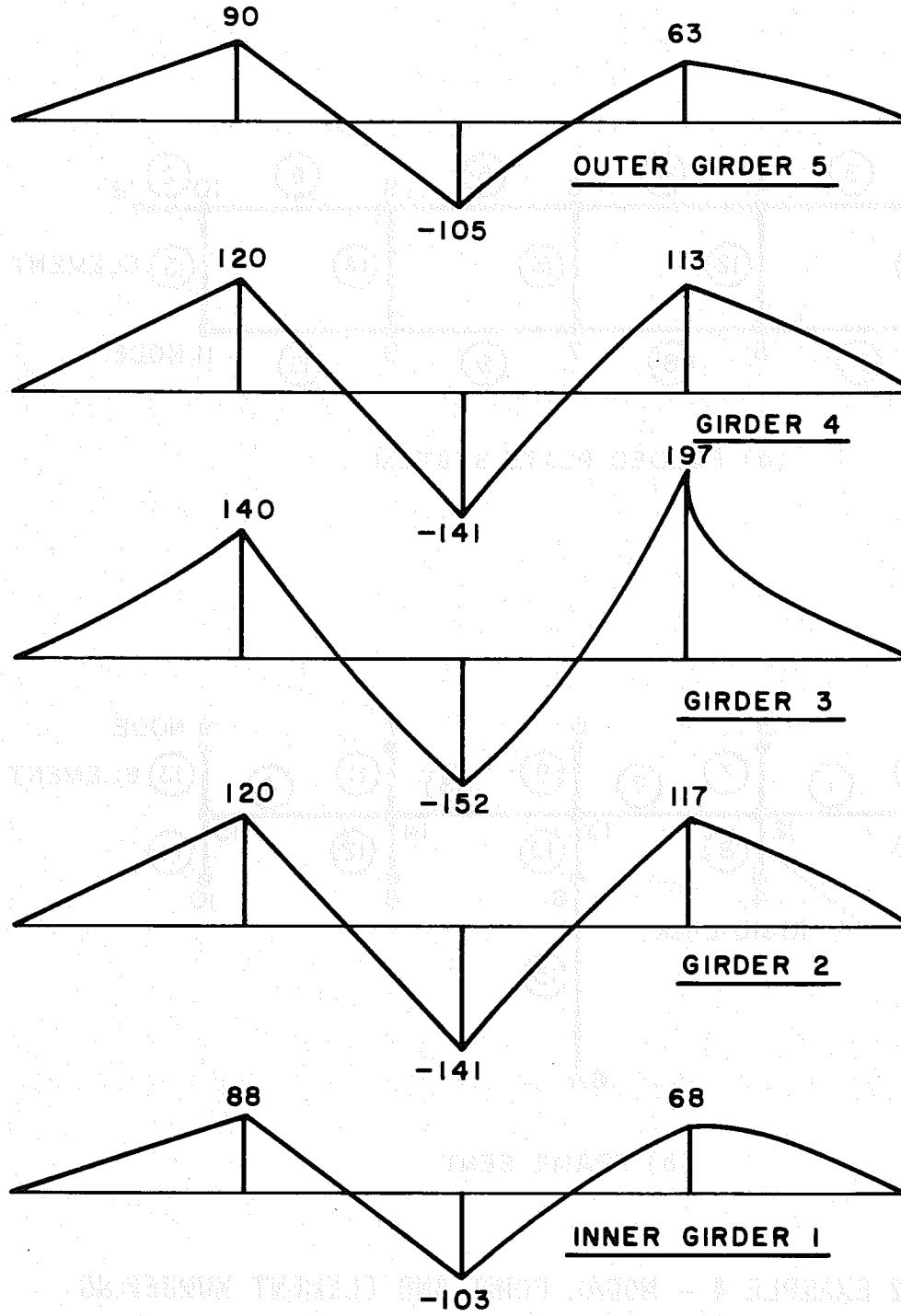


(a) FOLDED PLATE SYSTEM

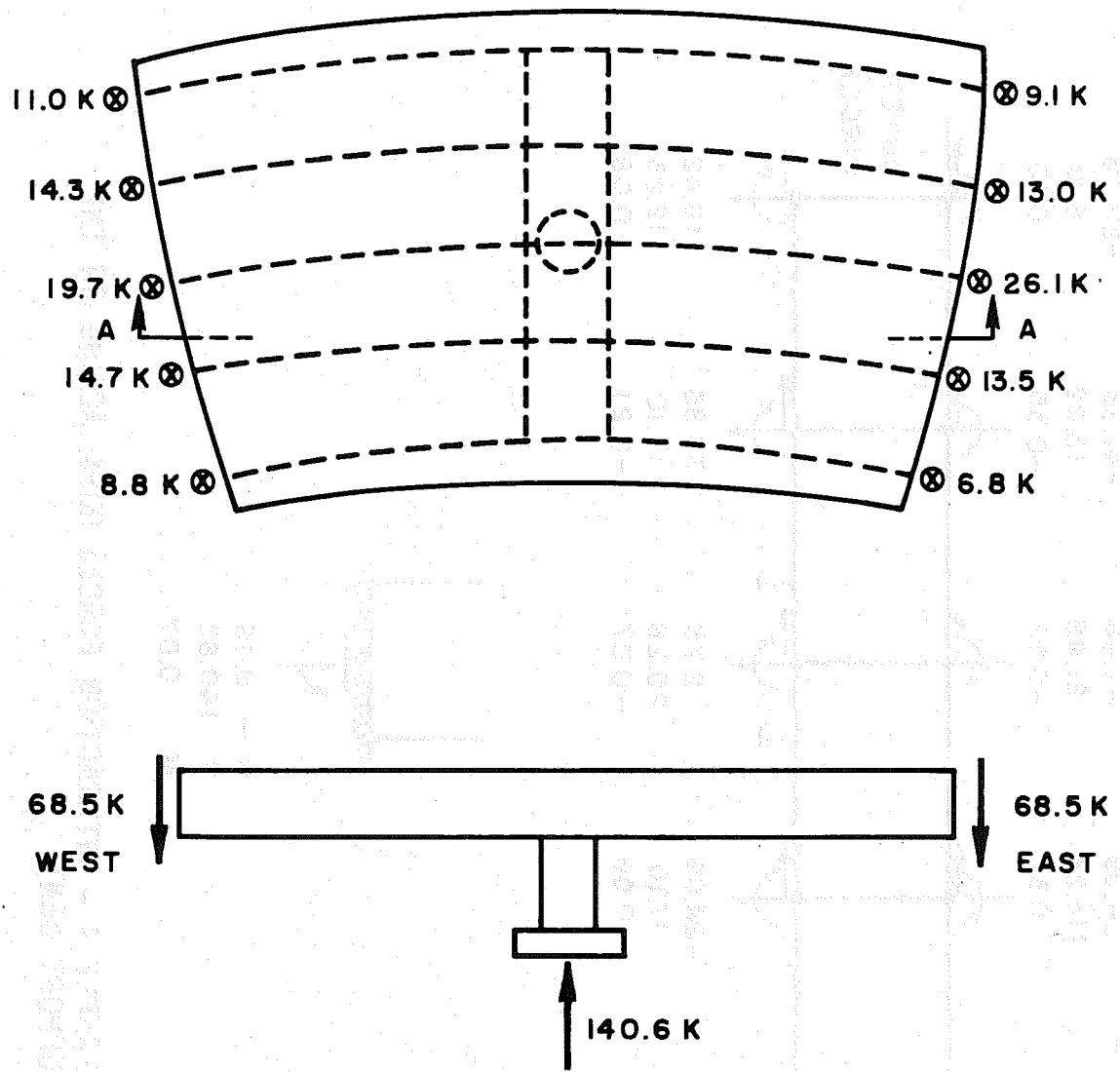


(b) FRAME BENT

FIG. 5.22 EXAMPLE 4 - NODAL POINT AND ELEMENT NUMBERING



**FIG. 5.23 EXAMPLE 4 – LONGITUDINAL DISTRIBUTION OF GIRDER MOMENTS (FT-KIPS)**



**FIG. 5.24 EXAMPLE 4 – VERTICAL FORCES (KIPS) ACTING ON THE CENTER SUPPORT BENT AND AN ADJACENT PORTION OF THE BRIDGE**

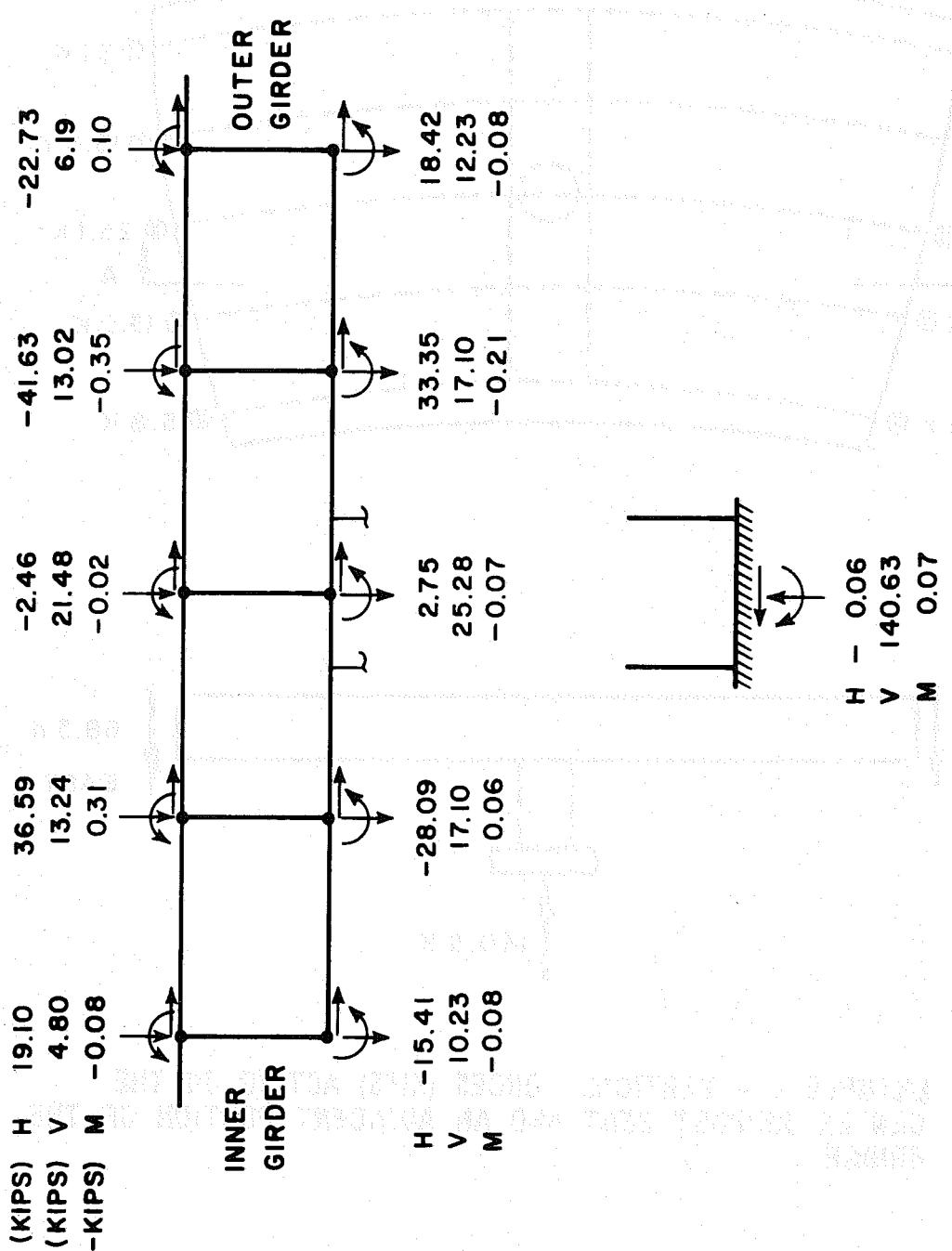
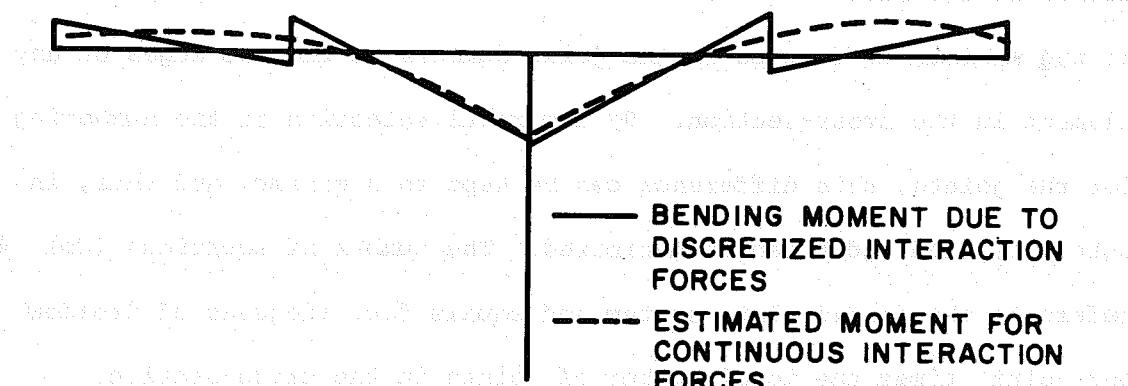


FIG. 5.25 EXAMPLE 4 - INTERACTION FORCES (KIPS) ACTING ON THE SUPPORT BENT

	SHEAR FORCE AND MOMENT DISTRIBUTION FOR THE SUPPORT BENT							
	M	-12.0	37.4	-79.5	-83.5	41.4	-15.8	31.7
M	26.7							
V	(15.0)		(45.4)		(-48.5)		(-18.4)	
P	[-3.7]		[-12.2]		[-12.6]		[-4.3]	
<b>INNER GIRDERS</b>				<b>OUTER GIRDERS</b>				
+ P, V, M				0.07	0.06	-140.6		
	0.09			0.09				

**FIG. 5.26 EXAMPLE 4 – MOMENTS (FT-KIPS), SHEAR FORCES (KIPS) AND AXIAL FORCES (KIPS) IN THE SUPPORT BENT**



**FIG. 5.27 EXAMPLE 4 – BENDING MOMENT DIAGRAM FOR THE SUPPORT BENT**

normal to its own plane or longitudinal moments. Thus for unsymmetric loadings or conditions in the two spans, the results obtained by CURDI can only be considered to approximate the true values.

### 5.6 Computer Times and Costs

All of the computer analyses of the examples by the CURDI computer program were made using the CDC 6400 computer at the University of California Computer Center at Berkeley. For reference purposes, Table 5.1 summarizes the central processor time (CP) and the peripheral processor time (PP) used in running each example. Also indicated is the computer cost for each example. Times and costs on other computer systems will, of course, depend on the computer being used and the corresponding rate schedule.

As can be seen from Table 5.1, the required computer times are a function of the band width, number of harmonics, number of equations and number of interaction forces. The band width (Col. 2) is proportional to the maximum difference in the joint numbers at the two edges of any element in the cross-section. By a careful selection of the numbering for the joints, this difference can be kept to a minimum and thus, in turn, the band width can be minimized. The number of equations (Col. 4) refers to the folded plate system and equals four (degrees of freedom per joint) times the total number of joints in the cross-section.

TABLE 5.1 CDC 6400 CP AND PP COMPUTER TIMES (SECONDS) AND COSTS FOR ANALYSIS OF EXAMPLES BY CURDI COMPUTER PROGRAM

EXAMPLE	BAND WIDTH	NUMBER OF HARMONICS	NUMBER OF EQUATIONS	NUMBER OF INTERACTION FORCES	COMPUTER TIME (SECONDS)		COST (\$)
					CP	PP	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1A	16	100	60	0	83	45	9
1B	16	100	60	0	83	45	9
1C	16	100	60	24	131	87	12
2A-1	12	50	36	0	56	41	5
2A-2	12	50	36	42	83	45	9
2A-3	12	50	36	0	56	41	5
2B-2	12	100	36	63	106	96	10
3	12	50	48	30	96	89	9
4	12	100	48	90	204	104	16

CP - CENTRAL PROCESSOR TIME (SECONDS)

PP - PERIPHERAL PROCESSOR TIME (SECONDS)

COST - RATE X (CP + A X PP)

A - FACTOR DEPENDENT ON AMOUNT OF CENTRAL MEMORY USED

## 6. CONCLUSIONS AND RECOMMENDATIONS FOR IMPLEMENTATION

A computer program has been presented for the linear elastic analysis of circularly curved, continuous highway bridges with flexible interior diaphragms or planar 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 curved bridges and support bents by analyzing a number of bridge structures, in which important design parameters such as cross-sectional dimensions, radius of curvature, central angle or span along arc length, 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 cases.

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 4 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. ACKNOWLEDGMENTS

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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

8. REFERENCES

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Copies of many of the research reports [1-19] in the above reference list have been placed on file with the U. S. Department of Commerce and may be obtained on request for cost of reproducing 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 specified when ordering a particular report.

**APPENDIX A**

**CURDI User's Guide**

UNIVERSITY OF CALIFORNIA  
September 1974

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

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

IDENTIFICATION

CURDI - Analysis of Curved Prismatic Folded Plate Structures with Interior Flexible Diaphragms or Planar Rigid Frame Support Bents

Programmed by: A. F. Kabir, University of California, September 1974.

PURPOSE

The program provides a rapid solution for curved 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 two ends. The structure is assumed to be restrained radially at the two ends. The plate elements may in general be segments of conical frustra. Uniform or partial surface loads, as well as line loads and concentrated loads, may be applied anywhere on the structure. Resulting joint displacements 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 finite strip method is used to evaluate plate 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 on a cross section taken by each girder of a box girder bridge. The program is written in FORTRAN IV language.

**FORM OF INPUT DATA**

Input data are key punched on cards as specified below. It is very important that the sequential order is strictly adhered to and consistent units are used throughout a problem.

**1. TITLE CARD (12A6)**

Col. 1 to 76 - **TITLE(I) = Title of problem to be printed with output for identification**

**2. CONTROL CARD (2F10.0, 14I4)**

Col. 1 to 10 - **TETAO = angle of curvature (in degrees) between end supports (360 degrees for axisymmetric shell with axisymmetric loading)**

Col. 11 to 20 - **R = radius of curvature of structure reference line**

Col. 21 to 24 - **NPL = number of plate types, max. = 15**

Col. 25 to 28 - **NEL = number of elements, max. = 30**

Col. 29 to 32 - **NJT = number of joints, max. = 20**

Col. 33 to 36 - **NDIAPH = number of diaphragms (includes frame bents), max. = 12**

Col. 37 to 40 - **NXP = number of x-coordinates at which results are desired, max. = 14**

Col. 41 to 44 - **MHARM = maximum Fourier series limit**

max. = 100 for NCHECK = 0

max. = 200 for NCHECK = +1 or -1

Col. 45 to 48 - **NCHECK = check on odd or even harmonics**

+1 to work on odd series only (sym.)

0 to include all series

-1 to work on even series only (anti-sym.)

Col. 49 to 52 - **MCHECK = moment integration option**

0 no moment integration

1 moment integration desired

Col. 53 to 56 - **NBT = number of types of flexible supporting frame bents, max. = 8**

Col. 57 to 60 - **NFMD = number of types of flexible movable diaphragms, max. = 8**

Col. 61 to 64 - KFOR = FORCE program option (calculates internal forces and displacements in frame bents)

0 to skip FORCE program

1 to execute FORCE program

Col. 65 to 68 - IO = input/output option indicator

1 sections for input/output given by angular degrees

0 sections for input/output given by arc lengths measured from origin along the reference line or joint under consideration

Col. 69 to 72 - MI = material option indicator

0 for inputting material properties

1 for inputting constitutive relations directly

Col. 73 to 76 - IAX = axisymmetric index

0 for axisymmetric shell only, TETAO = 360°

1 for all other cases

### **3. CIRCUMFERENTIAL COORDINATE CARD (10F7.2)**

Col. 1 to 70 - XP(I) = X-coordinates along reference line, in arc length (if IO=0) or angles measured in degrees (if IO=1) of transverse sections at which results are desired. Use second card if more than 10 sections.

### **4. DIAPHRAGM CARDS (I10, 2F10.0, 2I4)**

One card for each diaphragm or frame bent; omit if NDIAPH = 0.

Col. 1 to 10 - I = diaphragm number

Col. 11 to 20 - DIAPHX(I) = X-coordinate at which diaphragm exists, arc length (if IO=0) or angle in degrees (if IO = 1)

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

Col. 31 to 34 - KODIA(I) = diaphragm classification code

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 - KDIP(I) = type number of supporting bent or flexible movable diaphragm, leave blank if the diaphragm is rigid, therefore 1 or 2 above. (See paragraphs 14 and 16 for type description.)

### 5. PLATE TYPE CARDS

If MI = 0, two cards are required for each plate type

#### a. FIRST CARD - MEMBRANE CHARACTERISTICS (I10, 5F10.0)

Col. 1 to 10 - I = type number

Col. 11 to 20 - THM(I) = effective thickness

Col. 21 to 30 - ETM(I) = modulus of elasticity in hoop direction

Col. 31 to 40 - ESM(I) = modulus of elasticity in meridional direction

Col. 41 to 50 - GM(I) = shear modulus in meridional direction

Col. 51 to 60 - PRM(I) = Poisson's ratio (negative strain in hoop direction for unit strain in meridional direction)

#### b. SECOND CARD - BENDING CHARACTERISTICS (10X, 5F10.0)

Col. 11 to 20 - THB(I) = effective thickness

Col. 21 to 30 - ETB(I) = modulus of elasticity in hoop direction

Col. 31 to 40 - ESB(I) = modulus of elasticity in meridional direction

Col. 41 to 50 - GB(I) = shear modulus

Col. 51 to 60 - PRB(I) = Poisson's ratio (negative strain in hoop direction for unit strain in meridional direction)

If MI = 1, two cards are required for each plate type

#### a. FIRST CARD - MEMBRANE CONSTITUTIVE CONSTANTS (I10, 4F10.0)

Col. 1 to 10 - I = type number

Col. 11 to 20 - D11(I)

Col. 21 to 30 - D12(I)

Col. 31 to 40 - D22(I)

Col. 41 to 50 - D33(I)

b. SECOND CARD - PLATE BENDING CONSTITUTIVE CONSTANTS (10X, 4F10.0)

Col. 11 to 20 - D44(I)

Col. 21 to 30 - D45(I)

Col. 31 to 40 - D55(I)

Col. 41 to 50 - D66(I)

6. ELEMENT CARDS (5I4, 5F10.0)

Each element requires one card.

Col. 1 to 4 - I = element number

Col. 5 to 8 - NPI(I) = joint i of element I

Col. 9 to 12 - NPJ(I) = joint j of element I

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

Col. 17 to 20 - NSEC(I) = number of element transverse subdivisions for output of internal forces and displacements, max. = 12. If NSEC(I) = 0, no internal forces and displacements will be output for element I.

Col. 21 to 30 - DL(I) = dead load (force per unit plate area)

Col. 31 to 40 - HLI(I) = horizontal load intensity at joint i (force per unit vertically projected area)

Col. 41 to 50 - HLJ(I) = horizontal load intensity at joint j

Col. 51 to 60 - VLI(I) = vertical load intensity at joint i (force per unit horizontally projected area)

Col. 61 to 70 - VLJ(I) = vertical load intensity at joint j

Note that horizontal and vertical load intensities are uniformly distributed along the entire structure length.

7. NUMBER OF PARTIAL SURFACE LOADS CARD (I4)

Col. 1 to 4 - NSURL = number of partial surface loads, max. = 30

8. PARTIAL SURFACE LOADS CARDS (I10, 6F10.0)

Each partial surface load requires one card. No cards are required if NSURL = 0

- Col. 1 to 10 - LEL(I) = element number
- Col. 11 to 20 - PHLI(I) = horizontal load intensity at joint i  
(force per unit vertically projected area or length)
- Col. 21 to 30 - PHLJ(I) = horizontal load intensity at joint j
- Col. 31 to 40 - PVLI(I) = vertical load intensity at joint i  
(force per unit horizontally projected area or length)
- Col. 41 to 50 - PVLJ(I) = vertical load intensity at joint j
- Col. 51 to 60 - SURT(I) = X-coordinate measured along mid-element line  
(if IO = 0) or angle measured in degrees (if IO = 1)  
from origin to center of loaded area
- Col. 61 to 70 - SURL(I) = length measured along mid-element line  
(if IO = 0) or angle measured in degrees (if IO = 1)  
subtended by distributed load. Note that for SURL(I)  
= 0.0 (transverse line load), loads are input as force  
per unit length. For SURL(I) ≠ 0.0, loads are input  
as force per unit area.

#### 9. JOINT CARDS (I10, 6F10.0, 7I1)

One card for each joint. All joints require a card.

- Col. 1 to 10 - I = joint number
- Col. 11 to 20 - Y(I) = Y-coordinate of joint I
- Col. 21 to 30 - Z(I) = Z-coordinate of joint I
- Col. 31 to 40 - AJFOR (1,I) = applied horizontal joint force or  
displacement
- Col. 41 to 50 - AJFOR (2,I) = applied vertical joint force or displace-  
ment
- Col. 51 to 60 - AJFOR (3,I) = applied joint moment or rotation
- Col. 61 to 70 - AJFOR (4,I) = applied longitudinal joint force or  
displacement
- Col. 71 - LCASE (1,I) = index for horizontal force or displace-  
ment (can be 0, 1, 2, or 3)
- Col. 72 - LCASE (2,I) = index for vertical force or displacement  
(can be 0, 1, 2 or 3)

Col. 73 - LCASE (3,I) = index for moment or rotation (can be 0, 1, 2 or 3)

For Cols. 71, 72 and 73, indices are as follows:

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

Col. 74 - LCASE (4,I) = index for longitudinal force or displacement, can be (0, 2, or 3)

For Col. 74 indices are as follows:

- 0 for given zero force
- 2 for prestress P at each end (input total force at one end for AJFOR, + towards midspan)
- 3 for given zero displacement

The following three indices define whether or not the joint is connected to the interior diaphragm or bents that exist in the structure horizontally, vertically or rotationally and are called 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)

- 0 to consider restraint from diaphragms or bents
- 1 to neglect restraint from diaphragms or bents

#### **10. NUMBER OF PARTIAL JOINT LOADS CARD (I4)**

Col. 1 to 4 - NCONL = number of partial joint loads, max. = 30

#### **11. PARTIAL JOINT LOAD CARDS (I10, 6F10.0)**

One card is required for each partial joint load. No cards are 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 - LJT(I) = joint number

Col. 11 to 20 - FH(I) = total horizontal force

Col. 21 to 30 - FV(I) = total vertical force

Col. 31 to 40 - FM(I) = total moment

Col. 41 to 50 - FP(I) = total longitudinal force (Note that this force must be balanced by another force FP(I) somewhere on the same joint.)

Col. 51 to 60 - FTL(I) = X-coordinate measured along joint LJT (if IO = 0) or angle measured in degrees (if IO = 1) from origin to center of joint load

Col. 61 to 70 - FTT(I) = length measured along joint LJT (if IO = 0 or angle measured in degrees (if IO = 1) subtended by joint load. For concentrated joint load, FTT(I) = 0.0. Note that each joint may be loaded with more than one joint load, but each joint load requires one separate card.

## 12. GIRDER MOMENT INTEGRATION 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 7. Normally, NSEC = 4 is recommended.

### a. FIRST CARD (2I4)

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

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

### b. SECOND CARD (10F7.3)

Col. 1 to 70 - XMP(I) = X-coordinates at which girder moments are desired, must be a subset of the coordinates listed in paragraph 3. Use second card if more than 10 sections.

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

Col. 1 to 4 - I = element number

Col. 5 to 8 - NGIEL (I,1) = first girder number to which this element belongs; 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 - NGIEL (I,2) = second girder number to which this element belongs; punch zero if no second girder.

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

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

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

### 13. FLEXIBLE SUPPORTING FRAME BENT CARD DECK

No cards required if no bents called for on CONTROL CARD (paragraph 2). Otherwise, one set of the following cards required 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 (max. = 80)

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

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

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

#### b. MATERIAL PROPERTY CARDS (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. ELASTIC SUPPORT CARDS (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. SECTION PROPERTY CARDS (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. NODAL POINT DATA CARDS (2I5, 2F10.0, 2I5) - one for each frame bent node

Col. 1 to 5 - frame 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 in frame coordinate system

See page A-14

Col. 21 to 30 - global Y in frame coordinate system

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

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

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

Col. 1 to 5 - identification number

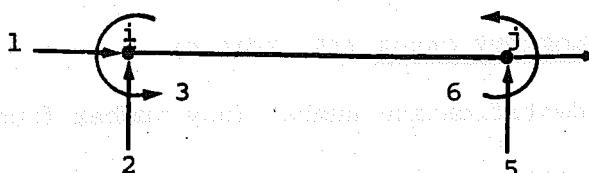
Col. 6 to 10 - node I

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. REPEAT preceding frame bent card deck for each frame type number.

15. FLEXIBLE MOVABLE DIAPHRAGM CARD DECK

No cards required if no flexible movable diaphragms called for on CONTROL CARD (paragraph 2). Otherwise, one set of the following two cards required for each type of flexible movable diaphragm.

a. FIRST CARD (2I4)

Col. 1 to 4 - type number

Col. 5 to 8 - option code (option for the two ways of inputting data)

1 option one

2 option two

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

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

Col. 1 to 10 - DITH = diaphragm thickness

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

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

Col. 31 to 40 - DIE = modulus of elasticity

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

2) Option two (6F10.0)

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

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

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

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

+ if neutral axis above joint 1

- if neutral axis below joint 1

Col. 41 to 50 - DIE = modulus of elasticity

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

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 complete 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 A-16.
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  $(M) \times NDIAPH < 120$ .

#### OUTPUT DESCRIPTION

The output consists of two parts:

1. 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.
2. Results  
The final results consist of the following quantities: (see pages A-14 and A-15 for sign convention).
  - a. If NDIAPH is not zero, the interaction (restraint) joint forces between each diaphragm or bent and the folded plate system are printed.
  - b. Resulting displacements at joints - Horizontal, vertical, rotational, and longitudinal displacements of the folded plates are given successively for each joint.

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

- 1) Longitudinal moment per unit length;  $M_\theta$
- 2) Transverse moment per unit length;  $M_s$
- 3) Torsional moment per unit length;  $M_{s\theta}$
- 4) Longitudinal membrane force per unit length;  $N_\theta$
- 5) Transverse membrane force per unit length;  $N_s$
- 6) Membrane shear per unit length;  $N_{s\theta}$
- 7) Longitudinal displacement;  $u$
- 8) Transverse displacement;  $v$
- 9) Normal displacement;  $w$

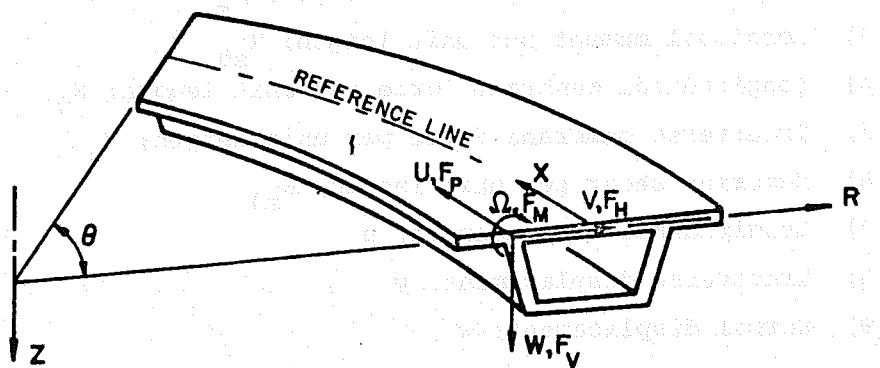
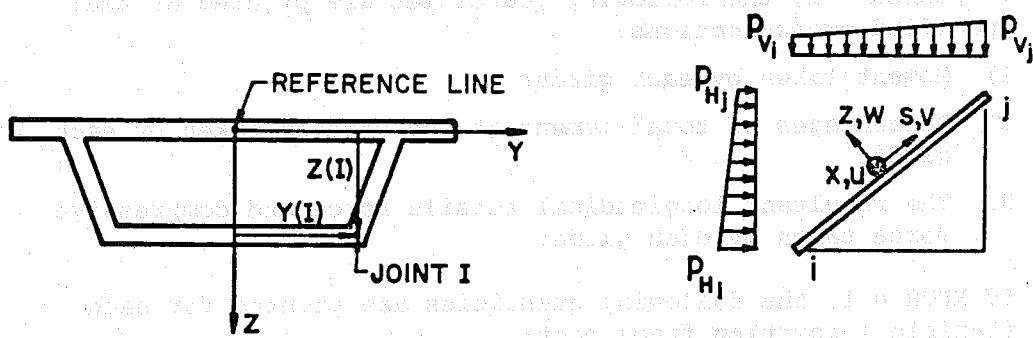
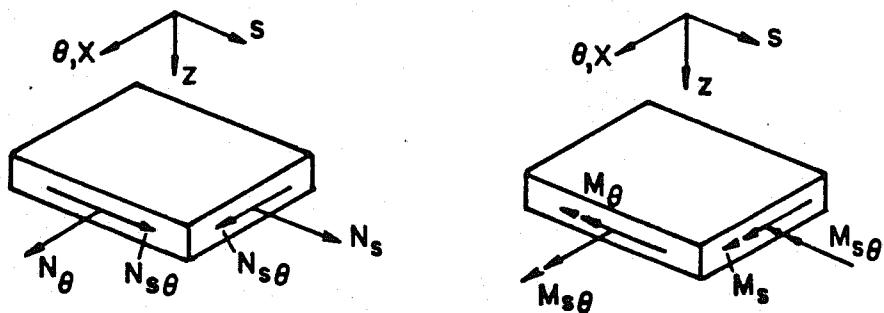
Each of these quantities is printed for each transverse section specified across the plate width and at the X-coordinate specified along the plate length.

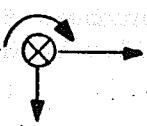
d. If MCHECK = 1, the following quantities are printed at the specified cross-sections:

- 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

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

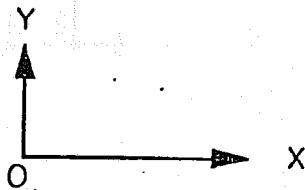
- 1) Joint displacements
- 2) Member end forces
- 3) Applied joint loads (i.e., interaction forces acting on the frame bent) and reactions

**SIGN CONVENTIONS****1. SIGN CONVENTIONS FOR THE FOLDED PLATE SYSTEM****a) GLOBAL JOINT DISPLACEMENTS  $U, V, W, \Omega$  AND JOINT LOADS  $F_P, F_H, F_V, F_M$** **b) JOINT COORDINATES****c) SURFACE LOADS AND ELEMENT DISPLACEMENTS****d) INTERNAL FORCES AND MOMENTS**

- e) 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 looking away from the origin of the plate system

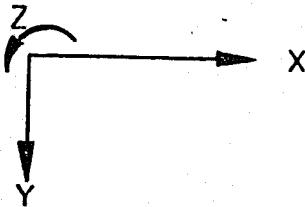
2. SIGN CONVENTIONS FOR THE SUPPORTING FRAME BENTS (assumed looking away from the origin of the folded plate system)

- a) COORDINATE SYSTEM FOR THE GEOMETRY OF THE FRAME BENTS (Note this is independent of folded plate coordinate system)

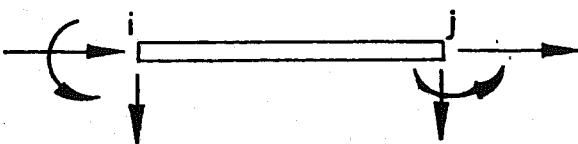


(location of origin can be arbitrary)

- b) JOINT FORCES AND DISPLACEMENTS (Joint forces include interaction forces and reactions acting on the supporting frame bent)



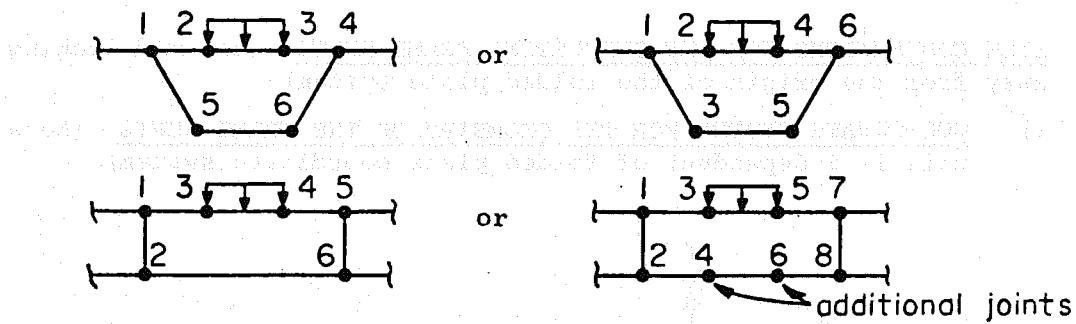
- c) POSITIVE MEMBER END FORCES



### 3. ALTERNATE METHODS OF NUMBERING JOINTS OF THE FOLDED PLATE SYSTEM

The sections shown are assumed looking away from origin

of the folded plate system towards the sections. In both cases the joint numbering on the right gives a smaller maximum difference in the joint numbers for any element in the cross-section and thus a smaller band width for the equations to be solved.



Numbered joints are right-hand side of diagram

APPENDIX B

**Listing of Input Data for Example 4**

**EX 4-2SPAN, 4CELL, CURVED, RC BRIDGE MODEL (CURD I REPORT)**

1	54.0	0.234	4	1	
2	36.0	1.960	3	1	
1	0.255	550800.0	550800.0	239478.2	0.15
	0.255	550800.0	550800.0	239478.2	0.15
2	0.188	550800.0	550800.0	239478.2	0.15
	0.188	550800.0	550800.0	239478.2	0.15
3	0.162	432000.0	432000.0	187800.0	0.15
	0.162	432000.0	432000.0	187800.0	0.15
4	0.234	432000.0	432000.0	187800.0	0.15
	0.234	432000.0	432000.0	187800.0	0.15
1	1	2	1	4	
2	10	12	1	4	
3	2	4	2	4	
4	4	6	2	4	
5	6	8	2	4	
6	8	10	2	4	
7	3	5	3	4	
8	5	7	3	4	
9	7	9	3	4	
10	9	11	3	4	
11	3	2	4	4	
12	5	4	4	4	
13	7	6	4	4	
14	9	8	4	4	
15	11	10	4	4	
0					

1	-6.0	0.0
2	-5.15	0.0
3	-5.15	1.539
4	-2.575	0.0
5	-2.575	1.539
6	0.0	0.0
7	0.0	1.539
8	2.575	0.0
9	2.575	1.539
10	5.15	0.0
11	5.15	1.539
12	6.00	0.0

2  
6 100.0 18.0 0.0  
6 100.0 54.0 0.0

1	1	-0.687	-0.687	
2	5	-0.687	-0.687	
3	1	2 -0.687	-0.687	1.2875
4	2	3 -0.687	-0.687	1.2875
5	3	4 -0.687	-0.687	1.2875
6	4	5 -0.687	-0.687	1.2875

## B-2

7	1	2	0.852	0.852	1.2875
8	2	3	0.852	0.852	1.2875
9	3	4	0.852	0.852	1.2875
10	4	5	0.852	0.852	1.2875
11	1		0.852	-0.687	
12	2		0.852	-0.687	
13	3		0.852	-0.687	
14	4		0.852	-0.687	
15	5		0.852	-0.687	
1	15	16	2	2	0
1	4.32000+06		0.15		
2	4.32000+11		0.15		
1	3.020		2.520	0.595	
2	1.767		1.590	0.249	
1		0.85		1.539	
2		0.85		0.0	
3		3.425		1.539	
4		3.425		0.0	
5		6.0		1.539	
6		6.0		0.0	
7		8.575		1.539	
8		8.575		0.0	
9		11.15		1.539	
10		11.15		0.0	
11		0.85		0.7695	
12		3.425		0.7695	
13		6.0		0.7695	
14		8.575		0.7695	
15		11.150		0.7695	
16		111	6.0	-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	-1.0	432000.0	0.15

APPENDIX C

**FORTRAN IV Listing of CURDI**

Considerable time, effort, and expense have gone into the development of the 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 this research 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 by the sponsors of this research project.

```

OVERLAY(MASTER,0,0)
PROGRAM CURDI(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,TACURD
1PE3,TAPE4,TAPE7,TAPE8,TAPE9) CURD 1
C CURDIAN: A COMPUTER PROGRAM FOR THE ANALYSIS OF PLATES AND SHELLS BY THE FINITE ELEMENT METHOD. CURD 2
C ***** CURD 3
C ***** LINEAR ELASTIC ANALYSIS FOR CURVED FOLDED PLATE STRUCTURES SIMPLY CURD 4
C SUPPORTED AT THE ENDS WITH RIGID OR FLEXIBLE INTERIOR DIAPHRAGMS CURD 5
C OR SUPPORT BENTS CURD 6
C ***** CURD 7
C ***** PROGRAMMED BY AHMAD F. KABIR CURD 8
C ***** UNIVERSITY OF CALIFORNIA, SEPT. 1972 CURD 9
C ***** CURD 10
C ***** CURD 11
COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD CURD 12
1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,TITLE(12),SPACE(220) CURD 13
COMMON /PLATE/ XP(14),NPI(30),NPJ(30),KPL(30),NSEC(30),PWT(30),SICURD 14
1NEL(30),COSEL(30),Y(30),Z(30),TP(14) CURD 15
COMMON /PROPT/ THM(15),THB(15),ETM(15),ETB(15),ESM(15),ESB(15),GM(CURD
115),GB(15),PRM(15),PRB(15) CURD 16
COMMON /PERM/ NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(3CURD
10),DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)CURD 18
COMMON /CASE/ AJP(80),LCASE(4,20),JFOR(3,20),XORD(20),YORD(20) CURD 19
COMMON /FDM/ IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),XDCURD 20
100(120),BF(3,120),IT CURD 21
COMMON /PARAM/ NUMEL,NUMNP,NEQ,NJMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(CURD
18),NUSPRG(8),NPT(8),NPR(80) CURD 22
C ***** CURD 23
C ***** CURD 24
C ***** CURD 25
10 READ 50, (TITLE(I),I=1,12) CURD 26
READ 60, TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD CURD 27
1MD,KFOR,IO,MI,IAX CURD 28
IF (R) 40,40,20 CURD 29
20 PRINT 70, (TITLE(I),I=1,12) CURD 30
CALL OVERLAY (6HMASTER,1,0) CURD 31
IF (NDIAPH.EQ.0) GO TO 30 CURD 32
CALL OVERLAY (6HMASTER,2,0) CURD 33
IF (NBT.NE.0) CALL OVERLAY (6HMASTER,3,0) CURD 34
IF (NFMD.NE.0) CALL OVERLAY (6HMASTER,4,0) CURD 35
CALL OVERLAY (6HMASTER,5,0) CURD 36
30 CALL OVERLAY (6HMASTER,6,0) CURD 37
IF (KFOR.EQ.1) CALL OVERLAY (6HMASTER,7,0) CURD 38
GO TO 10 CURD 39
40 STOP CURD 40
C ***** CURD 41
50 FORMAT (12A6) CURD 42
60 FORMAT (2F10.0,14I4) CURD 43
70 FORMAT (1H1,12A6) CURD 44
END CURD 45
C ***** CURD 46

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OVERLAY(MASTER,1,0)
PROGRAM MAIN
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. NO AUTO CRITICAL ANALYSIS
C ****
C COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDMAIN
C 1,KFOR, ID, MI, INTRES, PI, MX, NI, N2, IAX, DIAPHX(12), DIADEL(12), KODTA(12)MAIN
C 2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60),CF(120)MAIN
C 3,COMMON /CASE/ AJP(80),LCASE(4,20),JFOR(3,20),XORD(20),YORD(20)MAIN
C 4,COMMON /PLATE/ XP(14),NPI(30),NPJ(30),KPL(30),NSEC(30),PWTH(30),SIMAIN
C 5,INEL(30),COSEL(30),Y(30),Z(30),TP(14)MAIN
C 6,COMMON /PROPT/ THM(15),THB(15),ETM(15),ETB(15),ESM(15),ESB(15),GM(15)
C 7,GB(15),PRM(15),PRB(15)MAIN
C 8,COMMON /STIFF/ SMALLK(8,8)MAIN
C 9,COMMON /PERM/ NOXMP,NBOX,NGIEL(30,2),BOXMOD(14,10),XDIV(30),DNAI(3
C 10),DNAJ(30),MCPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)MAIN
C 11,DIMENSION D11(15), D12(15), D22(15), D33(15), D44(15), D45(15), D5MAIN
C 12,15(15), D66(15), NPDIIF(30), SINKX(200,14), COSKX(200,14), NQ(2), LIMAIN
C 13,2ND(80), BIGK(80,20), PTOT(80), PTTT(80,81), AJFOR(4,2C), BKMAIN
C 14,(1600), DISP(80,81)MAIN
C 15,DIMENSION LEL(30), PHLI(30), PH LJ(30), PVL I(30), PV LJ(30), SURT(30)MAIN
C 16,1), SURL(30), LJ T(30), FH(30), FV(30), FM(30), FP(30), FTL(30), FT TMAIN
C 17,2(30), DL(30), HLI(30), HLJ(30), VLI(30), VLJ(30), H(30), V(30)MAIN
C 18,EQUIVALENCE (LIND,LCASE), (AJP,AJFOR)MAIN
C 19,EQUIVALENCE (THM,D11), (THB,D12), (ETM,D22), (ETB,D33), (ESM,D44),MAIN
C 20,(ESB,D45), (GM,D55), (GB,D66)MAIN
C 21
C 22
C 23
C 24
C 25
C 26
C 27
C 28
C 29
C 30
C 31
C 32
C 33
C 34
C 35
C 36
C 37
C 38
C 39
C 40
C 41
C 42
C 43
C 44
C 45
C 46
C 47
C 48
C 49
C 50
C 51
C 52
C 53
C ***** READ AND PRINT INPUT DATA
C ****
C 100 PRINT 1120, TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NBT,NFMD
C 110 MH = (MHARM/2)*2
C 120 IF (NCHECK) 10,30,20
C 130 PRINT 1090
C 140 IF (MHARM.NE.MH) MHARM=MHARM-1
C 150 GO TO 30
C 20 PRINT 1100
C 21 IF (MHARM.EQ.MH)MHARM=MHARM-1
C 300 IF (MCHECK.EQ.1) PRINT 1110
C 310 IF (KFOR.EQ.1) PRINT 1080
C 320 READ 1130, (XP(I),I=1,NXP)
C 330 IF (ID.EQ.0) PRINT 1370
C 340 IF (ID.EQ.1) PRINT 1380
C 350 PRINT 1360, (XP(I),I=1,NXP)
C
C 400 IF (NDIAPH) 60,60,50
C 50 READ 1160, (I,DIAPHX(I),DIADEL(I),KODIA(I),KDTP(I),J=1,NDIAPH) MAIN
C 51 PRINT 1170, (I,DIAPHX(I),DIADEL(I),KODIA(I),KDTP(I),I=1,NDIAPH) MAIN

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      PRINT 1180
160 IF (MI.EQ.1) GO TO 80
      DO 70 J=1,NPL
      READ 1290, I,THM(I),ETM(I),ESM(I),GM(I),PRM(I)
70 READ 1270, THB(I),ETB(I),ESB(I),GB(I),PRB(I)
      PRINT 1400
      PRINT 1410, (I,THM(I),ETM(I),ESM(I),GM(I),PRM(I),THB(I),ETB(I),ESBMAIN
1(I),GB(I),PRB(I),I=1,NPL)
      GO TO 100
80 DO 90 J=1,NPL
      READ 1300, I,D11(I),D12(I),D22(I),D33(I)
90 READ 1260, D44(I),D45(I),D55(I),D66(I)
      PRINT 1340
      PRINT 1350, (I,D11(I),D12(I),D22(I),D33(I),D44(I),D55(I),D66(I),I=MAIN
11,NPL)
C
100 READ 1280, (I,NPI(I),NPJ(I),KPL(I),NSEC(I),DL(I),HLI(I),HLJ(I),VLIMAIN
1(I),VLJ(I),J=1,NFL)
      PRINT 1420
      PRINT 1430, (I,NPI(I),NPJ(I),KPL(I),NSEC(I),DL(I),HLI(I),HLJ(I),VLIMAIN
1(I),VLJ(I),I=1,NEL)
C
110 READ 1140, NSURL
      IF (NSURL) 120,120,110
110 READ 1320, (LEL(I),PHLI(I),PHLJ(I),PVLI(I),PVLJ(I),SURT(I),SURL(I)MAIN
1,I=1,NSURL)
      PRINT 1460
      PRINT 1470, (LEL(I),PHLI(I),PHLJ(I),PVLI(I),PVLJ(I),SURT(I),SURL(I)MAIN
1,I=1,NSURL)
C
120 DO 130 L=1,NJT
130 READ 1330, I,Y(I),Z(I),(AJFOR(J,I),J=1,4),(LCASE(K,I),K=1,3)
      PRINT 1440
      DO 140 I=1,NJT
      PRINT 1450, I,Y(I),Z(I),(AJFOR(J,I),LCASE(J,I),J=1,4),(JFOR(K,I),K
1=1,3)
140 CONTINUE
C
      PRINT 1150
      PRINT 1190
      READ 1140, NCCNL
      IF (NCCNL) 160,160,150
150 READ 1310, (LJT(I),FH(I),FV(I),FM(I),FP(I),FTL(I),FTT(I),I=1,NCONLMAIN
1)
      PRINT 1480
      PRINT 1490, (LJT(I),FH(I),FV(I),FM(I),FP(I),FTL(I),FTT(I),I=1,NCONL
1)
C
160 CONTINUE
      IF (MCHECK) 220,220,170
170 READ 1200, NOXMP,NBOX
      READ 1130, (XMP(I),I=1,NOXMP)
      READ 1220, (I,NGIEL(I,1),NGIEL(I,2),DNAI(I),DNAJ(I),XDIV(I),J=1,NEMAIN
1)
      PRINT 1230, NCXMP,NBOX
      MAIN 54
      MAIN 55
      MAIN 56
      MAIN 57
      MAIN 58
      MAIN 59
      MAIN 60
      MAIN 61
      MAIN 62
      MAIN 63
      MAIN 64
      MAIN 65
      MAIN 66
      MAIN 67
      MAIN 68
      MAIN 69
      MAIN 70
      MAIN 71
      MAIN 72
      MAIN 73
      MAIN 74
      MAIN 75
      MAIN 76
      MAIN 77
      MAIN 78
      MAIN 79
      MAIN 80
      MAIN 81
      MAIN 82
      MAIN 83
      MAIN 84
      MAIN 85
      MAIN 86
      MAIN 87
      MAIN 88
      MAIN 89
      MAIN 90
      MAIN 91
      MAIN 92
      MAIN 93
      MAIN 94
      MAIN 95
      MAIN 96
      MAIN 97
      MAIN 98
      MAIN 99
      MAIN 100
      MAIN 101
      MAIN 102
      MAIN 103
      MAIN 104
      MAIN 105
      MAIN 106
      MAIN 107
      MAIN 108
      MAIN 109

```

```

PRINT 1240, (XMP(I),I=1,NOXMP)          MAIN 110
PRINT 1250, (I,NGIEL(I,1),NGIEL(I,2),DNAI(I),DNAJ(I),XDIV(I),I=1,NMAIN 111
1EL)
DO 200 I=1,NOXMP
DO 180 J=1,NXP
IF (XP(J).EQ.XMP(I)) GO TO 190
CONTINUE
PRINT 1210
GO TO 200
MOPX(I)=J
CONTINUE
DO 210 I=1,NOXMP
DO 210 J=1,NBCX
BOXMOM(I,J)=0.
COMP(I,J)=0.
TENS(I,J)=0.
CONTINUE
PI=3.14159265
MX=4*NJT
CONTINUE
COMPUTE PLATE WIDTHS AND SIN AND COS OF INCLINATION ANGLES
DO 230 I=1,NEL
II=NPI(I)
IJ=NPJ(I)
HH=Y(IJ)-Y(II)
VV=Z(IJ)-Z(II)
H(I)=HH
V(I)=-VV
HS(I)=H(I)
VS(I)=V(I)
PWT(I)=SQRT (HH*HH+VV*VV)
SINL(I)=VV/PWT(I)
COSL(I)=HH/PWT(I)
CALCULATE JOINT RADII Y(I)=Y(I)+R
FAC=3.14159265/180.
TETAO=TETAO*FAC
T2=0.5*TETAO
HSPAN=R*SIN(T2)
DO 240 I=1,NJT
Y(I)=Y(I)+R
CONVERT CIRCUMFERENTIAL COORDINATES TO RADIAN
S=1./R
IF (IO.EQ.1) S=FAC
DO 250 I=1,NXP
TP(I)=XP(I)*S
IF (NSURL.LE.0) GO TO 270
DO 260 I=1,NSURL
IK=LEL(I)
II=NPI(IK)

```

```

I=NPJ(IK)
RR=(Y(I)+Y(IJ))/2.
S=1./RR
IF (IO.EQ.1) S=FAC
SURT(I)=SURT(I)*S
260 SURL(I)=SURL(I)*S
270 IF (NCONL.LE.0) GO TO 290
DO 280 I=1,NCONL
II=LJT(I)
S=1./Y(II)
IF (IO.EQ.1) S=FAC
FTL(I)=FTL(I)*S
280 FTT(I)=FTT(I)*S
290 IF (NDIAPH.LE.0) GO TO 310
DO 300 I=1,NDIAPH
S=1.0/R
DIADEL(I)=DIADEL(I)*S
IF (IO.EQ.1) S=FAC
300 DIAPHX(I)=DIAPHX(I)*S
310 CONTINUE
C FIND X AND Y COORDINATES WITH ORIGIN AT JOINT 1
C
IF (NDIAPH) 320,320,330
320 CHPLRE=1.
MPC1=1
GO TO 400
330 XORD(1)=0.
YORD(1)=0.
NPDIF(1)=-1
DO 340 I=2,NJT
340 NPDIF(I)=1
II=1
350 DO 390 K=1,NEL
L=K
I=NPI(K)
J=NPJ(K)
IF (NPDIF(I)+NPDIF(J)) 390,360,390
360 IF (NPDIF(I)+1) 370,370,380
370 XORD(J)=XORD(I)+H(L)
YORD(J)=YORD(I)+V(L)
NPDIF(J)=-1
II=II+1
GO TO 390
380 XORD(I)=XORD(J)-H(L)
YORD(I)=YORD(J)-V(L)
NPDIF(I)=-1
II=II+1
390 CONTINUE
IF (II-NJT) 350,400,350
C
C
C MODIFY SUR. LOADS FOR ELE.(VL=ZL,HL=YL) AND CHECK FOR MAX. BAND W
C ALSO SET NPI=NPI*4-4, NPJ=NPJ*4-4
C
400 NXBAND=0
DO 410 I=1,NEL

```

```

H(I)=C          MAIN 222
V(I)=-S         MAIN 223
S=SINEL(I)      MAIN 224
C=COSEL(I)      MAIN 225
AS=ABS(S)        MAIN 226
AC=ABS(C)        MAIN 227
VV=VL(I)*AC+DL(I)  MAIN 228
HH=HL(I)*AS      MAIN 229
VL(I)=S*HH-C*VV  MAIN 230
HL(I)=C*HH+S*VV  MAIN 231
VV=VL(J)*AC+DL(I)  MAIN 232
HH=HL(J)*AS      MAIN 233
VL(J)=S*HH-C*VV  MAIN 234
HL(J)=C*HH+S*VV  MAIN 235
NPDIF(I)=NPJ(I)-NPI(I)  MAIN 236
K=IABS(NPDIF(I))  MAIN 237
IF (K.GT.NXBAND) NXBAND=K  MAIN 238
410 CONTINUE    MAIN 239
MAXJTD=NXBAND   MAIN 240
NXBAND=NXBAND*4+4  MAIN 241
C
C  MODIFY PARTIAL SURFACE LOADS (VL=ZL,HL=YL)
C
IF (NSURL) 440,440,420  MAIN 242
420 DO 430 I=1,NSURL  MAIN 243
    K=LEL(I)      MAIN 244
    S=SINEL(K)      MAIN 245
    C=COSEL(K)      MAIN 246
    AS=ABS(S)        MAIN 247
    AC=ABS(C)        MAIN 248
    VV=PVLI(I)*AC  MAIN 249
    HH=PHLI(I)*AS  MAIN 250
    PVLI(I)=S*HH-C*VV  MAIN 251
    PHLI(I)=C*HH+S*VV  MAIN 252
    VV=PV LJ(I)*AC  MAIN 253
    HH=PH LJ(I)*AS  MAIN 254
    PV LJ(I)=S*HH-C*VV  MAIN 255
    PHLJ(I)=C*HH+S*VV  MAIN 256
430 PHLJ(I)=C*HH+S*VV  MAIN 257
C
C  MODIFY LCASE (=LIND) MATRIX
C
440 DO 450 I=1,MX  MAIN 258
450 LIND(I)=LIND(I)+1  MAIN 259
    DO 470 I=1,NJT  MAIN 260
    IF (LCASE(4,I)-3) 470,460,470  MAIN 261
460 LCASE(4,I)=LCASE(4,I)+2  MAIN 262
    470 CONTINUE    MAIN 263
C
C  SET UP INDMPC MATRIX AND MPC, MPC1, MPCOL
C
IF (NDIAPH) 530,530,480  MAIN 264
480 MPCOL=0            MAIN 265
    DO 520 I=1,NJT  MAIN 266
    DO 520 J=1,3  MAIN 267
    IF (LCASE(J,I)-4) 500,490,500  MAIN 268
    490 JFOR(J,I)=1  MAIN 269
    500 MPC=0          MAIN 270
    510 MPC1=0         MAIN 271
    520 MPCOL=MPCOL+1  MAIN 272
    530 MPC=1          MAIN 273
    540 MPC1=1         MAIN 274
    550 MPCOL=MPCOL+1  MAIN 275
    560 MPC=2          MAIN 276
    570 MPC1=2         MAIN 277

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      GO TO 520
500 IF (JFOR(J,I)) 520,510,520
510 MPCOL=MPCOL+1
  INDMP(MPCOL)=(I-1)*4+J
520 CONTINUE
  MPC1=MPCOL+1
  MPC=MPCOL

C
C   CYCLE FOR EACH HARMONIC IS INITIATED
C

530 REWIND 3
  IF (NCHECK) 540,550,560
540 N1=2
  GO TO 570
550 N1=1
  N2=1
  IF (IAX.EQ.0) MHARM=1
  GO TO 580
560 N1=1
570 N2=2

C
  580 MM=0
  DO 1070 NN=N1,MHARM,N2
    MM=MM+1
    DO 590 J=1,NXBAND
      DO 590 I=1,MX
        BIGK(I,J)=0.
        IF (IAX.EQ.0) GO TO 610
C
        FN=NN
        FK=FN*PI/TETAO
C
C   HARMONIC AND FOURIER MULTIPLIERS ARE COMPUTED
C
        DO 600 I=1,NXP
          XX=FK*TP(I)
          SINKX(MM,I)=SIN(XX)
        600 CUSKX(MM,I)=COS(XX)
        N3=(-1)**NN
        S1=4./ (FN*PI)
        S2=(-1.)**((NN+3)/2)
        JT = NN
        GO TO 620
610 JT = 0
        N3=0
        S1=1.0
        S2=1.0

C
C   CALCULATE ELEMENT STIFFNESSES AND STORE THEM INTO BIGK
C

620 DO 650 IE=1,NEL
  IJ=KPL(IE)
  I=NPI(IE)
  J=NPJ(IE)
  R1=Y(I)
  R2=Y(J)
  MAIN 278
  MAIN 279
  MAIN 280
  MAIN 281
  MAIN 282
  MAIN 283
  MAIN 284
  MAIN 285
  MAIN 286
  MAIN 287
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  MAIN 331
  MAIN 332
  MAIN 333

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S=SINEL(IE)
C=COSEL(IE)
CALL CONE (IJ,R1,R2,S,C,PWTH(IE),JT)
NQ(1)=I
NQ(2)=J
DO 640 L=1,2
LL=4*NQ(L)-4
LV=4*L-4
DO 640 K=1,2
KK=4*NQ(K)-4
IF (KK.LT.LL) GO TO 640
KH=4*K-4
DO 630 II=1,4
LLI=LL+II
LVI=LV+II
DO 630 JJ=1,4
KKJ=KK+JJ
IF (KKJ.LT.LLI) GO TO 630
KKJ=KKJ-LLI+1
KHJ=KH+JJ
BIGK(LLI,KKJ)=BIGK(LLI,KKJ)+SMALLK(LVI,KHJ)
630 CONTINUE
640 CONTINUE
650 CONTINUE
C
C
C      SET UP LOAD VECTOR
C
DO 660 I=1,MX
660 PTOT(I)=0.0
IF (N3) 670,690,690
C
C      FIND CONSISTENT NODAL LOADS FOR UNIFORM PLATE FORCES
C      AND STORE THESE INTO LOAD VECTOR PTOT
C
670 DO 680 I=1,NEL
HI=HLI(I)*S1
HJ=HLJ(I)*S1
VI=VLI(I)*S1
VJ=VLJ(I)*S1
IF (HI.EQ.0..AND.HJ.EQ.0..AND.VI.EQ.0..AND.VJ.EQ.0..) GO TO 680
II=NPI(I)
IJ=NPJ(I)
R1=Y(II)
R2=Y(IJ)
S12=PWTH(I)
S=SINEL(I)
C=COSEL(I)
CALL LOADS (II,IJ,HI,HJ,VI,VJ,R1,R2,S12,S,C,PTOT)
680 CONTINUE
C
C      ADD CONTRIBUTIONS DUE TO PARTIAL SURFACE LOADS
C
690 IF (NSURL.LE.0) GO TO 740
DO 730 I=1,NSURL
L=LEL(I)
MAIN 334
MAIN 335
MAIN 336
MAIN 337
MAIN 338
MAIN 339
MAIN 340
MAIN 341
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MAIN 346
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MAIN 385
MAIN 386
MAIN 387
MAIN 388
MAIN 389

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II=NPI(L)
IJ=NPJ(L)
R1=Y(II)
R2=Y(IJ)
IF (SURL(I).EQ.0.) GO TO 700
C1=S1*SIN(FK*SURT(I))*SIN(.5*FK*SURL(I))
C2=C1
GO TO 720
700 IF (SURT(I).EQ.T2) GO TO 710
C=SIN(FK*SURT(I))/T2
C1=C/R1
C2=C/R2
GO TO 720
710 IF (N3.GT.0) GO TO 730
C1=S2/(R1*T2)
C2=S2/(R2*T2)
720 HI=PHL_I(I)*C1
HJ=PHL_J(I)*C2
VI=PVL_I(I)*C1
VJ=PVL_J(I)*C2
S12=PWT_H(L)
S=SINEL(L)
C=COSEL(L)
CALL LOADS (II,IJ,HI,HJ,VI,VJ,R1,R2,S12,S,C,PTOT)
730 CONTINUE
C
C ADD JOINT LOADS INTO PTOT
C
740 IF (N3.GT.0) GO TO 790
I=0
DO 780 J=1,NJT
R1=Y(J)
XX=R1*T2
DO 780 L=1,4
I=I+1
K=LIND(I)
GO TO (780,750,760,780,770), K
750 PTOT(I)=PTOT(I)+AJP(I)*S1*XX
GO TO 780
760 PTOT(I)=PTOT(I)+AJP(I)*S2
GO TO 780
770 PTOT(I)=PTOT(I)+AJP(I)*2.
780 CONTINUE
C
790 IF (NCONL.LE.0) GO TO 830
DO 820 I=1,NCONL
L=LJT(I)
J=L*4-4
R1=Y(L)
C=FK*FTL(I)
IF (FTT(I).LE.0.) GO TO 800
XX=FK*FTT(I)/2.
EQH=S1*R1*T2*SIN(XX)
EQS=EQH*COS(C)
EQH=EQH*SIN(C)
GO TO 810
MAIN 390
MAIN 391
MAIN 392
MAIN 393
MAIN 394
MAIN 395
MAIN 396
MAIN 397
MAIN 398
MAIN 399
MAIN 400
MAIN 401
MAIN 402
MAIN 403
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MAIN 443
MAIN 444
MAIN 445

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800 EQH=SIN(C)          MAIN 446
     EQS=COS(C)          MAIN 447
810 PTOT(J+1)=PTOT(J+1)+EQH*FH(I)   MAIN 448
     PTOT(J+2)=PTOT(J+2)+EQH*FV(I)   MAIN 449
     PTOT(J+3)=PTOT(J+3)+EQH*FM(I)   MAIN 450
820 PTOT(J+4)=PTOT(J+4)+EQS*FP(I)   MAIN 451
C
C      SET UP PTTT MATRIX (WITH 1'S AND 0'S), LAST VECTOR FOR EXTERNAL DOMAIN 453
C
C      830 IF (NDIAPH) 870,870,840   MAIN 454
     840 DO 860 J=1,MPCOL          MAIN 455
         DO 850 I=1,MX             MAIN 456
         850 PTTT(I,J)=0.0          MAIN 457
         K=INDMP(J)               MAIN 458
         860 PTTT(K,J)=1.0*HSPAN   MAIN 459
C
C      MODIFY BIGK AND PTOT MATRICES DUE TO BOUNDARY CONDITIONS   MAIN 460
C
C      870 DO 900 J=1,NJT          MAIN 461
         DO 900 I=1,4              MAIN 462
         IF (LCASE(I,J).NE.4) GO TO 900   MAIN 463
         IL=J*4-4+I
         IJ=IL-NXBAND+1
         IF (IJ.LT.1) IJ=1
         DO 880 L=IJ,IL           MAIN 464
         K=IL-L+1
         880 BIGK(L,K)=0.0          MAIN 465
         DO 890 L=2,NXBAND        MAIN 466
         890 BIGK(IL,L)=0.0          MAIN 467
         PTOT(IL)=0.0              MAIN 468
900 CONTINUE
     DO 910 I=1,MX
     910 PTTT(I,MPC1)=PTOT(I)
C
C      SOLVE EQUATIONS FOR UNKNOWN JOINT DISPLACEMENTS   MAIN 469
C
C      NMM=MX*NXBAND          MAIN 470
     K=1
     DO 920 J=1,NXEAND        MAIN 471
         DO 920 I=1,MX          MAIN 472
         BK(K)=BIGK(I,J)        MAIN 473
         K=K+1
920 CONTINUE
     DO 930 I=1,MX
     930 PTOT(I)=PTTT(I,MPC1)  MAIN 474
     II=NXBAND+1
     CALL BANSOL (BK,PTOT,BIGK(1,II),MX,NXBAND,1)  MAIN 475
     DO 940 I=1,MX
     940 DISP(I,MPC1)=PTOT(I)  MAIN 476
     IF (NDIAPH.EQ.0) GO TO 980  MAIN 477
     J=1
     950 DO 960 I=1,MX
     960 PTOT(I)=PTTT(I,J)    MAIN 478
     CALL BANSOL (BK,PTOT,BIGK(1,II),MX,NXBAND,2)  MAIN 479
     DO 970 I=1,MX

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970 DISP(I,J)=PTOT(I)
      J=J+1
      IF (J.LE.MPCOL) GO TO 950
980 CONTINUE
      IF (NDIAPH.EQ.0) GO TO 1060
C CHANGE SIGN OF DIPLATE FOR THE CASE OF UNIPOLAR PLATES
C CHANGE SIGN OF DIPLATE FOR THE CASE OF UNIPOLAR PLATES
C CHANGE SIGNS TO CONFORM WITH MUPDIB
C
      J=1
990 DO 1040 I=1,3
      GO TO (1000,1000,1020), I
1000 DO 1010 K=3,MX,4
      DISP(K,J)=-DISP(K,J)
1010 DISP(K+1,J)=-DISP(K+1,J)
      J=J+1
      GO TO 1040
1020 DO 1030 K=1,MX,4
      DISP(K,J)=-DISP(K,J)
1030 DISP(K+1,J)=-DISP(K+1,J)
      J=J+1
1040 CONTINUE
      MPC3=MPC-2
      IF (J.LE.MPC3) GO TO 990
      DO 1050 K=3,MX,4
      DISP(K,MPC1)=-DISP(K,MPC1)
1050 DISP(K+1,MPC1)=-DISP(K+1,MPC1)
C
C      WRITE DISP ON TAPE 3
C
1060 WRITE (3) ((DISP(I,J),I=1,MX),J=1,MPC1)
1070 CONTINUE
      RETURN
C
C      FORMAT STATEMENTS
C
1080 FORMAT (94H0EXECUTION OF THE FORCE PROGRAM (INTERNAL FORCES AND DIMAIN 538
     1SPLACEMENTS IN FRAME BENT) IS REQUESTED) MAIN 539
1090 FORMAT (41H0CALCULATIONS SKIP ALL ODD FOURIER SERIES) MAIN 540
1100 FORMAT (42H0CALCULATIONS SKIP ALL EVEN FOURIER SERIES) MAIN 541
1110 FORMAT (41H0INTEGRATION OF GIRDER MOMENTS IS DESIRED) MAIN 542
1120 FORMAT (28H0ANGLE SUBTENDED AT CENTRE =F8.3/23H0RADIUS OF CENTER LMAIN 543
     1INE=F15.6/28H0NUMBER OF TYPES OF PLATE = I2/22H0NUMBER OF ELEMENTSMAIN 544
     2 = I3/20H0NUMBER OF JCINTS = I3/24H0NUMBER OF DIAPHRAGMS = I2/56H0MAIN 545
     3NUMBER OF X-CORDINATES AT WHICH RESULTS ARE DESIRED = I2/27H0MAXIMAIN 546
     4MUM HARMONIC NUMBER = I3/53H0NUMBER OF TYPES OF FLEXIBLE SUPPORTINMAIN 547
     5G FRAME BENT = I2/49H0LMBER OF TYPES OF FLEXIBLE MOVABLE DIAPHRAGMAIN 548
     6M = I2) MAIN 549
1130 FORMAT (10F7.3) MAIN 549
1140 FORMAT (14) MAIN 550
1150 FORMAT (//37H IH,IV,IM,IS = 0 FOR GIVEN ZERO FORCE/44H MAIN 551
     1 1 FOR UNIF. DISTRIBUTED FORCE/81H 2 MEANS CONC. FMAIN 552
     2FORCE AT MIDSPAN FOR IH, IV, IM AND PRESTRESS FOR IS/44H MAIN 553
     3 3 FOR GIVEN ZERO DISPLACEMENT) MAIN 554
1160 FORMAT (I10,2F10.0,2I4) MAIN 555
1170 FORMAT (////76H DIAPHRAGM LOCATION(X-COORD.) INTERACT. THICKMAIN 556
                                         ) MAIN 557

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1. CLASSIFICATION TYPE/(I6,F20.4,F21.6,2I14)) MAIN 558  
 1180 FORMAT (30HODIAPHRAGM CLASSIFICATION CODE/43H 1 EXTERNALLY SUPMAIN 559  
 1PORTED RIGID DIAPHRAGM/30H 2 MOVABLE RIGID DIAPHRAGM/37H 3 MAIN 560  
 2 FLEXIBLE SUPPORTING FRAME BENT/33H 4 FLEXIBLE MOVABLE DIAPHRAMAIN 561  
 3GM/42H TYPE NUMBER = 0 IF THE DIAPHRAGM IS RIGID) MAIN 562  
 1190 FORMAT (//60H RH,RV,RM = 0 - TO CONSIDER RESTRAINT FROM DIAMAIN 563  
 1PHRAGMS/59H NON-ZERO - TO NEGLECT RESTRAINT FROM DIAPHMAIN 564  
 2AGMS) MAIN 565  
 1200 FORMAT (2I4) MAIN 566  
 1210 FORMAT (//51H ERROR- INCOMPATIBLE X-COORDINATE FOR GIRDER MOMENT) MAIN 567  
 1220 FORMAT (3I4,3F10.0) MAIN 568  
 1230 FORMAT (1H1,70H ADDITIONAL INFORMATION FOR DETERMINATION OF GIRDERMAIN 569  
 1 MOMENT PERCENTAGES//,30H NO. OF SECTIONS FOR RESULTS =,16/,30H NMAIN 570  
 20. OF GIRDERS = ,16) MAIN 571  
 1240 FORMAT (///29H RESULTS ARE DESIRED AT X = /,(10F10.3)) MAIN 572  
 1250 FORMAT (////56H ELE.NO. BELONGS TO GIRDERS DNAl DNAlj MAIN 573  
 1 XDIV//(16,8X,2I6,F12.3,F10.3,F10.3)) MAIN 574  
 1260 FORMAT (10X,4F10.0) MAIN 575  
 1270 FORMAT (10X,5F10.0) MAIN 576  
 1280 FORMAT (5I4,5F10.0) MAIN 577  
 1290 FORMAT (I10,5F10.0) MAIN 578  
 1300 FORMAT (I10,4F10.0) MAIN 579  
 1310 FORMAT (I10,6F10.0) MAIN 580  
 1320 FORMAT (I10,6F10.0) MAIN 581  
 1330 FORMAT (I10,6F10.0,7I1) MAIN 582  
 1340 FORMAT (1H1,50X,20H PLATE ELEMENT TYPES//120HNUMBER D11 MAIN 583  
 1 D12 D22 D33 D44 D45MAIN 584  
 2 D55 D66 /) MAIN 585  
 1350 FORMAT (I6,2X,7E14.6) MAIN 586  
 1360 FORMAT (7F12.5) MAIN 587  
 1370 FORMAT (///42H PRINT RESULTS AT SECTIONS WITH X EQUAL TO/) MAIN 588  
 1380 FORMAT (////46H PRINT RESULTS AT SECTIONS WITH THETA EQUAL TC/) MAIN 589  
 1390 FORMAT (10F7.3) MAIN 590  
 1400 FORMAT (1H1,50X,20H PLATE ELEMENT TYPES//14X,20H MEMBRANE PROPERTIMAIN 591  
 1ES,35X,25H PLATE BENDING PROPERTIES/120H NO. TH EMAIN 592  
 2-T E-S G NU TH E-T EMAIN 593  
 3-S G NU /) MAIN 594  
 1410 FORMAT (I7,3X,10E11.4) MAIN 595  
 1420 FORMAT (1H2,52X,15H PLATE ELEMENTS//10X,100H ELE NO. NODE I MAIN 596  
 1NODE J PLATE TYPE NSEC DL HLI HLIj VLI MAIN 597  
 2 VLj /) MAIN 598  
 1430 FORMAT (6X,5I10,5F10.3) MAIN 599  
 1440 FORMAT (39H2INPUT LOADS OR DISPLACEMENTS AT JOINTS//106H JOINT YMAIN 600  
 1-COORD Z-COORD HORIZONTAL IH VERTICAL IV ROTMAIN 601  
 2ATIONAL IM LONGITUDINAL IS,13H RH RV RM/) MAIN 602  
 1450 FORMAT (I6,2F10.2,4(E17.6,I3),3I5) MAIN 603  
 1460 FORMAT (22H1PARTIAL SURFACE LOADS//71H ELE HLI HLIj MAIN 604  
 1 VLI VLj CENTER COORD LOAD WIDTH) MAIN 605  
 1470 FORMAT (I3,4F10.3,2F12.3) MAIN 606  
 1480 FORMAT (20H1PARTIAL JOINT LOADS//102H JOINT H-LOAD MAIN 607  
 1 V-LOAD MOMENT LONG. FORCE CENTER COORD LOAMAIN 608  
 2D WIDTH) MAIN 609  
 1490 FORMAT (I4,6F16.3) END MAIN 610  
 1490 FORMAT (I4,6F16.3)

## SUBROUTINE CONE (NT,R1,R2,S,C,S12,N)

```

C      ****
C      THIS SUBROUTINE CALCULATES THE GLOBAL ELEMENT STIFFNESS OF A
C      THIN SHELL CONICAL SEGMENT, USING LINEAR IN-PLANE AND CUBIC
C      OUT-OF-PLANE DISPLACEMENT FUNCTIONS.
C      BASED ON NOVOZHILOV-S STRAIN-DISPLACEMENT RELATIONS
C
C      - INPUT -
C
C      THM,FSM,ETM,GM,PRM - MATERIAL CONSTANTS FOR MEMBRANE BEHAVIOR
C      THB,ESB,ETB,GB,PRB - MATERIAL CONSTANTS FOR SHELL BENDING BEHAVIOR
C      IF MI=1 THEN THM=D11, THB=D12, ESM=D22,
C      ESB=D33, ETM=D44, ETB=D45, GM=D55, GB=D66
C      ARE THE ELEMENTS OF THE CONSTITUTIVE MATRIX
C      R1, R2           - RADII OF CURVATURE OF JOINT 1 AND 2
C      S, C             - SINE AND COSINE OF INCLINATION ANGLE
C      S12              - ELEMENT WIDTH BETWEEN JOINT 1 AND 2
C      N                - HARMONIC NUMBER
C      TETA0            - SEGMENT ANGLE (IN RADIANS)
C
C      - OUTPUT -
C
C      T(8,8)          - GLOBAL ELEMENT STIFFNESS
C
C      ****
C      COMMON TFTAO,RR,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFM
C      ID,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)
C      KDTDP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(50)
C      COMMON /PROPT/ THM(15),THB(15),ETM(15),ETB(15),ESM(15),ESB(15),GM(15),
C      GB(15),PRM(15),PRB(15)
C      COMMON /STIFF/ T(8,8)
C      DIMENSION X(8), W(8), F(3,7)
C      EQUIVALENCE (F(1,1),F11), (F(1,2),F12), (F(1,3),F13), (F(1,4),F14),
C      (F(1,5),F15), (F(1,6),F16), (F(1,7),F17), (F(2,1),F21), (F(2,2),F22),
C      (F(2,3),F23), (F(2,4),F24), (F(2,5),F25), (F(2,6),F26), (F(2,7),F27),
C      (F(3,1),F31), (F(3,2),F32), (F(3,3),F33), (F(3,4),F34),
C      (F(3,5),F35), (F(3,6),F36), (F(3,7),F37)
C      DATA X/.183434642455650,-.183434642495650,.525532409915329,-.52553
C      12409916329,.796666477413627,-.796666477413627,.960289856497536,-.9
C      260289856497536/,W/.362683783378362,.362683783378362,.3137066458778
C      387,.313706645877887,.222381034453374,.222381034453374,.10122853629
C      40376,.101228536290376/
C
C      SET UP MATRIX OF MATERIAL CONSTANTS
C
C      IF (MI.EQ.1) GO TO 10
C      FM=PRM(NT)*ETM(NT)/ESM(NT)
C      FB=PRB(NT)*ETB(NT)/ESB(NT)
C      DM=1./(1.-FM*PRM(NT))
C      DB=1./(1.-FB*PRB(NT))
C      TH3=THB(NT)**3/12.
C      D11=THM(NT)*ESM(NT)*DM
C      D22=THM(NT)*ETM(NT)*DM

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D12=D22*PRM(NT)
D33=GM(NT)*THM(NT)
D44=TH3*ESB(NT)*DB
D55=TH3*ETB(NT)*DB
D45=D55*PRM(NT)
D66=GB(NT)*TH3*4.0
GO TO 20
10 D11=THM(NT)
D12=THB(NT)
D22=ETM(NT)
D33=ETB(NT)
D44=ESM(NT)
D45=ESB(NT)
D55=GM(NT)
D66=GB(NT)
C
C      INITIALIZATION
C
20 A=0.5*(R2-R1)
B=0.5*(R2+R1)
SS=S*S
CC=C*C
XN=N
P=XN*PI/TETAO
PP=P*P
S2=0.5*S12
S122=S12*S12
S123=S12*S122
S124=S122*S122
C
C      INTEGRALS
C
30 F1=2.
F3=2./3.
F5=.4
F7=2.*7.
F8=2.*B
F9=F3*A
F10=F3*B
DO 30 I=1,3
DO 30 J=1,7
30 F(I,J)=0.0
DO 40 K=1,8
XX=X(K)
R=A*XX+B
WR=W(K)
DO 40 I=1,3
WR=WR/R
WX=WR/XX
DO 40 J=1,7
WX=WX*XX
40 F(I,J)=F(I,J)+WX
C
C      STIFFNESS COEFFICIENTS
C
H1=.25*(D22*PP+D33*CC)
CONE 55
CONE 56
CONE 57
CONE 58
CONE 59
CONE 60
CONE 61
CONE 62
CONE 63
CONE 64
CONE 65
CONE 66
CONE 67
CONE 68
CONE 69
CONE 70
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CONE 72
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CONE 96
CONE 97
CONE 98
CONE 99
CONE 100
CONE 101
CONE 102
CONE 103
CONE 104
CONE 105
CONE 106
CONE 107
CONE 108
CONE 109
CONE 110

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H2=.25*(D55*PP+D66*CC)*SS      CNE 111
H3=C*D33/S12                     CNE 112
H4=D66*C*SS/S122                 CNE 113
H5=D33/S122                      CNE 114
H6=D66*SS/S122                   CNE 115
G1=H5*F8+H6*F11                  CNE 116
G2=H3*F11                         CNE 117
G3=F11-2.*F12+F13                CNE 118
G4=F11+2.*F12+F13                CNE 119
G5=F11-F13                        CNE 120
T(1,1)=H1*G3+H2*(F31-2.*F32+F33)+G2-H4*(F22-F21)+G1-CNE 121
T(1,2)=H1*G5+H2*(F31-F33)+H4*F22-G1 CNE 122
T(2,2)=H1*G4+H2*(F31+2.*F32+F33)-G2-H4*(F21+F22)+G1-CNE 123
CNE 124
H1=-.25*P*C*(D22+D33)          CCNE 125
H2=P/(2.*S12)                    CNE 126
G1=H2*(D33+D12)*F1              CONF 127
G2=H2*(D33-D12)*F1              CONF 128
T(1,3)=H1*G3-G2                CNE 129
T(1,4)=H1*G5-G1                CNE 130
T(2,3)=H1*G5+G1                CNE 131
T(2,4)=H1*G4+G2                CNE 132
CNE 133
H1=.25*(D22*CC+PP*D33)          CONF 134
G1=C*D12/S12*F1                 CNE 135
G2=D11/S122*F8                  CNE 136
T(3,3)=H1*G3-G1+G2             CNE 137
T(3,4)=H1*G5-G2                CNE 138
T(4,4)=H1*G4+G1+G2             CNE 139
CNE 140
H1=-.125*S*P*D22               CNE 141
H2=.125*S*P*(D55*PP+D66*CC)    CNE 142
U1=S*C*P/(4.*S12)              CNE 143
U2=S*P/(2.*S122)                CNE 144
H3=U1*(D55+D66)                CNE 145
H4=U2*D45                       CNE 146
H5=U1*D66                       CNE 147
H6=U2*D66                       CNE 148
G1=2.*F11-5.*F12+3.*F13+F14-F15 CNE 149
G2=2.*F11+F12-3.*F13-F14+F15  CNE 150
G3=F11-2.*F12+2.*F14-F15       CONF 151
G4=-F11+2.*F13-F15             CONF 152
G5=2.*F11-F12-3.*F13+F14+F15  CNE 153
G6=2.*F11+5.*F12+3.*F13-F14-F15 CNE 154
G7=-F11-2.*F12+2.*F14+F15     CNE 155
G8=-F21+F22+F23-F24            CNE 156
G9=-F21-F22+F23+F24            CNE 157
T1=H1*S2                         CNE 158
T2=H2*S2                         CNE 159
T3=H3*S2                         CNE 160
T4=H4*S2                         CONF 161
T5=H5*S2                         CNE 162
T6=H6*S2                         CNE 163
U1=3.*H6*(F11-F13)               CNE 164
U2=6.*H4*(F12-F13)+3.*H3*G8     CNE 165
U3=6.*H4*(F12+F13)+3.*H3*G9     CNE 166

```

$U_4 = T_5 * G_8 - T_6 * (F_{11} + 2 * F_{12} - 3 * F_{13})$  CONE 167  
 $U_5 = T_5 * G_9 + T_6 * (F_{11} - 2 * F_{12} - 3 * F_{13})$  CONE 168  
 $T(1,5) = H_1 * G_1 - H_2 * (2 * F_{31} - 5 * F_{32} + 3 * F_{33} + F_{34} - F_{35}) + U_2 + H_5 * (-2 * F_{21} + 3 * F_{22} + F_{23} - 3 * F_{24}) - U_1$  CONE 169  
 $T(1,6) = H_1 * G_2 - H_2 * (2 * F_{31} + F_{32} - 3 * F_{33} - F_{34} + F_{35}) - U_2 + H_5 * (-2 * F_{21} - 3 * F_{22} + F_{23} + F_{24}) - U_1$  CONE 170  
 $T(1,7) = T_1 * G_3 - T_2 * (F_{31} - 2 * F_{32} + 2 * F_{34} - F_{35}) + T_3 * (-F_{21} - F_{22} + 5 * F_{23} - 3 * F_{24}) - T_4 * (-2 * F_{11} + 8 * F_{12} - 6 * F_{13}) + U_4$  CONE 171  
 $T(1,8) = T_1 * G_4 - T_2 * (-F_{31} + 2 * F_{33} - F_{35}) + T_3 * (-F_{21} + 3 * F_{22} + F_{23} - 3 * F_{24}) + T_4 * (2 * F_{11} + 4 * F_{12} - 6 * F_{13}) - U_5$  CONE 172  
 $T(2,5) = H_1 * G_5 - H_2 * (2 * F_{31} - F_{32} - 3 * F_{33} + F_{34} + F_{35}) + U_3 + H_5 * (2 * F_{21} - 3 * F_{22} + F_{23} - 3 * F_{24}) - U_1$  CONE 173  
 $T(2,6) = H_1 * G_6 - H_2 * (2 * F_{31} + 5 * F_{32} + 3 * F_{33} - F_{34} - F_{35}) - U_3 + H_5 * (2 * F_{21} + 3 * F_{22} + F_{23} + F_{24}) - U_1$  CONE 174  
 $T(2,7) = -T_1 * G_4 - T_2 * (F_{31} - 2 * F_{33} + F_{35}) + T_3 * (-F_{21} - 3 * F_{22} + F_{23} + 3 * F_{24}) + T_4 * (2 * F_{11} + 4 * F_{12} + 6 * F_{13}) - U_4$  CONE 175  
 $T(2,8) = T_1 * G_7 - T_2 * (-F_{31} - 2 * F_{32} + 2 * F_{34} + F_{35}) + T_3 * (-F_{21} + F_{22} + 5 * F_{23} + 3 * F_{24}) - T_4 * (2 * F_{11} + 8 * F_{12} + 6 * F_{13}) + U_5$  CONE 176  
**C**  
 $H_1 = .125 * S * C * D_{22}$  CONE 177  
 $H_2 = S * D_{12} / (4 * S_{12})$  CONE 178  
 $T_1 = H_1 * S_2$  CONE 179  
 $T_2 = H_2 * S_2$  CONE 180  
 $G_8 = 2 * H_2 * F_1$  CONE 181  
 $G_9 = T_2 * (F_1 - F_3)$  CONE 182  
 $T(3,5) = H_1 * G_1 - G_8$  CONE 183  
 $T(3,6) = H_1 * G_2 - G_8$  CONE 184  
 $T(3,7) = T_1 * G_3 - G_9$  CONE 185  
 $T(3,8) = T_1 * G_4 + G_9$  CONE 186  
 $T(4,5) = H_1 * G_5 + G_8$  CONE 187  
 $T(4,6) = H_1 * G_6 + G_8$  CONE 188  
 $T(4,7) = G_9 - T_1 * G_4$  CONE 189  
 $T(4,8) = T_1 * G_7 - G_9$  CONE 190  
**C**  
 $H_1 = .0625 * S * D_{22}$  CONE 191  
 $H_2 = .0625 * P * (D_{55} * P + D_{66} * C)$  CONE 192  
 $H_3 = C * P * (D_{55} + D_{66}) / (8 * S_{12})$  CONE 193  
 $H_4 = P * D_{45} / (4 * S_{122})$  CONE 194  
 $H_5 = (C * D_{55} + P * D_{66}) / (4 * S_{122})$  CONE 195  
 $H_6 = C * D_{45} / (2 * S_{123})$  CONE 196  
 $H_7 = D_{44} / S_{124}$  CONE 197  
 $T_1 = H_1 * S_2$  CONE 198  
 $T_2 = H_2 * S_2$  CONE 199  
 $T_3 = H_3 * S_2$  CONE 200  
 $T_4 = H_4 * S_2$  CONE 201  
 $T_5 = H_5 * S_2$  CONE 202  
 $T_6 = H_6 * S_2$  CONE 203  
 $T_7 = H_7 * S_2$  CONE 204  
 $U_1 = T_1 * S_2$  CONE 205  
 $U_2 = T_2 * S_2$  CONE 206  
 $U_3 = T_3 * S_2$  CONE 207  
 $U_4 = T_4 * S_2$  CONE 208  
 $U_5 = T_5 * S_2$  CONE 209  
 $U_6 = T_6 * S_2$  CONE 210  
 $U_7 = T_7 * S_2$  CONE 211  
 $G_1 = 6 * T_6 * (F_1 - 3 * F_3)$  CONE 212

```

G2=4.*U6*(F1-9.*F3)          CONE 223
G3=H5*9.*(F11-2.*F13+F15)+36.*H7*F10   CONE 224
G4=3.*F11-12.*F13+9.*F15      CONE 225
G5=12.*T7*(F9-3.*F10)        CONE 226
G6=12.*T7*(F9+3.*F10)        CONE 227
G7=6.*(F12-F14)              CONE 228
G8=F11-F13-F15+F17          CONE 229
G9=F12-2.*F14+F16           CONE 230
G10=2.*F11-5.*F13+4.*F15-F17    CONE 231
G11=F31-F33-F35+F37         CONE 232
G12=F32-2.*F34+F36          CONE 233
G13=2.*F31-5.*F33+4.*F35-F37    CONF 234
T(5,5)=H1*(4.*F11-12.*F12+9.*F13+4.*F14-6.*F15+F17)+H2*(4.*F31-12.*CONF 235
1.*F32+9.*F33+4.*F34-6.*F35+F37)-H3*(-12.*F21+18.*F22+12.*F23-24.*F2CONF 236
24+6.*F26)-H4*(24.*F12-36.*F13+12.*F15)+G3          CONE 237
T(5,6)=H1*(4.*F11-9.*F13+6.*F15-F17)+H2*(4.*F31-9.*F33+6.*F35-F37)CONE 238
1-H3*(-18.*F22+24.*F24-6.*F26)-H4*12.*(-3.*F13-F15)-G3          CONF 239
T(5,7)=T1*(2.*F11-5.*F12+F13+6.*F14-4.*F15-F16+F17)+T2*(2.*F31-5.*CONF 240
1.*F32+F33+6.*F34-4.*F35-F36+F37)-T3*(-5.*F21+2.*F22+18.*F23-16.*F24-CONF 241
25.*F25+6.*F26)-T4*(-4.*F11+24.*F12-24.*F13-8.*F14+12.*F15)+T5*(G4+CONF 242
3G7)+G1-G5          CONE 243
T(5,8)=T1*(G9-G10)+T2*(G12-G13)-T3*(F21+10.*F22-6.*F23-16.*F24+5.*CONF 244
1.*F25+6.*F26)-T4*(4.*F11-24.*F13+8.*F14+12.*F15)+T5*(G4-G7)-G1+G6          CONE 245
T(6,6)=H1*(4.*F11+12.*F12+9.*F13-4.*F14-6.*F15+F17)+H2*(4.*F31+12.*CONF 246
1.*F32+9.*F33-4.*F34-6.*F35+F37)-H3*(-12.*F21+18.*F22-12.*F23-24.*F24CONF 247
2+6.*F26)-12.*H4*(-2.*F12-3.*F13+F15)+G3          CONE 248
T(6,7)=T1*(G9+G10)+T2*(G12+G13)-T3*(F21-10.*F22-6.*F23+16.*F24+5.*CONF 249
1.*F25-6.*F26)-T4*(-4.*F11+24.*F13+8.*F14-12.*F15)-T5*(G4+G7)-G1+G5          CONF 250
T(6,8)=T1*(-2.*F11-5.*F12-F13+6.*F14+4.*F15-F16-F17)+T2*(-2.*F31-5CONF 251
1.*F32-F33+6.*F34+4.*F35-F36+F37)-T3*(-5.*F21-2.*F22+18.*F23+16.*F2CONF 252
24-5.*F25-6.*F26)-T4*(4.*F11+24.*F12+24.*F13-8.*F14-12.*F15)+T5*(G7CONF 253
3-G4)+G1-G6          CONE 254
T(7,7)=U1*(G8-2.*G9)+U2*(G11-2.*G12)-U3*(-2.*F21-2.*F22+12.*F23-4.*CONF 255
1.*F24-10.*F25+6.*F26)-U4*(-4.*F11+16.*F12-8.*F13-16.*F14+12.*F15)+UCONF 256
25*(F11+4.*F12-2.*F13-12.*F14+9.*F15)+G2+U7*(4.*F8-24.*F9+36.*F10) CONF 257
T(7,8)=U1*(-F11+3.*F13-3.*F15+F17)+U2*(-F31+3.*F33-3.*F35+F37)-U3*CONF 258
16.*F22-2.*F24+F26)-U4*(4.*F11-16.*F13+12.*F15)+U5*(F11-10.*F13+9.*CONF 259
2*F15)+U7*(-4.*F8+36.*F10)          CONE 260
T(8,8)=U1*(G8+2.*G9)+U2*(G11+2.*G12)-U3*(2.*F21-2.*F22-12.*F23-4.*CONF 261
1.*F24+10.*F25+6.*F26)-U4*(-4.*F11-16.*F12-8.*F13+16.*F14+12.*F15)+U5CONF 262
2*(F11-4.*F12-2.*F13+12.*F14+9.*F15)-G2+U7*(4.*F8+24.*F9+36.*F10) CONF 263
FAC=0.25*TETAC*S12          CONE 264
DO 50 I=1,8                  CONE 265
DO 50 J=I,8                  CONE 266
T(I,J)=FAC*T(I,J)          CONE 267
50 T(J,I)=T(I,J)          CONE 268
C                                     CONE 269
C                                     CONE 270
C TRANSFORMATION TO GLOBAL COORDINATES          CONE 271
C                                     CONE 272
DO 60 I=1,8                  CONE 273
TX=T(I,1)                      CONE 274
T(I,1)=T(I,3)*C+T(I,5)*S      CONE 275
TY=T(I,2)                      CONE 276
T(I,2)=T(I,3)*S-T(I,5)*C      CONE 277
T(I,3)=-T(I,7)                  CONE 278

```

```

T(I,5)=T(I,4)*C+T(I,6)*S
T(I,6)=T(I,4)*S-T(I,6)*C
T(I,4)=TX
T(I,7)=-T(I,8)
60 T(I,8)=TY
DO 70 I=1,8
TX=T(1,I)
T(1,I)=T(3,I)*C+T(5,I)*S
TY=T(2,I)
T(2,I)=T(3,I)*S-T(5,I)*C
T(3,I)=-T(7,I)
T(5,I)=T(4,I)*C+T(6,I)*S
T(6,I)=T(4,I)*S-T(6,I)*C
T(4,I)=TX
T(7,I)=-T(8,I)
70 T(8,I)=TY
RETURN
END

```

CONE	279
CONE	280
CONE	281
CONE	282
CONE	283
CONE	284
CONE	285
CONE	286
CONE	287
CONE	288
CONE	289
CONE	290
CONE	291
CONE	292
CONE	293
CONE	294
CONE	295
CONE	296

```

      SUBROUTINE LOADS (I,J,HI,HJ,VI,VJ,R1,R2,S12,S,C,PTOT)
C
C THIS SUBROUTINE TRANSFORMS DISTRIBUTED SURFACE LOADS INTO
C CONSISTENT NODAL LOADS AND ADDS THEM INTO THE LOAD VECTOR
C
COMMON TETAO
EQUIVALENCE (TETAO,T)
DIMENSION PTOT(1)
A=.5*(R2-R1)
B=.5*(R2+R1)
P=S12*T/120.
RVI=P#10.*((2.*B-A)*HI+P*HJ)
RVJ=P#10.*((B*HI+(2.*B+A)*HJ)
RWI=P*((21.*B-11.*A)*VI+(9.*B-A)*VJ)
RWJ=P*((9.*B+A)*VI+(21.*B+11.*A)*VJ)
RTI=P*S12*((3.*B-A)*VI+2.*B*VJ)
RTJ=-P*S12*(2.*B*VI+(3.*B+A)*VJ)
K=I#4-4
L=J#4-4
PTOT(K+1)=PTOT(K+1)+RVI*C+RWI*S
PTOT(K+2)=PTOT(K+2)+RVI*S-RWI*C
PTOT(K+3)=PTOT(K+3)-RTI
PTOT(L+1)=PTOT(L+1)+RVJ*C+RWJ*S
PTOT(L+2)=PTOT(L+2)+RVJ*S-RWJ*C
PTOT(L+3)=PTOT(L+3)-RTJ
RETURN
END
      LOAD 1
      LOAD 2
      LOAD 3
      LOAD 4
      LCAD 5
      LOAD 6
      LOAD 7
      LOAD 8
      LOAD 9
      LOAD 10
      LOAD 11
      LOAD 12
      LOAD 13
      LOAD 14
      LOAD 15
      LOAD 16
      LOAD 17
      LOAD 18
      LOAD 19
      LCAD 20
      LOAD 21
      LOAD 22
      LOAD 23
      LOAD 24
      LOAD 25
      LOAD 26
      LOAD 27

```

```

SUBROUTINE BANSOL (A,B,NBL,NEQ,MBAND,KKK)                                BANS  1
C
C ***** IN-CORE EQUATION SOLVER FOR BANDED, SYMMETRIC, POSITIVE DEFINITE BANS  2
C SYSTEMS, TAKING ACCOUNT OF VARIABLE BAND WIDTH AND AN ARBITRARY BANS  3
C NUMBER OF LOAD VECTORS.                                                 BANS  4
C
C          - INPUT -
C A(NEQ*MBAND) - UPPER HALF OF RECTIFIED COEFFICIENT MATRIX BAND      BANS  5
C           IN ONE-DIMENSIONAL FORM                                         BANS  6
C B(NEQ)       - SINGLE LOAD VECTOR                                       BANS  7
C NEQ          - NUMBER OF EQUATIONS                                      BANS  8
C MBAND        - MAXIMUM WIDTH OF HALF BAND                           BANS  9
C KKK          - LOAD CASE INDICATOR, EQUAL TO                         BANS 10
C           1 FOR FIRST LOAD CASE (REDUCTION OF A AND B WITH
C           BACKSUBSTITUTION)                                              BANS 11
C           2 FOR ANY SUBSEQUENT LOAD VECTOR (REDUCTION OF B
C           WITH BACKSUBSTITUTION)                                         BANS 12
C
C          - OUTPUT -
C B(NEQ)       - SOLUTION VECTOR                                         BANS 13
C A(NEQ*MBAND) - REDUCED STIFFNESS MATRIX                           BANS 14
C NBL(NEQ)     - VECTOR DEFINING BAND WIDTH OF EACH EQUATION          BANS 15
C *****                                                       ***** BANS 16
C
C DIMENSION A(1), B(NEQ), NBL(NEQ)                                     BANS 17
C
C NM=NEQ*MBAND
C NE=NEQ-1
C GO TO (10,90), KKK
C
C      DECOMPOSITION OF BAND MATRIX A
C
C 10 DO 80 I=1,NE
C     D=A(I)
C     IF (D) 20,80,30
C 20 PRINT 150, I,D
C
C      ESTABLISH VARIABLE BAND WIDTH
C
C 30 DO 40 J=NEQ,NM,NEQ
C     IF (A(NM-J+I).NE.0.0) GO TO 50
C 40 CONTINUE
C 50 NBL(I)=NM-J+I
C
C      REDUCTION OF MATRIX A
C
C JL=I+1
C II=I
C MAX=NBL(I)
C JH=(MAX-1)/NEQ+I
C DO 70 J=JL,JH
C     II=II+NEQ
C     C=A(II)/D
C

```

```

IF (C.EQ.0.0) GO TO 70                                RANS 55
KK=J
DO 60 JJ=II,MAX,NEQ                                    BANS 56
A(KK)=A(KK)-C*A(JJ)                                  BANS 57
60 KK=KK+NEQ                                         BANS 58
70 A(II)=C                                         BANS 59
80 CONTINUE                                         BANS 60
C
C      REDUCTION OF LOAD VECTOR B
C
90 DO 110 I=1,NE                                      BANS 61
IF (A(I).EQ.0.0) GO TO 110                           BANS 62
MAX=JL=I+1                                           BANS 63
II=I
JH=(NBL(I)-1)/NEQ+I                                 BANS 64
C=B(I)
IF (C.EQ.0.0) GO TO 110                           BANS 65
DO 100 J=JL,JH                                     BANS 66
II=II+NEQ                                         BANS 67
100 B(J)=B(J)-C*A(II)                               BANS 68
B(I)=B(I)/A(I)                                     BANS 69
110 CONTINUE                                         BANS 70
IF (A(NEQ).EQ.0.0) GO TO 120                         BANS 71
B(NEQ)=B(NEQ)/A(NEQ)                                BANS 72
C
C      SOLUTION BY BACKSUBSTITUTION
C
120 DO 140 I=1,NE                                      BANS 73
JI=NEQ-I
IF (A(JI).EQ.0.0) GO TO 140                         BANS 74
IL=JI+NEQ                                         BANS 75
MAX=NBL(JI)                                         BANS 76
C=B(JI)
JN=JI+1
DO 130 II=IL,MAX,NEQ                                BANS 77
C=C-A(II)*B(JN)                                     BANS 78
130 JN=JN+1                                         BANS 79
B(JI)=C                                         BANS 80
140 CONTINUE                                         BANS 81
RETURN
C
150 FORMAT (//20H PIVOT IS NEGATIVE /26H DIAGONAL TERM OF EQUATION I,BANS 82
18H EQUALS E20.6//)                                   BANS 83
END

```

## OVERLAY(MASTER,2,0)

PROGRAM FORMF

```

C      FORM 1
C      FORM 2
C ***** FORM 3
C FORM THE FLEXIBILITY MATRIX (FMAT) DUE TO RESTRAINING FORCES FROM FORM 4
C THE DIAPHRAGMS OR BENTS FORM 5
C ***** FORM 6
C FORM 7
C COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,FORM 8
C 1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)FORM 9
C 2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60) FORM 10
C COMMON /FOLD/ FMAT(120,120),DINP(120),L1,L2,DISP(80,81) FORM 11
C FORM 12
C DIMENSION SINKX(12), D(12) FORM 13
C FORM 14
C INITIATION AND SET F MATRIX = 0 FORM 15
C FORM 16
C KK=MPC*NDIAPH FORM 17
C DO 10 I=1,KK FORM 18
C DINP(I)=0. FORM 19
C DO 10 J=1,KK FORM 20
C 10 FMAT(I,J)=0.0 FORM 21
C REWIND 3 FORM 22
C FORM 23
C CYCLE FOR EACH HARMONIC IS INITIATED FORM 24
C FORM 25
C DO 50 NN=N1,MHARM,N2 FORM 26
C FN=NN FORM 27
C FK=FN*PI/TETAO FORM 28
C FORM 29
C FIND UNIT LOADS# COEFFICIENTS AND HARMONIC MULTIPLIERS FORM 30
C FORM 31
C DO 40 I=1,NDIAPH FORM 32
C S=SIN(FK*DIAPHX(I)) FORM 33
C IF (DIADEL(I)) 30,30,20 FORM 34
C 20 XX=FK*DIADEL(I)/2. FORM 35
C D(I)=2./(XX*R*TETAO)*SIN(XX)*S FORM 36
C GO TO 40 FORM 37
C 30 XX=2./(TETAO*R) FORM 38
C D(I)=XX*S FORM 39
C 40 SINKX(I)=S FORM 40
C FORM 41
C READ DISP FROM TAPE 3 FORM 42
C FORM 43
C READ (3) ((DISP(I,J),I=1,MX),J=1,MPC1) FORM 44
C FORM 45
C CALCULATE AND SUM UP FMAT AND DINP MATRICES FORM 46
C FORM 47
C CALL SIMSUM (SINKX,D) FORM 48
C 50 CONTINUE FORM 49
C CALL CORFI FORM 50
C RETURN FORM 51
C END FORM 52

```

```

SUBROUTINE SIMSUM (SINKX,D)
C
C ***** CALCULATE AND SUM UP FMAT AND DINP MATRICES *****
C ***** SIMS ***** 1
C ***** SIMS ***** 2
C ***** SIMS ***** 3
C ***** SIMS ***** 4
C ***** SIMS ***** 5
C ***** SIMS ***** 6
C ***** SIMS ***** 7
C ***** SIMS ***** 8
C ***** SIMS ***** 9
C ***** SIMS ***** 10
C ***** SIMS ***** 11
C ***** SIMS ***** 12
C ***** SIMS ***** 13
C ***** SIMS ***** 14
C ***** SIMS ***** 15
C ***** SIMS ***** 16
C ***** SIMS ***** 17
C ***** SIMS ***** 18
C ***** SIMS ***** 19
C ***** SIMS ***** 20
C ***** SIMS ***** 21
C ***** SIMS ***** 22
C ***** SIMS ***** 23
C ***** SIMS ***** 24
C ***** SIMS ***** 25
C ***** SIMS ***** 26
C ***** SIMS ***** 27
C ***** SIMS ***** 28
C ***** SIMS ***** 29
C ***** SIMS ***** 30
C ***** SIMS ***** 31
C ***** SIMS ***** 32
C ***** SIMS ***** 33
C ***** SIMS ***** 34
C ***** SIMS ***** 35
C ***** SIMS ***** 36
C ***** SIMS ***** 37
C ***** SIMS ***** 38
C ***** SIMS ***** 39
C ***** SIMS ***** 40
C ***** SIMS ***** 41
C ***** SIMS ***** 42
C ***** SIMS ***** 43
C ***** SIMS ***** 44
C ***** SIMS ***** 45
C ***** SIMS ***** 46
C ***** SIMS ***** 47
C
COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDIMS
1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)SIMS
2,KDTP(12),CHPLRE,MPC1,MFCOL,MPC,INDMP(60)SIMS
3COMMON /FOLD/ FMAT(120,120),DINP(120),L1,L2,DISP(80,81)SIMS
4DIMENSION SINKX(12), D(12)SIMS
5
C
10 DO 20 I=1,MPCOL
6      K=INDMP(I)
7      DO 20 J=1,MPC1
8          DISP(I,J)=DISP(K,J)
9
C
10 IF (NDIAPH.EQ.1) GO TO 50
11 DO 30 L=2,NDIAPH
12      C=SINKX(L)
13      C1=SINKX(1)*D(L)
14      C2=SINKX(L)*D(1)
15      M=(L-1)*MPCOL
16      DO 30 I=1,MPCOL
17          K=M+I
18          DINP(K)=DINP(K)+DISP(I,MPC1)*C
19      DO 30 J=1,MPCOL
20          FMAT(K,J)=FMAT(K,J)+DISP(I,J)*C2
21
30 FMAT(J,K)=FMAT(J,K)+DISP(J,I)*C1
22
23 DO 40 M=2,NDIAPH
24      IM=(M-1)*MPCOL
25      DO 40 N=2,NDIAPH
26          IN=(N-1)*MPCOL
27          C=SINKX(M)*D(N)
28          DO 40 I=1,MPCOL
29              K=IM+I
30              DO 40 J=1,MPCOL
31                  L=IN+J
32                  DINP(K,L)=DINP(K,L)+DISP(I,J)*C
33
34 50 C=SINKX(1)*D(1)
35      C1=SINKX(1)
36      DO 60 I=1,MPCOL
37          DINP(I)=DINP(I)+DISP(I,MPC1)*C1
38
39 60 FMAT(I,J)=FMAT(I,J)+DISP(I,J)*C
40
41 RETURN
42
43 END

```

```

SUBROUTINE CORFI
*****FIND THE TRANSFORMED FMAT AND DINP MATRICES*****
COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD,COMMON
1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)COMMON
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60)COMMON /FOLD/ FMAT(120,120),DINP(120),L1,L2,DISP(80,81)COMMON /CASE/ AJP(80),LCASE(4,20),JFOR(3,20),XORD(20),YORD(20)COMMON /FXDM/ IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),XDCOR1
100(120),BF(3,120),IT
DIMENSION JNUM(2), B(3,120), KB12(3), SD(3), BT(3,120), SFM(3,120)
1 , KK(3)

EQUIVALENCE (JNUM(1),JN1), (SFM,BT)

PRINT INITIAL DISPLACEMENTS
K=MPC*NDIAPH
PRINT 760, (I,DINP(I),I=1,K)

CHANGE SIGN OF INITIAL DISPLACEMENTS
DO 10 I=1,K
10 DINP(I)=-DINP(I)

CHECK DIAPHRAGMS WHICH ARE EXTERNALLY SUPPORTED
II=0
DO 20 I=1,NDIAPH
IF (KODIA(I).EQ.2.OR.KODIA(I).EQ.4) GO TO 20
II=II+1
NDIA(II)=I
20 CONTINUE

CHECK IF ALL DIAPHRAGMS ARE EXTERNALLY SUPPORTED
IF ( II.EQ.NDIAPH ) GO TO 730

GENERATING INITIAL CONNECTIONS
KK(1)=0
KK(2)=0
KK(3)=0
DO 30 I=1,NJT
DO 30 J=1,3
IF (LCASE(J,I).EQ.4) GO TO 40
30 CONTINUE
GO TO 80
40 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 60
JJ=J+1
DO 50 LB=JJ,3
IF (LCASE(LB,I).EQ.4) KK(LB)=1
50 CONTINUE
60 II=I+1
DO 70 IB=II,NJT
DO 70 LD=1,3
IF (LCASE(LD,IR).EQ.4) KK(LD)=1
70 CONTINUE
IF (KK(1)*KK(2)*KK(3).EQ.1) GO TO 730
GO TO 170
C
80 DO 90 I=1,NJT
IF (JFOR(2,I).EQ.0) GO TO 100
90 CONTINUE
100 JN1=I
JJ=JN1+1
C1=XORD(JN1)
CT=0.
IC(2,1)=1
JN2=JJ
IF (JFOR(1,JN1).EQ.0) GO TO 120
IC(1,1)=0
DO 110 I=JJ,NJT
IF (JFOR(1,I).NE.0.OR.JFOR(2,I).NE.0) GO TO 110
CT1=ABS(XORD(I)-C1)
IF (CT1.LE.CT) GO TO 110
CT=CT1
JN2=I
110 CONTINUE
GO TO 140
120 IC(1,1)=1
DO 130 I=JJ,NJT
IF (JFOR(2,I).NE.0) GO TO 130
CT1=ABS(XORD(I)-C1)
IF (CT1.LE.CT) GO TO 130
CT=CT1
JN2=I
130 CONTINUE
140 IC(2,2)=1
IF (IC(1,1).EQ.1) GO TO 150
IC(1,2)=1
C2=YORD(JN2)
GO TO 160
150 IC(1,2)=0
C2=YORD(JN1)
160 IC(3,1)=0
IC(3,2)=0
IBTYPE=2
GO TO 290
      COR1  55
      COR1  56
      COR1  57
      COR1  58
      COR1  59
      COR1  60
      COR1  61
      COR1  62
      COR1  63
      COR1  64
      COR1  65
      COR1  66
      COR1  67
      COR1  68
      COR1  69
      COR1  70
      COR1  71
      COR1  72
      COR1  73
      COR1  74
      COR1  75
      COR1  76
      COR1  77
      COR1  78
      COR1  79
      COR1  80
      COR1  81
      COR1  82
      COR1  83
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      COR1  86
      COR1  87
      COR1  88
      COR1  89
      COR1  90
      COR1  91
      COR1  92
      COR1  93
      COR1  94
      COR1  95
      COR1  96
      COR1  97
      COR1  98
      COR1  99
      COR1 100
      COR1 101
      COR1 102
      COR1 103
      COR1 104
      COR1 105
      COR1 106
      COR1 107
      COR1 108
      COR1 109
      COR1 110

```

```

C
C      TO FORM TRANSFORMATION MATRIX
C
170 IBTYPE=1
C1=XORD(JN1)
C2=YORD(JN1)
I=0
DO 180 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
180 B(3,J2)=-1.
DO 190 I=1,MPCOL
J=INDMP(I)
DO 190 K=1,3
190 B(K,I)=B(K,J)

C
K=0
DO 220 I=1,NJT
IF (I-JN1) 200,230,200
200 DO 220 J=1,3
IF (JFOR(J,I)) 220,210,220
210 K=K+1
INDB(K)=K
220 CONTINUE
230 KB=0
L=K
DO 280 J=1,3
IF (JFOR(J,JN1)) 280,240,280
240 L=L+1
IF (IC(J,1)) 260,250,250
250 K=K+1
INDB(K)=L
GO TO 280
260 KB=KB+1
KB12(KB)=L
DO 270 M=1,MPC
270 B(KB,M)=B(J,M)
280 CONTINUE
GO TO 490
C
C
290 CC=XORD(JN2)-C1
IF (ABS(CC).LE.0.00001) GO TO 300
C=1./CC
GO TO 310
300 JN2=0
IC(1,1)=1
          COR1 111
          COR1 112
          COR1 113
          COR1 114
          COR1 115
          COR1 116
          COR1 117
          COR1 118
          COR1 119
          COR1 120
          COR1 121
          COR1 122
          COR1 123
          COR1 124
          COR1 125
          COR1 126
          COR1 127
          COR1 128
          COR1 129
          COR1 130
          COR1 131
          COR1 132
          COR1 133
          COR1 134
          COR1 135
          COR1 136
          COR1 137
          COR1 138
          COR1 139
          COR1 140
          COR1 141
          COR1 142
          COR1 143
          COR1 144
          COR1 145
          COR1 146
          COR1 147
          COR1 148
          COR1 149
          COR1 150
          COR1 151
          COR1 152
          COR1 153
          COR1 154
          COR1 155
          COR1 156
          COR1 157
          COR1 158
          COR1 159
          COR1 160
          COR1 161
          COR1 162
          COR1 163
          COR1 164
          COR1 165
          COR1 166

```

```

      IC(2,1)=1          COR1 167
      IC(3,1)=1          COR1 168
      GO TO 170          COR1 169
      C
      310 I=0             COR1 170
      DO 330 J=1,MX,4    COR1 171
      I=I+1              COR1 172
      J1=J+1              COR1 173
      C
      J2=J+2              COR1 174
      BT(2,J)=-(YORD(I)-C2)*C  COR1 175
      RT(2,J1)=-(XORD(I)-C1)*C  COR1 176
      GO TO (330,320), IBTYPE  COR1 177
      C
      320 BT(3,J)=-1.     COR1 178
      BT(1,J)=-BT(2,J)     COR1 179
      BT(1,J1)=-BT(2,J1)-1.  COR1 180
      BT(3,J1)=0.          COR1 181
      BT(1,J2)=-C          COR1 182
      BT(2,J2)=C          COR1 183
      330 BT(3,J2)=0.     COR1 184
      DO 340 I=1,MPCOL   COR1 185
      J=INDMP(I)          COR1 186
      DO 340 K=1,3        COR1 187
      340 BT(K,I)=BT(K,J)  COR1 188
      C
      K=0                COR1 189
      L=0                COR1 190
      KB=0               COR1 191
      II=1               COR1 192
      DO 480 IT=1,2       COR1 193
      IJ=JNUM(IT)         COR1 194
      DO 370 I=II,NJT    COR1 195
      IF (I-IJ) 350,380,350  COR1 196
      350 DO 370 J=1,3    COR1 197
      IF (JFOR(J,I)) 370,360,370  COR1 198
      360 L=L+1           COR1 199
      K=K+1              COR1 200
      INDB(K)=L           COR1 201
      370 CONTINUE        COR1 202
      380 DO 470 J=1,3    COR1 203
      IF (JFOR(J,IJ)) 470,390,470  COR1 204
      390 L=L+1           COR1 205
      IF (IC(J,IT)) 410,400,410  COR1 206
      400 K=K+1           COR1 207
      INDB(K)=L           COR1 208
      GO TO 470           COR1 209
      410 KB=KB+1         COR1 210
      KB12(KB)=L          COR1 211
      GO TO (470,420), IBTYPE  COR1 212
      C
      420 GO TO (430,450), J  COR1 213
      430 DO 440 M=1,MPC   COR1 214
      440 B(KB,M)=BT(3,M)  COR1 215
      GO TO 470           COR1 216
      450 DO 460 M=1,MPC   COR1 217
      460 B(KB,M)=BT(IT,M) COR1 218

```

```

470 CONTINUE
    II=JN1+1
480 CONTINUE
C
490 MBCOL=MPC-KB
    IF (K-MBCOL) 500,520,500
500 K=K+1
    DO 510 I=K,MBCOL
        J=I+KB
510 INDB(I)=J
    DO 530 I=1,MBCOL
        J=INDB(I)
        DO 530 K=1,KB
530 E(K,I)=B(K,J)
C
C FIND B TRANSPOSE * FMAT AND B TRANSPOSE * DINP
C
IT=NDIA*PH*MPC
II=1
DO 550 I=1,NDIA
    IF (II-NDIA(I)) 560,540,560
540 II=II+1
550 KTEM(I+1)=MPC*I
C
560 IJ=(II-1)*MPC
IK=II
IL=IJ
DO 650 IS=II,NDIA
    IF (NDIA(IK)-IS) 600,570,600
C
570 IK=IK+1
DO 590 J=1,MPC
    K=J+IJ
    M=J+IL
    DO 580 L=1,IT
580 FMAT(K,L)=FMAT(M,L)
590 DINP(K)=DINP(M)
    TJ=IJ+MPC
    GO TO 640
C
600 DO 610 I=1,KB
    J=KB12(I)+IL
    SD(I)=DINP(J)
    DO 610 K=1,IT
610 SFM(I,K)=FMAT(J,K)
C
    DO 630 I=1,MBCOL
        M=I+IJ
        K=INDB(I)+IL
        DO 620 J=1,IT
        FMAT(M,J)=FMAT(K,J)
        DO 620 L=1,KB
620 FMAT(M,J)=FMAT(M,J)+B(L,I)*SFM(L,J)
        DINP(M)=DINP(K)
        DO 630 L=1,KB
630 DINP(M)=DINP(M)+B(L,I)*SD(L)

```

COR1 223  
COR1 224  
COR1 225  
COR1 226  
COR1 227  
COR1 228  
COR1 229  
COR1 230  
COR1 231  
COR1 232  
COR1 233  
COR1 234  
COR1 235  
COR1 236  
COR1 237  
COR1 238  
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COR1 268  
COR1 269  
COR1 270  
COR1 271  
COR1 272  
COR1 273  
COR1 274  
COR1 275  
COR1 276  
COR1 277  
COR1 278

```

      IJ=IJ+MBCOL
  640 IL=IL+MPC
      KTEM(IS+1)=IJ
  650 CONTINUE
      KTEM(1)=0
C
C FIND B TRANSPOSE* FMAT * B
C
      IT=IJ
      IJ=(II-1)*MPC
      IL=IJ
      IK=II
      DO 720 IS=II,NDIAPH
      IF (NDIA(IK)-IS) 680,660,680
C
      660 IK=IK+1
      DO 670 J=1,MPC
      K=J+IJ
      M=J+IL
      DO 670 L=1,IT
      670 FMAT(L,K)=FMAT(L,M)
      IJ=IJ+MPC
      GO TO 710
C
      680 DO 690 I=1,KB
      J=KB12(I)+IL
      DO 690 K=1,IT
      690 SFM(I,K)=FMAT(K,J)
C
      DO 700 I=1,MBCOL
      M=I+IJ
      K=INDB(I)+IL
      DO 700 J=1,IT
      FMAT(J,M)=FMAT(J,K)
      DO 700 L=1,KB
      700 FMAT(J,M)=FMAT(J,M)+SFM(L,J)*B(L,I)
      IJ=IJ+MBCOL
      710 IL=IL+MPC
      720 CONTINUE
      GO TO 750
      730 IT=NDIAPH*MPC
      DO 740 I=1,NDIAPH
      KTEM(I)=(I-1)*MPC
      KTEM(NDIAPH+1)=IT
C
C SAVE INFORMATION ON TAPE 1
C
      750 REWIND 1
      WRITE (1) ((FMAT(I,J),I=1,IT),J=1,IT),(DINP(I),I=1,IT),KB12,B,KB
      RETURN
C
      760 FORMAT (////4E14.4 INITIAL DISPLACEMENTS AT POINTS OF RESTRAINT/(I4,ECOR1 330
     117.8,4(I7,E17.8)))
      END
      DATA
      DATA
      DATA

```

COR1 279  
COR1 280  
COR1 281  
COR1 282  
COR1 283  
COR1 284  
COR1 285  
COR1 286  
COR1 287  
COR1 288  
COR1 289  
COR1 290  
COR1 291  
COR1 292  
COR1 293  
COR1 294  
COR1 295  
COR1 296  
CCR1 297  
COR1 298  
COR1 299  
COR1 300  
COR1 301  
COR1 302  
COR1 303  
COR1 304  
COR1 305  
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COR1 307  
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COR1 320  
COR1 321  
COR1 322  
COR1 323  
COR1 324  
COR1 325  
COR1 326  
COR1 327  
COR1 328  
COR1 329  
COR1 330  
COR1 331  
COR1 332

## OVERLAY (MASTER, 3, 0)

## PROGRAM FRAME

```

C ***** FRAM 1
C ***** FRAM 2
C ***** FRAM 3
C ***** FRAM 4
C ***** FRAM 5
C ***** FRAM 6
C ***** FRAM 7
C ***** FRAM 8
C ***** FRAM 9
C ***** FRAM 10
C ***** FRAM 11
C ***** FRAM 12
C ***** FRAM 13
C ***** FRAM 14
C ***** FRAM 15
C ***** FRAM 16
C ***** FRAM 17
C ***** FRAM 18
C ***** FRAM 19
C ***** FRAM 20
C ***** FRAM 21
C ***** FRAM 22
C ***** FRAM 23
C ***** FRAM 24
C ***** FRAM 25
C ***** FRAM 26
C ***** FRAM 27
C ***** FRAM 28
C ***** FRAM 29
C ***** FRAM 30
C ***** FRAM 31
C ***** FRAM 32
C ***** FRAM 33
C ***** FRAM 34
C ***** FRAM 35
C ***** FRAM 36
C ***** FRAM 37
C ***** FRAM 38
C ***** FRAM 39
C ***** FRAM 40
C ***** FRAM 41
C ***** FRAM 42
C ***** FRAM 43
C ***** FRAM 44
C ***** FRAM 45
C ***** FRAM 46
C ***** FRAM 47
C ***** FRAM 48
C ***** FRAM 49
C ***** FRAM 50
C ***** FRAM 51
C ***** FRAM 52
C ***** FRAM 53

COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDFRAM
1,KFOR,10,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KDDIA(12)FRAM
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60)
COMMON /CASE/ AJP(80),LCASE(4,20),JFOR(3,20),XORD(20),YORD(20) FRAM
COMMON /PARAM/ NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(FRAM
18),NUSPRG(8),NPT(8),NPR(80)
COMMON /FBENT/ EFM(10),G(10),LM(6),SA(6,6),ASA(6,6),T(3,3),S(6,6),FRAM
1RF(6),JK(3),NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(FRAM
280),COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),NPQ(80)FRAM
3),NFP(80),A(120,120)
DIMENSION HHH(14400), LSIZE(8)
EQUIVALENCE (HHH,A)

READ AND PRINT CONTROL DATA
C ***** FRAM 21
C ***** FRAM 22
WRITE (6,320)
REWIND 4
REWIND 7
REWIND 9
DO 140 MCOUNT=1,NBT
READ (5,330) NFT,NUMEL,NUMNP,NUMMAT,NUMETP,NUMSPR
WRITE (6,380) NFT,NUMEL,NUMNP,NUMMAT,NUMETP,NUMSPR
C ***** FRAM 23
C ***** FRAM 24
C ***** FRAM 25
C ***** FRAM 26
C ***** FRAM 27
C ***** FRAM 28
C ***** FRAM 29
C ***** FRAM 30
C ***** FRAM 31
C ***** FRAM 32
C ***** FRAM 33
C ***** FRAM 34
C ***** FRAM 35
C ***** FRAM 36
C ***** FRAM 37
C ***** FRAM 38
C ***** FRAM 39
C ***** FRAM 40
C ***** FRAM 41
C ***** FRAM 42
C ***** FRAM 43
C ***** FRAM 44
C ***** FRAM 45
C ***** FRAM 46
C ***** FRAM 47
C ***** FRAM 48
C ***** FRAM 49
C ***** FRAM 50
C ***** FRAM 51
C ***** FRAM 52
C ***** FRAM 53

READ AND PRINT MATERIAL PROPERTY DATA
C ***** FRAM 30
C ***** FRAM 31
C ***** FRAM 32
C ***** FRAM 33
C ***** FRAM 34
C ***** FRAM 35
C ***** FRAM 36
C ***** FRAM 37
C ***** FRAM 38
C ***** FRAM 39
C ***** FRAM 40
C ***** FRAM 41
C ***** FRAM 42
C ***** FRAM 43
C ***** FRAM 44
C ***** FRAM 45
C ***** FRAM 46
C ***** FRAM 47
C ***** FRAM 48
C ***** FRAM 49
C ***** FRAM 50
C ***** FRAM 51
C ***** FRAM 52
C ***** FRAM 53

READ AND PRINT STIFFNESS OF ELASTIC SUPPORTS
C ***** FRAM 39
C ***** FRAM 40
IF (NUMSPR.EQ.0) GO TO 30
WRITE (6,450)
DO 20 I=1,NUMSPR
READ (5,360) N,(SP(N,J),J=1,3)
20 WRITE (6,460) N,(SP(N,J),J=1,3)
30 CONTINUE
C ***** FRAM 41
C ***** FRAM 42
C ***** FRAM 43
C ***** FRAM 44
C ***** FRAM 45
C ***** FRAM 46
C ***** FRAM 47
C ***** FRAM 48
C ***** FRAM 49
C ***** FRAM 50
C ***** FRAM 51
C ***** FRAM 52
C ***** FRAM 53

READ AND PRINT GEOMETRIC PROPERTIES OF COMMON ELEMENTS.
C ***** FRAM 48
C ***** FRAM 49
WRITE (6,410)
DO 50 I=1,NUMETP
READ (5,350) N,COAX(N),COAY(N),COAAZ(N)
TF ((COAX(N).NE.0.0).AND.(COAAZ(N).NE.0.0)) GO TO 40
C ***** FRAM 50
C ***** FRAM 51
C ***** FRAM 52
C ***** FRAM 53

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```

      WRITE (6,470)
      CALL EXIT
  40 WRITE (6,420) N,COAX(N),COAY(N),COAAZ(N)
  50 CONTINUE
C
C READ AND PRINT NODAL POINT DATA
C
      WRITE (6,430)
      READ (5,370) (N,KODE(N),X(N),Y(N),NPSTP(N),NFP(N),I=1,NUMNP)
      WRITE (6,440) (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 70 N=1,NUMNP
      IF (NFP(N).EQ.0) GO TO 60
      INM=INM+1
      NPQ(INM)=N
      GO TO 70
  60 INK=INK-1
      NPQ(INK)=N
  70 CONTINUE
      DO 90 N=2,INM
      NN1=N-1
      DO 80 MM=1,NN1
      M=N-MM
      M1=M+1
      NA=NPQ(M1)
      NB=NPQ(M)
      IF (NFP(NA).GT.NFP(NB)) GO TO 90
      NPQ(M1)=NB
      NPQ(M)=NA
  80 CONTINUE
  90 CONTINUE
      DO 100 I=1,NUMNP
      J=NPQ(I)
      NPR(J)=I
  100 CONTINUE
C
C SET UP ID ARRAY(ROW NC. OF DEGREES OF FREEDOM ELIMINATED)
C
      NP=0
      DO 110 N=1,INM
      NA=NPQ(N)
      NR=NFP(NA)
      NN1=N-1
      DO 110 M=1,3
      IF (JFOR(M,NB).EQ.0) GO TO 110
      NP=NP+1
      ID(NP)=3*NN1+M
  110 CONTINUE
      INM1=INM+1
      DO 120 N=INM1,NUMNP
      NN1=N-1
      DO 120 M=1,3

```

FRAM 54  
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FRAM 100  
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FRAM 103  
FRAM 104  
FRAM 105  
FRAM 106  
FRAM 107  
FRAM 108  
FRAM 109

```

NP=NP+1                               FRAM 110
ID(NP)=3*NN1+M                         FRAM 111
120 CONTINUE                           FRAM 112
C
C   FORM STIFFNESS FOR EACH ELEMENT    FRAM 113
C
REWIND 2                               FRAM 114
CALL ELSTIF                            FRAM 115
C
C   ADD ELEMENT STIFFNESS TO STRUCTURE STIFFNESS   FRAM 116
C
CALL STIFF (A,120)                      FRAM 117
C
C   STATIC CONDENSATION                 FRAM 118
C
CALL STACON (A, ID, IQ, NEQ, 120, NP)   FRAM 119
C
C   STORE ELASTIC SUPPORT DATA ON TAPE 4   FRAM 120
C
IF (NUMSPR.EQ.0) GO TO 130             FRAM 121
WRITE (4) (NPSTP(I),I=1,NUMNP)        FRAM 122
WRITE (4) ((SP(I,J),I=1,NUMSPR),J=1,3)  FRAM 123
C
C   INVERSE THE STIFFNESS MATRIX       FRAM 124
C
130 NMAX=NEQ-NP                        FRAM 125
CALL SYMINV (A,NMAX,120)              FRAM 126
C
C   STORE THE FLEXIBILITY MATRIX ON TAPE 9   FRAM 127
C
WRITE (9) ((A(I,J),J=1,NMAX),I=1,NMAX)  FRAM 128
NUMELT(NFT)=NUMEL                     FRAM 129
NUMNPT(NFT)=NUMNP                     FRAM 130
NEQN(NFT)=NEQ                        FRAM 131
NUSPRG(NFT)=NUMSPR                   FRAM 132
NPT(NFT)=NP                          FRAM 133
C
140 CONTINUE                           FRAM 134
C
C   STORE INFORMATION ACCORDING TO THE SEQUENCE OF THE BENT   FRAM 135
C
REWIND 2                               FRAM 136
REWIND 7                               FRAM 137
DO 160 I=1,NBT                       FRAM 138
NUMEL=NUMELT(I)                      FRAM 139
DO 150 J=1,NUMEL                     FRAM 140
K1=1+(J-1)*87                        FRAM 141
K2=K1+86                             FRAM 142
150 READ (7) (HHH(K),K=K1,K2)         FRAM 143
K3=NUMEL*90                           FRAM 144
WRITE (2) (HHH(K),K=1,K3)             FRAM 145
160 CONTINUE                           FRAM 146
REWIND 7                               FRAM 147
DO 200 I=1,NDIAPH                    FRAM 148
IF (KODIA(I).NE.3) GO TO 200          FRAM 149
REWIND 2                               FRAM 150
IN=KDTP(I)                            FRAM 151

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```

IF (IN.EQ.1) GO TO 180
DO 170 J=2,IN
170 READ (2) HH
180 NUMEL=NUMELT(IN)
K3=NUMEL*87
READ (2) (HHH(K),K=1,K3)
DO 190 L=1,NUMEL
K1=1+(L-1)*87
K2=K1+86
190 WRITE (7) (HHH(K),K=K1,K2)
200 CONTINUE
REWIND 2
REWIND 4
DO 230 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 210 M=1,NP
L2=L2+L1
READ (4) (HHH(J),J=L,L2)
L=L2+1
L1=L1+1
210 CONTINUE
IF (NUMSPR.FQ.0) GO TO 220
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)
220 WRITE (2) (HHH(J),J=1,L2)
LSIZE(I)=L2
230 CONTINUE
REWIND 4
DO 270 I=1,NDIAPH
IF (KDDIA(I).NE.3) GO TO 270
REWIND 2
IN=KDTP(I)
IF (IN.EQ.1) GO TO 250
DO 240 J=2,IN
240 READ (2) HH
250 CONTINUE
ISIZE = LSIZE(IN)
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

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FRAM 166  
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FRAM 218  
FRAM 219  
FRAM 220  
FRAM 221

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      DO 260 M=1,NP
      L2=L2+L1
      WRITE (4) (HHH(J),J=L,L2)
      L=L2+1
260  L1=L1+1
      IF (NUMSPR.EQ.0) GO TO 270
      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)
270  CONTINUE
      REWIND 2
      DO 310 I=1,NDIAPH
      IF (KODIA(I).NE.3) GO TO 310
      REWIND 9
      IN=KDTP(I)
      IF (IN.EQ.1) GO TO 290
      DO 280 J=2,IN
280  READ (9) HH
      290 NMAX=NEQN(IN)-NPT(IN)
      N=NMAX*NMAX
      READ (9) (HHH(J),J=1,N)
      NN1=1
      NN2=NMAX
      DO 300 L=1,NMAX
      WRITE (2) (HHH(J),J=NN1,NN2)
      NN1=NN1+NMAX
300  NN2=NN2+NMAX
310  CONTINUE
      RETURN
      C DATA
      CAADA
      320 FORMAT (37H1FRAME BENT PROGRAM IS TO BE EXECUTED/19H INPUT DATA FOR
      1LLWS)
      330 FORMAT (6I5)
      340 FORMAT (15,E10.0,F10.0)
      350 FORMAT (15,3F10.0)
      360 FORMAT (15,3F10.0)
      370 FORMAT (2I5,2F10.0,2I5)
      380 FORMAT (34H2FRAME BENT TYPE NUMBER           =16/34H NUMBER OF ELEM
      1ENTS           =16/34H NUMBER OF NODAL POINTS           =16/34H FRAM 255
      2NUMBER OF MATERIALS          =16/34H NUMBER OF ELEMENT TYPES           =16/34H FRAM 256
      3           =16/34H NUMBER OF ELASTIC SUPPORT TYPES =16/////
      390 FORMAT (50H1MATERIAL YOUNG S   POISSON S /50H FRAM 257
      1           MCDULUS     RATIO           )           /50H FRAM 258
      400 FORMAT (1H ,15,3X,E13.4,F14.5)
      410 FORMAT (1H1/60H ELEMENT      AXIAL      SHEAR      MOMENT OF
      1           /60H TYPE        AREA       AREA      INERTIA   FRAM 259
      2           )
      420 FORMAT (1H ,15,3X,3F12.3)
      430 FORMAT (1H1,39H FRAME      NODAL COORDINATES /54H ELA
      1STIC SUPPORT    CORRESPONDING NODE /10H NODE CODE,7X, FRAM 260
      21HX,1IX,1HY,20X,4HTYPE,14X,1SHIN FOLDED PLATE)           /54H ELA FRAM 261
      440 FORMAT (1H ,14,I5,2F12.3,2I20)
      450 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 262
      1           )
      460 FORMAT (1H ,14,I5,2F12.3,2I20)
      470 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 263
      1           )
      480 FORMAT (1H ,14,I5,2F12.3,2I20)
      490 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 264
      1           )
      500 FORMAT (1H ,14,I5,2F12.3,2I20)
      510 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 265
      1           )
      520 FORMAT (1H ,14,I5,2F12.3,2I20)
      530 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 266
      1           )
      540 FORMAT (1H ,14,I5,2F12.3,2I20)
      550 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 267
      1           )
      560 FORMAT (1H ,14,I5,2F12.3,2I20)
      570 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 268
      1           )
      580 FORMAT (1H ,14,I5,2F12.3,2I20)
      590 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 269
      1           )
      600 FORMAT (1H ,14,I5,2F12.3,2I20)
      610 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 270
      1           )
      620 FORMAT (1H ,14,I5,2F12.3,2I20)
      630 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 271
      1           )
      640 FORMAT (1H ,14,I5,2F12.3,2I20)
      650 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 272
      1           )
      660 FORMAT (1H ,14,I5,2F12.3,2I20)
      670 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 273
      1           )
      680 FORMAT (1H ,14,I5,2F12.3,2I20)
      690 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 274
      1           )
      700 FORMAT (1H ,14,I5,2F12.3,2I20)
      710 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 275
      1           )
      720 FORMAT (1H ,14,I5,2F12.3,2I20)
      730 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 276
      1           )
      740 FORMAT (1H ,14,I5,2F12.3,2I20)
      750 FORMAT (1H1/60H      SPRING CONSTANTS OF ELASTIC SUPPORTS FRAM 277
      1           )

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1	//60H	LINEAR	LINEAR	ROTATIONAL	FRAM 278
2	/60H	TYPE STIFFNESS X	STIFFNESS Y	STIFFNESS Z	FRAM 279
3	)				FRAM 280

**460 FORMAT (1H ,I4,3F16.3)**

**470 FORMAT (1H0/60H AXIAL AREA OR FLEXURAL INERTIA CANNOT BE SPECIFIED  
1 AS ZERO.)**

**END**

```

      SUBROUTINE ELSTIF
C
C ***** FORM ELEMENT STIFFNESS FOR ONE DIMENSIONAL ELEMENT *****
C
      COMMON /PARAM/ NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(ELST
18),NUSPRG(8),NPT(8),NPR(80)
      COMMON /FBENT/ EFM(10),E(10),LM(6),SA(6,6),ASA(6,6),T(3,3),S(6,6),ELST
1RF(6),JK(3),NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(ELST
280),CDAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IG(120),NPQ(80)ELST
3),NFP(80),A(120,120)
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
      READ AND PRINT ELEMENT DATA
C
      WRITE (6,210)
30     READ (5,200) NEL,NI,NJ,MATTYP,MELTYP,NELKOD
      SIJ=4.0
      SJI=4.0
      CIJ=0.5
      WRITE (6,220) NEL,NI,NJ,MATTYP,MELTYP,NELKOD
C
      AX=COAX(MELTYP)
      AY=COAY(MELTYP)
      AAZ=CDAAZ(MELTYP)
C
      DX=X(NJ)-X(NI)
      DY=Y(NJ)-Y(NI)
      DL=SQRT(DX*DX+DY*DY)
      IF (DL) 40,40,50
40     WRITE (6,240) NEL
      CALL EXIT
50     COSA=DX/DL
      SINA=DY/DL
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
      ELST    1
      ELST    2
      ELST    3
      ELST    4
      ELST    5
      ELST    6
      ELST    7
      ELST    8
      ELST    9
      ELST   10
      ELST   11
      ELST   12
      ELST   13
      ELST   14
      ELST   15
      ELST   16
      ELST   17
      ELST   18
      ELST   19
      ELST   20
      ELST   21
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      ELST   45
      ELST   46
      ELST   47
      ELST   48
      ELST   49
      ELST   50
      ELST   51
      ELST   52
      ELST   53
      ELST   54

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SIJ=SI J*COMM      ELST 55
SJI=SJI*COMM      ELST 56
CIJ=(CIJ-0.5*SHF)/(1.+0.5*SHF)   FLST 57
CJI=CIJ*SI J/SJI    ELST 58
C
C
C FORM GLOBAL TO LOCAL COORDINATE TRANSFORMATION.
C
T(1,1)=COSA      ELST 59
T(1,2)=-SINA     ELST 60
T(2,1)=SINA      ELST 61
T(2,2)=COSA      ELST 62
C
C FORM ELEMENT STIFFNESS IN LOCAL COORDINATES
C
S(1,1)=AX*EFM(MATTYP)/DL      ELST 63
S(4,1)=-S(1,1)      ELST 64
S(3,2)=-SIJ*(1.+CIJ)/DL      ELST 65
S(6,2)=-SJI*(1.+CJI)/DL      ELST 66
S(2,2)=-(S(3,2)+S(6,2))/DL    ELST 67
S(5,2)=-S(2,2)      ELST 68
S(3,3)=SIJ      ELST 69
S(6,3)=CIJ*SIJ      ELST 70
S(5,3)=(S(3,3)+S(6,3))/DL    ELST 71
S(4,4)=S(1,1)      ELST 72
S(5,5)=-S(5,2)      ELST 73
S(6,5)=-S(6,2)      ELST 74
S(6,6)=SJI      ELST 75
DO 60 I=1,5      ELST 76
M=I+1      ELST 77
DO 60 J=M,6      ELST 78
60 S(I,J)=S(J,I)    ELST 79
C
C MODIFY ELEMENT STIFFNESS FOR KNOWN ZERO MEMBER END FORCES
C
IF (NELKOD.EQ.0) GO TO 110      ELST 80
KK=NELKOD      ELST 81
KD=100000      ELST 82
DO 100 I=1,6      ELST 83
IF (KK-KD) 100,70,70      ELST 84
70 SII=S(I,I)      ELST 85
DO 80 N=1,6      ELST 86
80 SA(1,N)=S(I,N)    ELST 87
DO 90 M=1,6      ELST 88
COF=S(M,I)/SII      ELST 89
DO 90 N=1,6      ELST 90
90 S(M,N)=S(M,N)-COF*SA(1,N)    ELST 91
KK=KK-KD      ELST 92
100 KD=KD/10      ELST 93
C
C OBTAIN SA(6,6) RELATING ELEMENT END FORCES (LOCAL) AND JOINT
C DISPLACEMENTS (GLOBAL).
C
110 DO 120 I=1,6      ELST 94
DO 120 J=1,3      ELST 95
SA(I,J)=0.0      ELST 96
      ELST 97
      ELST 98
      ELST 99
      ELST 100
      ELST 101
      ELST 102
      ELST 103
      ELST 104
      ELST 105
      ELST 106
      ELST 107
      ELST 108
      ELST 109
      ELST 110

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SA(I,J+3)=0.0 ELST 111
DO 120 K=1,3 ELST 112
IF (T(K,J).EQ.0.0) GO TO 120 ELST 113
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)
120 CONTINUE ELST 114
C ELST 115
C OBTAIN ELEMENT STIFFNESS ASA(6,6) IN GLOBAL COORDINATES ELST 116
C ELST 117
C DO 130 I=1,3 ELST 118
C DO 130 J=1,6 ELST 119
ASA(I,J)=0.0 ELST 120
ASA(I+3,J)=0.0 ELST 121
DO 130 K=1,3 ELST 122
IF (T(K,I).EQ.0.0) GO TO 130 ELST 123
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)
130 CONTINUE ELST 124
C ELST 125
C FORM LOCAL LOCATION MATRIX FOR ELEMENT ELST 126
C ELST 127
C NMI=NPR(NI) ELST 128
NMJ=NPR(NJ) ELST 129
DO 140 M=1,3 ELST 130
J=M-3 ELST 131
LM(M)=3*NMI+J ELST 132
140 LM(M+3)=3*NMJ+J ELST 133
C ELST 134
C MODIFY GLOBAL STIFFNESS AND BOUNDARY CONDITIONS FOR KNOWN JOINT ELST 135
C DISPLACEMENTS ELST 136
C ELST 137
JK(1)=KODE(NI) ELST 138
JK(2)=KODE(NJ) ELST 139
DO 170 N=1,2 ELST 140
KD=100 ELST 141
KK=JK(N) ELST 142
DO 170 M=1,3 ELST 143
I=3*(N-1)+M ELST 144
II=LM(I) ELST 145
IF (KK-KD) 170,150,150 ELST 146
150 DO 160 K=1,6 ELST 147
ASA(I,K)=0.0 ELST 148
160 ASA(K,I)=0.0 ELST 149
ASA(I,I)=1.0 ELST 150
KK=KK-KD ELST 151
170 KD=KD/10 ELST 152
C ELST 153
C STORE ELEMENT INFORMATION ON TAPE 2 ELST 154
C ELST 155
WRITE (2) LM,SA,ASA,T ELST 156
C ELST 157
WRITE (7) LM,SA,ASA,T ELST 158
IF (NUMEL-NEL) 180,190,30 ELST 159
180 WRITE (6,230) NEL ELST 160
CALL EXIT ELST 161
190 RETURN ELST 162

```

C C  
200 FORMAT (5I5,I10) ELST 167  
210 FORMAT (1H1/60H ELEMENT NODE NODE MATERIAL ELEMENT ELEMENT  
1H1/60H ELEMENT NODE NODE MATERIAL ELEMENT ELEMENT  
2 ) TYPE TYPE CODE ELST 171  
220 FORMAT (1H,,I5,I7,I6,I8,I10,I11) ELST 172  
230 FORMAT (36HOELEMENT CARD ERROR, ELEMENT NUMBER=16) ELST 173  
240 FORMAT (8HOELEMENT,I5,39H HAS ZERO LENGTH. EXECUTION TERMINATED.) ELST 175  
END ELST 176

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SUBROUTINE STIFF (A,ND)          SUBROUTINE STIFF (A,ND)      STIF    1
C                                *****STIFF*****STIF    2
C                                ASSEMBLE THE TOTAL FRAME BENT STIFFNESS MATRIX   STIF    3
C                                *****STIFF*****STIF    4
C                                *****STIFF*****STIF    5
C                                *****STIFF*****STIF    6
C                                COMMON /PARAM/ NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(STIF 7
18),NUSPRG(8),NPT(8),NPR(80)
C                                COMMON /FBENT/ EFM(10),G(10),LM(6),SA(6,6),ASA(6,6),T(3,3),S(6,6),STIF 8
1RF(6),JK(3),NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(STIF 10
280),COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),NPQ(80)STIF 11
3),NFP(80)
C                                DIMENSION A(ND,ND)                      STIF    12
C                                STIF    13
C                                INITIALIZATION                   STIF    14
C                                STIF    15
C                                DO 10 I=1,NEQ                      STIF    16
C                                DO 10 J=1,NEQ                      STIF    17
10 A(I,J)=0.0                  STIF    18
C                                ADD ELEMENT STIFFNESS TO STRUCTURE STIFFNESS   STIF    19
C                                REWIND 2                         STIF    20
DO 30 N=1,NUMEL                STIF    21
READ (2) (LM(I),I=1,87)        STIF    22
DO 20 I=1,6                     STIF    23
II=LM(I)                       STIF    24
DO 20 J=1,6                     STIF    25
JJ=LM(J)                       STIF    26
IF (JJ.LE.0) GO TO 20          STIF    27
A(II,JJ)=A(II,JJ)+ASA(I,J)    STIF    28
20 CONTINUE                      STIF    29
30 CONTINUE                      STIF    30
C                                ADD STIFFNESS OF ELASTIC FOUNDATION TO STRUCTURE STIFFNESS   STIF    31
C                                IF (NUMSPR.EQ.0) GO TO 60          STIF    32
DO 50 J=1,NUMNP                STIF    33
MSPR=NPSTP(J)                  STIF    34
IF (MSPR.EQ.0) GO TO 50        STIF    35
DO 40 K=1,3                     STIF    36
KJ=3*(J-1)+K                  STIF    37
40 A(KJ,1)=A(KJ,1)+SP(MSPR,K)  STIF    38
50 CONTINUE                      STIF    39
60 RETURN                        STIF    40
END                            STIF    41
                                STIF    42
                                STIF    43
                                STIF    44
                                STIF    45
                                STIF    46

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```

SUBROUTINE STACON (A, ID, IQ, N, ND, NP)                                STAC  1
***** STATIC CONDENSATION ROUTINE TO ELIMINATE CERTAIN DEGREES OF      STAC  2
FREEDOM FROM A SYMMETRIC SYSTEM OF EQUATIONS                            STAC  3
***** - INPUT - *****                                                 STAC  4
N - NUMBER OF EQUATIONS                                              STAC  5
NP - NUMBER OF DEGREES OF FREEDOM TO BE ELIMINATED                      STAC  6
ND - NUMBER OF ROWS IN DIMENSION STATEMENT OF MATRIX A                 STAC  7
A - COEFFICIENT MATRIX OF ORDER N                                     STAC  8
B - LOAD VECTOR OF ORDER N                                         STAC  9
ID - ARRAY CONTAINING ROW NUMBERS OF DEGREES OF FREEDOM              STAC 10
TO BE ELIMINATED                                               STAC 11
***** - OUTPUT - *****                                                 STAC 12
A - REDUCED COEFFICIENT MATRIX OF ORDER N-NP                         STAC 13
B - REDUCED LOAD VECTOR OF ORDER N-NP                           STAC 14
IQ - ARRAY CONTAINING SEQUENCE OF UNKNOWNNS IN REDUCED SYSTEM        STAC 15
OF EQUATIONS                                               STAC 16
***** DIMENSION A(ND,N), ID(NP), IQ(N)                                STAC 17
SET UP IQ-ARRAY                                              STAC 18
DO 10 I=1,N
10 IQ(I)=I                                              STAC 19
INTERCHANGE ROWS                                              STAC 20
DO 70 I=1,NP
II=NP-I+1                                              STAC 21
IJ=ID(II)
KI=N-I+1
IF (KI.EQ.IJ) GO TO 70
MKI=KI-1
DO 30 J=1,N
X=A(IJ,J)
DO 20 M=IJ,MKI
ML=M+1
20 A(M,J)=A(ML,J)
30 A(KI,J)=X
INTERCHANGE COLUMNS
DO 50 J=1,N
X=A(J,IJ)
DO 40 M=IJ,MKI
ML=M+1
40 A(J,M)=A(J,ML)
50 A(J,KI)=X
IX=IQ(IJ)

```

STAC 22  
STAC 23  
STAC 24  
STAC 25  
STAC 26  
STAC 27  
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STAC 51  
STAC 52  
STAC 53  
STAC 54

```

DO 60 M=IJ,MKI      STAC 55
ML=M+1               STAC 56
60 IQ(M)=IQ(ML)      STAC 57
IQ(KI)=IX             STAC 58
70 CONTINUE            STAC 59
C STORE IQ ON TAPE 4    STAC 60
C STORE IQ ON TAPE 4    STAC 61
C WRITE (4) (IQ(I),I=1,N)  STAC 62
C WRITE (4) (IQ(I),I=1,N)  STAC 63
C STATIC CONDENSATION   STAC 64
C DO 90 M=1,NP          STAC 65
DO 90 M=1,NP          STAC 66
K=N-M                 STAC 67
L=K+1                 STAC 68
DO 80 I=1,K           STAC 69
A(L,I)=A(L,I)/A(L,L)  STAC 70
DO 80 J=I,K           STAC 71
A(J,I)=A(J,I)-A(L,I)*A(J,L)  STAC 72
80 A(I,J)=A(J,I)      STAC 73
90 CONTINUE            STAC 74
C STORE STIFFNESS COEFF. OF ELIMINATED DEG. OF FREEDOM ON TAPE 4  STAC 75
C DO 100 I=K,N          STAC 76
DO 100 I=K,N          STAC 77
L=I-1                 STAC 78
100 WRITE (4) (A(I,J),J=1,L)  STAC 79
C RETURN                STAC 80
END                   STAC 81
STAC 82
STAC 83
STAC 84
STAC 85

```

## SUBROUTINE SYMINV (A,NMAX,NSIZE)

```

C ***** INVERSE A SYMMETRIC MATRIX *****
C ***** DIMENSION A(NSIZE,NSIZE) *****
C
DO 10 N=1,NMAX
10 A(N,1)=A(1,N)
C
DO 80 N=1,NMAX
PIVOT=A(N,N)
A(N,N)=-1.
DO 20 J=1,NMAX
20 A(N,J)=A(N,J)/PIVOT
DO 70 I=1,NMAX
IF (N-I) 30,70,30
30 IF (A(I,N)) 40,70,40
40 DO 60 J=I,NMAX
IF (N-J) 50,60,50
50 A(I,J)=A(I,J)-A(I,N)*A(N,J)
A(J,I)=A(I,J)
60 CONTINUE
70 CONTINUE
DO 80 I=1,NMAX
80 A(I,N)=A(N,I)
C
DO 90 I=1,NMAX
DO 90 J=1,NMAX
90 A(I,J)=-A(I,J)
RETURN
END

```

	SYMN	1
	SYMN	2
	SYMN	3
	SYMN	4
	SYMN	5
	SYMN	6
	SYMN	7
	SYMN	8
	SYMN	9
	SYMN	10
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	SYMN	31
	SYMN	32
	SYMN	33

```

OVERLAY(MASTER,4,0)
PROGRAM FLEXD          FLEX   1
C *****          FLEX   2
C *****          FLEX   3
C *****          FLEX   4
C *****          FLEX   5
C *****          FLEX   6
C *****          FLEX   7
C *****          FLEX   8
C *****          FLEX   9
C *****          FLEX  10
C *****          FLEX  11
C *****          FLEX  12
C *****          FLEX  13
C *****          FLEX  14
C *****          FLEX  15
C *****          FLEX  16
C *****          FLEX  17
C *****          FLEX  18
C *****          FLEX  19
C *****          FLEX  20
C *****          FLEX  21
C *****          FLEX  22
C *****          FLEX  23
C *****          FLEX  24
C *****          FLEX  25
C *****          FLEX  26
C *****          FLEX  27
C *****          FLEX  28
C *****          FLEX  29
C *****          FLEX  30
C *****          FLEX  31
C *****          FLEX  32
C *****          FLEX  33
C *****          FLEX  34
C *****          FLEX  35
C *****          FLEX  36
C *****          FLEX  37
C *****          FLEX  38
C *****          FLEX  39
C *****          FLEX  40
C *****          FLEX  41
C *****          FLEX  42
C *****          FLEX  43
C *****          FLEX  44
C *****          FLEX  45
C *****          FLEX  46
C *****          FLEX  47
C *****          FLEX  48
C *****          FLEX  49
C *****          FLEX  50
C *****          FLEX  51
C *****          FLEX  52
C *****          FLEX  53

C ANALYZE EACH TYPE OF THE FLEXIBLE MOBILE DIAPHRAGMS BY FORCE
C METHOD. STORE THE FLEXIBILITY MATRICES ON TAPES.
C *****
COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMD          FLEX
1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IA,IAX,DIAPHX(12),DIADEL(12),KODIA(12)          FLEX
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60)                                     FLEX
COMMON /FXDM/ IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),XDFLEX          FLEX
10D(120),BF(3,120)                                                       FLEX
COMMON /PLATE/ XP(14),NPI(30),NPJ(30),KPL(30),NSEC(30),PWTH(30),SIFLEX          FLEX
INEL(30),COSEL(30),Y(30),Z(30),TP(14)                                         FLEX
COMMON /CASE/ AJP(80),LCASE(4,20),JFOR(3,20),XORD(20),YORD(20)          FLEX
DIMENSION FE(3,3), FLE(120,120), TB(3), D1(8), D2(8), D3(8), HHH(1          FLEX
14400)                                                               FLEX
EQUIVALENCE (FLE,HHH)                                         FLEX
READ DIAPHRAGM PROPERTIES                                     FLEX
PRINT 480                                         FLEX
DO 50 I=1,NFMD                                     FLEX
READ 470, IN,MOP                                     FLEX
PRINT 490, IN                                     FLEX
GO TO 10,20), MOP                                     FLEX
10 READ 500, DITH,DIDP,CODE,DIE,DINU          FLEX
CC=0.5*CODE*DIDP                                     FLEX
PRINT 510, DITH,DIDP,CC,DIE,DINU          FLEX
DIPHA=DITH*DIDP                                     FLEX
DIPHI=DIPHA*DIDP*DIDP/12.                         FLEX
DIAS=DIPHA/1.2                                     FLEX
GO TO 30                                         FLEX
20 READ 500, DIPHI,DIPHA,DIAS,CC,DIE,DINU          FLEX
PRINT 520, DIPHI,DIPHA,DIAS,CC,DIE,DINU          FLEX
DIDP=SQRT(12.*DIPHI/DIPHA)                         FLEX
CALCULATE CONSTANTS                                     FLEX
30 D1(I)=1./(DIPHA*DIE)                           FLEX
D3(I)=1./(12.*DIE*DIPHI)                         FLEX
IF (DIAS.EQ.0.) GO TO 40                         FLEX
D2(I)=24.*(1.+DINU)*DIPHI/DIAS                   FLEX
GO TO 50                                         FLEX
40 D2(I)=0.                                         FLEX
50 CONTINUE                                       FLEX
GENERATE COORDINATES OF THE BEAM ELEMENTS          FLEX
K=0                                              FLEX
DO 70 L=1,NEL                                     FLEX
I=NPI(L)                                         FLEX
J=NPJ(L)                                         FLEX

```

```

      IF (JFOR(1,I)*JFOR(2,I)*JFOR(3,I).NE.0) GO TO 60
      K=K+1
      XDOD(K)=XORD(I)
      60 IF (JFOR(1,J)*JFOR(2,J)*JFOR(3,J).NE.0) GO TO 70
      K=K+1
      XDOD(K)=XORD(J)
      70 CONTINUE
      EPSI=0.01*DIDP
      HGH=-99999.
      IBM=0
      DO 100 I=1,K
      G=XDOD(I)
      N=I
      J=I+1
      IF (J.GT.K) GO TO 90
      DO 80 M=J,K
      IF (XDOD(M).GE.G) GO TO 80
      G=XDOD(M)
      N=M
      80 CONTINUE
      XDOD(N)=XDOD(I)
      90 IF ((G-HGH).LE.EPSI) GO TO 100
      IBM=IBM+1
      XDOD(IBM)=G
      HGH=G
      100 CONTINUE
      C
      C   TO FORM FORCE TRANSFORMATION MATRIX
      C
      REWIND 9
      DO 110 I=1,MBCOL
      DO 110 J=1,MBCOL
      110 FLE(I,J)=0.
      DO 120 L=1,NFMD
      120 WRITE (9) ((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
      IF (JN2) 130,130,140
      130 C1=XORD(JN1)
      C2=C1
      C4=YORD(JN1)
      GO TO 180
      140 IF (IC(1,1).EQ.1) GO TO 160
      C4=YORD(JN2)
      IF (XORD(JN2).GT.XORD(JN1)) GO TO 150
      IFTYPE=1
      C1=XORD(JN2)
      C2=XORD(JN1)
      GO TO 180
      150 IFTYPE=2
      C1=XORD(JN1)
      C2=XORD(JN2)
      GO TO 180
      160 C4=YORD(JN1)
      IF (XORD(JN1).GT.XORD(JN2)) GO TO 170
      IFTYPE=1
      C1=XORD(JN1)
      C2=XORD(JN2)

```

FLEX	54
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FLEX	107
FLEX	108
FLEX	109

```

GO TO 180                                FLEX 110
170 IFTYPE=2                               FLEX 111
C1=XORD(JN2)                             FLEX 112
C2=XORD(JN1)                             FLEX 113
180 EPSI=0.5*EPSI                         FLEX 114
IBM1=IBM-1                               FLEX 115
KTAPE=-1                                 FLEX 116
DO 400 JK=1,LEM1                         FLEX 117
KTAPE=-KTAPE                            FLEX 118
X1=XDDD(JK)-C1                          FLEX 119
X2=XDDD(JK+1)-C1                        FLEX 120
I=0                                      FLEX 121
IF (X1.LE.-EPSI) GO TO 290               FLEX 122
C3=C2-C1                                FLEX 123
IF (X1.GE.(C3-EPSI)) GO TO 250          FLEX 124
GO TO (190,220),IFTYPE                   FLEX 125
190 IMTYPE=3                               FLEX 126
DO 210 J=1,MX,4                           FLEX 127
I=I+1                                    FLEX 128
J1=J+1                                  FLEX 129
J2=J+2                                  FLEX 130
XX=XORD(I)-C1                           FLEX 131
YY=YORD(I)-C4                           FLEX 132
IF (XX.LE.(X1+EPSI)) GO TO 200          FLEX 133
BF(1,J)=1.                                FLEX 134
BF(1,J1)=0.                               FLEX 135
BF(1,J2)=0.                               FLEX 136
BF(2,J)=CC-C4-(YY*X1/C3)                FLEX 137
BF(2,J1)=(1.-XX/C3)*X1                  FLEX 138
BF(2,J2)=X1/C3                           FLEX 139
BF(3,J)=CC-C4-YY*X2/C3                 FLEX 140
BF(3,J1)=(1.-XX/C3)*X2                  FLEX 141
BF(3,J2)=X2/C3                           FLEX 142
GO TO 210                                FLEX 143
200 BF(1,J)=0.                            FLEX 144
BF(1,J1)=0.                            FLEX 145
BF(1,J2)=0.                            FLEX 146
BF(2,J)=(C3-X1)*YY/C3                 FLEX 147
BF(2,J1)=(C3-X1)*XX/C3                FLEX 148
BF(2,J2)=(X1-C3)/C3                  FLEX 149
BF(3,J)=(C3-X2)*YY/C3                 FLEX 150
BF(3,J1)=(C3-X2)*XX/C3                FLEX 151
BF(3,J2)=(X2-C3)/C3                  FLEX 152
210 CONTINUE                            FLEX 153
GO TO 330                                FLEX 154
220 IMTYPE=4                               FLEX 155
DO 240 J=1,MX,4                           FLEX 156
I=I+1                                    FLEX 157
J1=J+1                                  FLEX 158
J2=J+2                                  FLEX 159
XX=XORD(I)-C1                           FLEX 160
YY=YORD(I)-C4                           FLEX 161
IF (XX.LE.(X1+EPSI)) GO TO 230          FLEX 162
BF(1,J)=0.                                FLEX 163
BF(1,J1)=0.                                FLEX 164
BF(1,J2)=0.                                FLEX 165

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      BF(2,J)=-YY*X1/C3          FLEX 166
      BF(2,J1)=(1.-XX/C3)*X1    FLEX 167
      BF(2,J2)=X1/C3            FLEX 168
      BF(3,J)=-YY*X2/C3          FLEX 169
      BF(3,J1)=(1.-XX/C3)*X2    FLEX 170
      BF(3,J2)=X2/C3            FLEX 171
      GO TO 240                 FLEX 172
230   BF(1,J)=-1.               FLEX 173
      BF(1,J1)=0.                FLEX 174
      BF(1,J2)=0.                FLEX 175
      BF(2,J)=-CC+C4+YY*(1.-X1/C3) FLEX 176
      BF(2,J1)=XX*(1.-X1/C3)     FLEX 177
      BF(2,J2)=-1.+X1/C3        FLEX 178
      BF(3,J)=-CC+C4+YY*(1.-X2/C3) FLEX 179
      BF(3,J1)=XX*(1.-X2/C3)     FLEX 180
      BF(3,J2)=-1.+X2/C3        FLEX 181
240   CONTINUE                 FLEX 182
      GO TO 330                 FLEX 183
250   IMTYPE=2                 FLEX 184
      DO 280 J=1,MX,4           FLEX 185
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      IF (XX.GE.(X2-EPSI)) GO TO 270
      DO 260 L=1,3
      BF(L,J)=0.
      BF(L,J1)=0.
      BF(L,J2)=0.
260   CONTINUE                 FLEX 191
      GO TO 280                 FLEX 192
270   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.
280   CONTINUE                 FLEX 193
      GO TO 330                 FLEX 194
290   IMTYPE=1                 FLEX 195
      DO 320 J=1,MX,4           FLEX 196
      I=I+1
      J1=J+1
      J2=J+2
      XX=XORD(I)-C1
      IF (XX.LE.(X1+EPSI)) GO TO 310
      DO 300 L=1,3
      BF(L,J)=0.
      BF(L,J1)=0.
      BF(L,J2)=0.
300   CONTINUE                 FLEX 201
      GO TO 320                 FLEX 202
310   BF(1,J)=-1.              FLEX 203
      FLEX 204
      FLEX 205
      FLEX 206
      FLEX 207
      FLEX 208
      FLEX 209
      FLEX 210
      FLEX 211
      FLEX 212
      FLEX 213
      FLEX 214
      FLEX 215
      FLEX 216
      FLEX 217
      FLEX 218
      FLEX 219
      FLEX 220
      FLEX 221

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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.
320 CONTINUE
C
330 DO 340 I=1,MPCOL
J=INDMP(I)
DO 340 K=1,3
340 BF(K,I)=BF(K,J)
C
DO 350 I=1,MBCOL
J=INDR(I)
DO 350 K=1,3
350 BF(K,I)=BF(K,J)

C FIND AND SUM UP B TRANSPOSE * F * B
S=XDOD(JK+1)-XDOD(JK)
REWIND 8
REWIND 9
IF (KTAPE.LT.0) GO TO 360
MTAPE=9
NTAPE=8
GO TO 370
360 MTAPE=8
NTAPE=9
370 DO 400 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 390 I=1,MBCOL
DO 380 J=1,3
TB(J)=0.
DO 380 K=1,3
380 TB(J)=TB(J)+BF(K,I)*FE(K,J)
DO 390 J=1,MBCOL
DO 390 K=1,3
390 FLE(I,J)=FLE(I,J)+TB(K)*BF(K,J)
WRITE (NTAPE) ((FLE(I,J),J=1,MBCOL),I=1,MBCOL)
400 CONTINUE
C
IF (NTAPE.EQ.9) GO TO 420
REWIND 8

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FLEX 222  
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FLEX 277

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REWIND 9                                FLEX 278
DO 410 L=1,NFMD                         FLEX 279
READ (8) ((FLE(I,J),J=1,MBCOL),I=1,MBCOL) FLEX 280
410 WRITE (9) ((FLE(I,J),J=1,MBCOL),I=1,MBCOL) FLEX 281
C                                         FLEX 282
C   STORE FLEXIBILITY MATRICES ON TAPE 8    FLEX 283
C                                         FLEX 284
420 REWIND 8                                FLEX 285
DO 460 I=1,NDIAFH                         FLEX 286
IF (KODIA(I).NE.4) GO TO 460               FLEX 287
REWIND 9                                FLEX 288
IN=KDTP(I)                               FLEX 289
N=MBCOL*MBCOL                           FLEX 290
IF (IN.EQ.1) GO TO 440                  FLEX 291
DO 430 J=2,IN                            FLEX 292
430 READ (9) HH                           FLEX 293
440 READ (9) (HHH(J),J=1,N)              FLEX 294
NN1=1                                     FLEX 295
NN2=MBCOL                                FLEX 296
DO 450 L=1,MBCOL                         FLEX 297
WRITE (8) (HHH(J),J=NN1,NN2)             FLEX 298
NN1=NN1+MBCOL                           FLEX 299
450 NN2=NN2+MBCOL                         FLEX 300
460 CONTINUE                               FLEX 301
RETURN                                   FLEX 302
C                                         FLEX 303
470 FORMAT (2I4)                          FLEX 304
480 FORMAT (46H1PROPERTIES OF THE FLEXIBLE MOBILE DIAPHRAGMS) FLEX 305
490 FORMAT (33H3FLEXIBLE MOBILE DIAPHRAGM TYPE ,I3)        FLEX 306
500 FORMAT (6F10.0)                        FLEX 307
510 FORMAT (1H0,8X,9HTHICKNESS,11X,5HDEPTH,13X,12HNEUTRAL AXIS,11X,1HEFLEX 308
     1,16X,1HV/4E20.8,F10.3)                 FLEX 309
520 FORMAT (20H0 MOMENT OF INERTIA,10X,4HAREA,13X,10HSHEAR AREA,10X,1FLEX 310
     12HNEUTRAL AXIS,13X,1HE,14X,1HV/5E20.8,F10.3)           FLEX 311
END                                       FLEX 312

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OVERLAY(MASTER,5,0)
PROGRAM CORF2
C
C ***** *****
C SUM UP THE FLEXIBILITY MATRICES OF THE FOLDED PLATES, THE FLEXIBLECOR2 1
C BENTS AND THE FLEXIBLE MOVABLE DIAPHRAGMS. SOLVE FOR THE CORREC-COR2 2
C TIVE FORCES.***** *****
C
C COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDCOR2 3
1,KFOR, IO, MI, INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)COR2 4
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60),CF(120)COR2 5
COMMON /FOLD/ FMAT(120,120),DINP(120),L1,L2,DISP(80,81)COR2 6
COMMON /FXDM/ IC(3,2),KTEM(13),MBCOL,NDIA(12),JN1,JN2,INDB(120),XDCOR2 7
10D(120),BF(3,120),ITCOR2 8
DIMENSION RB(120), ERASE(120), DD1(80), T(120), FRAM(120), DD(4,20)COR2 9
1), KB12(3), B(3,120),TDX(12),TDL(12)COR2 10
EQUIVALENCE (FRAM,CF), (DD,DD1)COR2 11
C
C RESTORE INFORMATION SAVED ON TAPE 1
C
C REWIND 1
READ (1) ((FMAT(I,J),I=1,IT),J=1,IT),(DINP(I),I=1,IT),KB12,B,KB COR2 12
C
C SUM UP THE FLEXIBILITIES OF THE FOLDED PLATE AND THE FLEXIBLE BENTCOR2 13
C
C REWIND 2
REWIND 8
DO 50 K=1,NDIAPH
IK=KODIA(K)
GO TO (50,50,10,30), IKCOR2 14
10 KMK=KTEM(K)
DO 20 I=1,MPC
READ (2) (FRAM(J),J=1,MPC)
IXYZ=KMK+I
DO 20 J=1,MPC
JXYZ=KMK+J
20 FMAT(IXYZ,JXYZ)=FMAT(IXYZ,JXYZ)+FRAM(J)
GO TO 50COR2 15
C
C ADD THE FLEXIBILITY OF THE FLEXIBLE MOVABLE DIAPHRAGM
C
C 30 KMK=KTEM(K)
DO 40 I=1,MBCCL
READ (8) (FRAM(J),J=1,MECOL)
IXYZ=KMK+I
DO 40 J=1,MBCOL
JXYZ=KMK+J
40 FMAT(IXYZ,JXYZ)=FMAT(IXYZ,JXYZ)+FRAM(J)
50 CONTINUE
C
C SOLVE FOR CORRECTIVE FORCES
C

```

```

      C      REWIND 1
      C      WRITE (1) ((FMAT(I,J),I=1,IT),J=1,IT)
      C      DO 60 J=1,IT
      C      60 RB(J)=DINP(J)
      C      C=0.
      C      L=ISIMEQ(120,IT,1,FMAT,RB,C,ERASE)
      C      GO TO (90,70,80), L
      C      70 PRINT 250
      C      STOP
      C      80 PRINT 260
      C      STOP
      C      90 DO 100 J=1,IT
      C      100 RB(J)=FMAT(J,1)
      C
      C      PRINT DINP AND FMAT*RB FOR CHECK
      C
      C      REWIND 1
      C      READ (1) ((FMAT(I,J),I=1,IT),J=1,IT)
      C      PRINT 270
      C      DO 110 J=1,IT
      C      ERASE(J)=0.
      C      DO 110 K=1,IT
      C      110 ERASE(J)=ERASE(J)+FMAT(J,K)*RB(K)
      C      PRINT 280, (L,DINP(L),ERASE(L),L=1,IT)
      C
      C      STORE INTERACTION FORCES ON TAPE 9
      C
      C      REWIND 9
      C      DO 120 M=1,NDIAPH
      C      II=KTEM(M)+1
      C      IJ=KTEM(M+1)
      C      120 WRITE (9) (RB(J),J=II,IJ)
      C
      C      PRINT CORRECTIVE JOINT FORCES
      C
      PRINT 290
      DO 130 I=1,MX
      130 DD1(I)=0.
      DO 230 M=1,NDIAPH
      IF (IO.EQ.0)PRINT 300,M,DIAPHX(M),DIADEL(M)
      IF (IO.EQ.0)GO TO 320
      TDX(M)=DIAPHX(M)*(180./PI)
      TDL(M)=DIADEL(M)*(180./PI)
      PRINT 310,M,TDX(M),TDL(M)
      320 CONTINUE
      II=KTEM(M)
      IJ=KTEM(M+1)
      IF (IJ-II-MPC) 160,140,160
      140 DO 150 I=1,MPC
      J=I+II
      150 ERASE(I)=RB(J)
      GO TO 200
      160 DO 170 I=1,MBCOL
      K=I+II
      J=INDB(I)
      T(I)=RB(K)
      COR2 54
      COR2 55
      COR2 56
      COR2 57
      COR2 58
      COR2 59
      COR2 60
      COR2 61
      COR2 62
      COR2 63
      COR2 64
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      COR2 96
      COR2 97
      COR2 98
      COR2 99
      COR2 100
      COR2 101
      COR2 102
      COR2 103
      COR2 104
      COR2 105
      COR2 106
      COR2 107
      COR2 108
      COR2 109

```

```

170 ERASE(J)=T(I)
DO 190 I=1,KB
J=KB12(I)
C=0.
DO 180 K=1,MBCOL
180 C=C+B(I,K)*T(K)
190 ERASE(J)=C
200 DO 210 I=1,MPCOL
J=INDMP(I)
210 DD1(J)=ERASE(I)
PRINT 240, (I,(DD(J,I),J=1,3),I=1,NJT)
C
DO 220 I=1,MPCOL
K=I+(M-1)*MPCOL
220 CF(K)=ERASE(I)
230 CONTINUE
C
RETURN
C
240 FORMAT (I5,3E20.8)
250 FORMAT (27H1OVERFLOW WHEN SOLVING FMAT)
260 FFORMAT (17H1FMAT IS SINGULAR)
270 FORMAT (64H1CHECK ACCURACY OF SOLVING EQUATIONS, TO COMPARE -DISPLCOR2 132
1 WITH F*R//17X,7H -DISPL14X,6H F * R) COR2 133
280 FORMAT (I4,2E20.6) COR2 134
290 FORMAT (40H1FINAL CORRECTIVE JOINT FORCES) COR2 135
300 FORMAT (///14H DIAPHRAGM NO.I4,8X,4H X =F10.4,8X,12H THICKNESS =FCOR2 136
110.6//6H JOINT11X,8H H-FORCE12X,8H V-FORCE13X,7H MOMENT) COR2 137
310 FORMAT (///14H DIAPHRAGM NO.I4,8X,8H THETA =F10.4,8X,12H THICKNESCOR2 138
1S =F10.6//6H JOINT11X,8H H-FORCE12X,8H V-FORCE13X,7H MOMENT) COR2 139
END

```

```

C FUNCTION ISIMEQ (MAX,NN,LL,A,B,SCALE, ID)
C ***** SOLVE SYMMETRICAL SIMULTANEOUS EQUATIONS WITH PIVOTING *****
C ***** DIMENSION A(MAX,MAX), B(MAX,1), ID(1) *****
C SET I-D. ARRAY
C DO 10 N=1,NN
10 ID(N)=N
C DO 140 N=1,NN
N1=N+1
C LOCATE LARGEST ELEMENT
C D=0.0
DO 30 I=N,NN
DO 30 J=N,NN
IF (ABS(A(I,J))-D) 30,20,20
20 D=ABS(A(I,J))
II=I
JJ=J
30 CONTINUE
C INTERCHANGE COLUMNS
C DO 40 I=1,NN
D=A(I,N)
A(I,N)=A(I,JJ)
40 A(I,JJ)=D
C RECORD COLUMN INTERCHANGE
C I=ID(N)
ID(N)=ID(JJ)
ID(JJ)=I
C INTERCHANGE ROWS
C DO 50 J=N,NN
D=A(N,J)
A(N,J)=A(II,J)
50 A(II,J)=D
C DO 60 L=1,LL
D=B(N,L)
B(N,L)=B(II,L)
60 B(II,L)=D
C FORM D(N,L)

```

```

DO 70 L=1,LL ISIM 55
70 B(N,L)=B(N,L)/A(N,N) ISIM 56
C ISIM 57
C CHECK FOR LAST EQUATION ISIM 58
C ISIM 59
C IF (N>NN) 80,150,80 ISIM 60
C ISIM 61
80 DO 130 J=N1,NN ISIM 62
C ISIM 63
C FORM H(N,J) ISIM 64
C ISIM 65
C IF (A(N,J)) 90,110,90 ISIM 66
90 A(N,J)=A(N,J)/A(N,N) ISIM 67
C ISIM 68
C MODIFY A(I,J) ISIM 69
C ISIM 70
DO 100 I=N1,NN ISIM 71
100 A(I,J)=A(I,J)-A(I,N)*A(N,J) ISIM 72
C ISIM 73
C MODIFY B(I,L) ISIM 74
C ISIM 75
110 DO 120 L=1,LL ISIM 76
120 B(J,L)=B(J,L)-A(J,N)*B(N,L) ISIM 77
130 CONTINUE ISIM 78
140 CONTINUE ISIM 79
C ISIM 80
C BACK-SUBSTITUTION ISIM 81
C ISIM 82
150 N1=N ISIM 83
N=N-1 ISIM 84
IF (N) 180,180,160 ISIM 85
C ISIM 86
160 DO 170 L=1,LL ISIM 87
DO 170 J=N1,NN ISIM 88
170 B(N,L)=B(N,L)-A(N,J)*B(J,L) ISIM 89
C ISIM 90
GO TO 150 ISIM 91
C ISIM 92
C REORDER UNKNOWNs ISIM 93
C ISIM 94
180 DO 220 N=1,NN ISIM 95
DO 210 I=N,NN ISIM 96
IF (ID(I)-N) 210,190,210 ISIM 97
190 DO 200 L=1,LL ISIM 98
D=B(N,L)
B(N,L)=B(I,L) ISIM 99
200 B(I,L)=D ISIM 100
GO TO 220 ISIM 101
210 CONTINUE ISIM 102
220 ID(I)=ID(N) ISIM 103
C ISIM 104
ISIMEQ=1 ISIM 105
C ISIM 106
C PUT ANSWERS IN A ARRAY ISIM 107
C ISIM 108
DO 230 L=1,LL ISIM 109
C ISIM 110

```

```
DO 230 I=1,NN
230 A(I,L)=B(I,L)
```

C RETURN

C END

ISIM	111
ISIM	112
ISIM	113
ISIM	114
ISIM	115
ISIM	116

## OVERLAY (MASTER, 6, 0)

PROGRAM EDGDIS

```

C ***** EDGD 1
C ***** EDGD 2
C ***** EDGD 3
C ***** EDGD 4
C ***** EDGD 5
C ***** EDGD 6
C ***** EDGD 7
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C ***** EDGD 10
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C ***** EDGD 39
C ***** EDGD 40
C ***** EDGD 41
C ***** EDGD 42
C ***** EDGD 43
C ***** EDGD 44
C ***** EDGD 45
C ***** EDGD 46
C ***** EDGD 47
C ***** FDGD 48
C ***** EDGD 49
C ***** EDGD 50
C ***** EDGD 51
C ***** EDGD 52
C ***** EDGD 53

```

COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDEDGD  
1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)EDGD  
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60),CF(120)EDGD  
COMMON /PERM/ NOXMF,NBDX,NGIEL(30,2),BOXMOD(14,10),XDIV(30),DNAI(30)  
10,DNAJ(30),MOPX(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)EDGD  
COMMON /EDGE/ SINKX(100,14),COSKX(100,14)EDGD  
COMMON /PROPT/ THM(15),THB(15),ETM(15),ETR(15),ESM(15),ESB(15),GM(15)  
115),GB(15),PRM(15),PRB(15)EDGD  
COMMON /PLATE/ XP(14),NPI(30),NPJ(30),KPL(30),NSEC(30),PWTH(30),SIEDGD  
INEL(30),COSEL(30),Y(30),Z(30),TP(14)EDGD  
DIMENSION RJDIS(80,14), DISP(80), EDP(240), DI(80,81), LIND(80),  
1(12), P(80)EDGD  
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 180 NN=N1,MHARM,N2  
MM=MM+1  
FN=NN  
FK=FN\*PI/TETAO  
C  
C READ DISPLACEMENT MATRIX FROM TAPE 3  
C  
READ (3) ((DI(I,J),I=1,MX),J=1,MPC1)  
IF (NDIAPH) 20,20,40  
20 DO 30 I=1,MX  
30 DISP(I)=DI(I,1)  
GO TO 120  
C  
C FOURIER MULTIPLIERS ARE COMPUTED  
C  
40 DO 70 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*TETAO*R)*C*S          EDGD 54
GO TO 70                           EDGD 55
60 D(I)=2./(TETAO*R)*S            EDGD 56
70 CONTINUE                         EDGD 57
C
C FIND FINAL JOINT DISPLACEMENTS (DISP)   EDGD 58
C
DO 80 I=1,MPCOL                   EDGD 59
P(I)=0.                            EDGD 60
DO 80 J=1,NDIAPH                 EDGD 61
K=I+(J-1)*MPCOL                  EDGD 62
80 P(I)=P(I)+CF(K)*D(J)          EDGD 63
DO 100 I=1,MX                     EDGD 64
C=0.                               EDGD 65
DO 90 J=1,MPCOL                  EDGD 66
90 C=C+DI(I,J)*P(J)             EDGD 67
100 DISP(I)=C+DI(I,MPC1)         EDGD 68
IF (NDIAPH.EQ.0) GO TO 120       EDGD 69
C
C CHANGE SIGNS TO CONFORM WITH CURSTR    EDGD 70
C
DO 110 I=3,MX,4                  EDGD 71
DISP(I)=-DISP(I)                 EDGD 72
110 DISP(I+1)=-DISP(I+1)         EDGD 73
C
C CALCULATE AND SUM UP JOINT DISPLACEMENTS AT DIFFERENT POINTS   EDGD 74
C
120 DO 160 II=1,NXP              EDGD 75
IF (IAx.GT.0) GO TO 130         EDGD 76
S=1.0                            EDGD 77
C=0.0                            EDGD 78
GO TO 140                         EDGD 79
130 XX=FK#TP(II)                EDGD 80
C=COS(XX)                         EDGD 81
S=SIN(XX)                         EDGD 82
140 COSKX(MM,II)=C              EDGD 83
SINKX(MM,II)=S                   EDGD 84
DO 160 L=4,MX,4                  EDGD 85
I=L-3                            EDGD 86
J=L-1                            EDGD 87
DO 150 K=I,J                     EDGD 88
150 RJDIS(K,II)=RJDIS(K,II)+DISP(K)*S   EDGD 89
160 RJDIS(L,II)=RJDIS(L,II)+DISP(L)*C   EDGD 90
C
C CALCULATE EDGE DISPLACEMENTS FOR EACH ELEMENT AND STORE ON TAPE 1   EDGD 91
C
N=0
DO 170 L=1,NEL                  EDGD 92
K=KPL(L)                         EDGD 93
I=NPI(L)*4-4                     EDGD 94
J=NPJ(L)*4-4                     EDGD 95
C=COSEL(L)                        EDGD 96
S=SINEL(L)                        EDGD 97
EDP(N+1)=DISP(I+4)               EDGD 98
EDP(N+2)=DISP(J+4)               EDGD 99
EDP(N+3)=DISP(I+1)*C+DISP(I+2)*S   EDGD 100

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EDP(N+4)=DISP(J+1)*C+DISP(J+2)*S          EDGD 110
EDP(N+5)=DISP(I+1)*S-DISP(I+2)*C          EDGD 111
EDP(N+6)=DISP(J+1)*S-DISP(J+2)*C          EDGD 112
EDP(N+7)=-DISP(I+3)                         EDGD 113
EDP(N+8)=-DISP(J+3)                         EDGD 114
170 N=N+8
      WRITE (1) (EDP(I),I=1,N)                EDGD 115
C
C
180 CONTINUE
C
C      PRINT RESULTS FOR JOINT DISPLACEMENTS
C
DO 190 I=1,NJT
J=4*I
LIND(J)=I
LIND(J-1)=I
LIND(J-2)=I
190 LIND(J-3)=I
IF (NXP=7) 200,200,210
200 II=NXP
IL=1
GO TO 220
210 II=7
IJ=NXP
IL=2
220 PRINT 300
CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,IO,1)    EDGD 136
PRINT 310
CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,IO,2)    EDGD 137
PRINT 320
CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,IO,3)    EDGD 138
PRINT 330
CALL PINVAL (LIND,RJDIS,80,14,XP,MX,II,IJ,IL,IO,4)    EDGD 139
C
CALL PLFOR (MM,II,IJ,IL)
C
IF (MCHECK.EQ.0) GO TO 260
DO 250 I=1,NOXMP
PP=0.0
TOT=0.0
TOTEN=0.
TOCOM=0.
DO 230 J=1,NBOX
TOTEN=TOTEN+TENS(I,J)
TOCOM=TOCOM+COMP(I,J)
230 TOT=TOT+BOXMOM(I,J)
IF (TOT.EQ.0.) GO TO 250
IF (IO.EQ.0) PRINT 270,XMP(I)
C
IF (IO.EQ.1) PRINT 340,XMP(I)
DO 240 J=1,NBOX
PC=BOXMOM(I,J)/TOT*100.
PP=PP+PC
240 PRINT 280, J,BOXMOM(I,J),PC,TENS(I,J),COMP(I,J)
PRINT 290, TOT,PP,TOTEN,TOCOM
C

```

```

250 CONTINUE          EDGD 166
260 RETURN           EDGD 167
C
270 FORMAT (1H1,38H MOMENTS TAKEN BY EACH GIRDER AT X = ,F10.3///,58HEDGD 169
1 GIRDER NO.   MOMENT PERCENTAGE TENSION COMPRESSION//) EDGD 170
280 FORMAT (I6,E16.6,F9.2,2E16.6) EDGD 171
290 FORMAT (//6H TOTAL,E16.6,F9.2,2E16.6) EDGD 172
300 FORMAT (26HFINAL JOINT DISPLACEMENTS///10X,25H HORIZONTAL DISPLAEDGD 173
1CEMENTS)
310 FORMAT (////10X,23H VERTICAL DISPLACEMENTS) EDGD 174
320 FORMAT (////10X,10H ROTATIONS) EDGD 175
330 FORMAT (////10X,27H LONGITUDINAL DISPLACEMENTS) EDGD 176
340 FORMAT(1H1,42H MOMENTS TAKEN BY EACH GIRDER AT THETA = ,F10.5///,EDGD 178
1 58H GIRDER NO.   MOMENT PERCENTAGE TENSION COMPRESSION//) EDGD 179
END               EDGD 180

```

## SUBROUTINE PLFOR (MM, II, IJ, IL)

```

C *****PLFOR***** 1
C *****PLFO***** 2
C *****PLFO***** 3
C *****PLFO***** 4
C *****PLFO***** 5
C *****PLFO***** 6
C *****PLFO***** 7
C *****PLFO***** 8
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C *****PLFO***** 53
C *****PLFO***** 54

```

C CALCULATE AND PRINT FINAL INTERNAL FORCES FOR EACH PLATE ELEMENT PLFO

C \*\*\*\*PLFO\*\*\*\*\* 1

C \*\*\*\*PLFO\*\*\*\*\* 2

C \*\*\*\*PLFO\*\*\*\*\* 3

C \*\*\*\*PLFO\*\*\*\*\* 4

C \*\*\*\*PLFO\*\*\*\*\* 5

C \*\*\*\*PLFO\*\*\*\*\* 6

C \*\*\*\*PLFO\*\*\*\*\* 7

C \*\*\*\*PLFO\*\*\*\*\* 8

C \*\*\*\*PLFO\*\*\*\*\* 9

C \*\*\*\*PLFO\*\*\*\*\* 10

C \*\*\*\*PLFO\*\*\*\*\* 11

C \*\*\*\*PLFO\*\*\*\*\* 12

C \*\*\*\*PLFO\*\*\*\*\* 13

C \*\*\*\*PLFO\*\*\*\*\* 14

C \*\*\*\*PLFO\*\*\*\*\* 15

C \*\*\*\*PLFO\*\*\*\*\* 16

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C \*\*\*\*PLFO\*\*\*\*\* 49

C \*\*\*\*PLFO\*\*\*\*\* 50

C \*\*\*\*PLFO\*\*\*\*\* 51

C \*\*\*\*PLFO\*\*\*\*\* 52

C \*\*\*\*PLFO\*\*\*\*\* 53

C \*\*\*\*PLFO\*\*\*\*\* 54

COMMON TETAO,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDPLFO

1,KFOR,IO,MI,INTRES,PI,MX,N1,N2,IA,IAX,DIAPHX(12),DIADEL(12),KDDIA(12)PLFO

2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60),CF(120)PLFO

COMMON /PROPT/ THM(15),THB(15),ETM(15),ETB(15),ESM(15),ESB(15),GM(PLFO

115),GB(15),PRM(15),PRB(15)PLFO

COMMON /EDGE/ SINKX(100,14),COSKX(100,14)PLFO

COMMON /PERM/ NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(3PLFO

10),DNAJ(30),MCpx(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)PLFO

COMMON /PLATE/ XP(14),NPI(30),NPJ(30),KPL(30),NSEC(30),PWTH(30),SIPLFO

1NEL(30),COSEL(30),Y(30),Z(30),TP(14)PLFO

DIMENSION DI(240), D(8,1500), DIS(8,30), DISP(8)PLFO

DIMENSION U(14,13),VD(14,13),W(14,13), SN(14,13),TN(14,13)PLFO

1,STN(14,13),SM(14,13),TM(14,13),STM(14,13)PLFO

EQUIVALENCE (DI,DIS)PLFO

NELINC=12000/(MM\*8)-1PLFO

NOFPL=0PLFO

NEL2=0PLFO

READ EDGE DISPLACEMENTS FROM TAPE 1PLFO

10 NEL1=NEL2+1PLFO

IF (NEL1-NEL) 20,20,200PLFO

20 NEL2=MINO((NEL1+NELINC),NEL)PLFO

NDI=NEL2\*8PLFO

REWIND 1PLFO

L=0PLFO

DO 30 I=1,MMPLFO

READ (1) (DI(J),J=1,NDI)PLFO

DO 30 J=NEL1,NEL2PLFO

L=L+1PLFO

DO 30 K=1,8PLFO

30 D(K,L)=DIS(K,J)PLFO

FOR EACH ELEMENTPLFO

NDI=NEL2-NEL1+1PLFO

DO 190 IE=NEL1,NEL2PLFO

FN=NSEC(IE)PLFO

IF (FN) 190,190,40PLFO

40 NUMY=NSEC(IE)+1PLFO

IEPL=KPL(IE)PLFO

XL=2./FNPLFO

ISW=1PLFO

DO 50 J=1,NUMYPLFO

DO 50 K=1,NXPPLFO

U(K,J)=0. PLFO

```

VD(K,J)=0. PLFO 55
W(K,J)=0. PLFO 56
SN(K,J)=0. PLFO 57
TN(K,J)=0. PLFO 58
STN(K,J)=0. PLFO 59
SM(K,J)=0. PLFO 60
TM(K,J)=0. PLFO 61
50 STM(K,J)=0. PLFO 62
IF (IEPL-NDFPL) 60,80,60 PLFO 63
60 IF (MI.EQ.1) GO TO 70 PLFO 64
FM=PRM(IEPL)*ETM(IEPL)/ESM(IEPL) PLFO 65
FB=PRB(IEPL)*ETB(IEPL)/ESB(IEPL) PLFO 66
DM=1.-FM*PRM(IEPL) PLFO 67
DB=1.-FB*PRB(IEPL) PLFO 68
TH3=THB(IEPL)**3/12. PLFO 69
D11=THM(IEPL)*ESM(IEPL)/DM PLFO 70
D22=THM(IEPL)*ETM(IEPL)/DM PLFO 71
D12=D22*PRM(IEPL) PLFO 72
D33=GM(IEPL)*THM(IEPL) PLFO 73
D44=TH3*ESB(IEPL)/DB PLFO 74
D55=TH3*ETB(IEPL)/DB PLFO 75
D45=D55*PRB(IEPL) PLFO 76
D66=GB(IEPL)*TH3**4.0 PLFO 77
GO TO 80 PLFO 78
70 D11=THM(IEPL) PLFO 79
D12=THB(IEPL) PLFO 80
D22=ETM(IEPL) PLFO 81
D33=ETB(IEPL) PLFO 82
D44=ESM(IEPL) PLFO 83
D45=ESB(IEPL) PLFO 84
D55=GM(IEPL) PLFO 85
D66=GB(IEPL) PLFO 86
C PLFO 87
80 S12=PWTI(IE) PLFO 88
S122=S12*S12 PLFO 89
I=NPI(IE) PLFO 90
J=NPJ(IE) PLFO 91
R1=Y(I) PLFO 92
R2=Y(J) PLFO 93
A=0.5*(R2-R1) PLFO 94
B=0.5*(R2+R1) PLFO 95
SP=SINEL(IE) PLFO 96
CP=COSEL(IE) PLFO 97
C PLFO 98
C FOR EACH HARMONIC PLFO 99
C
N=0 PLFO 100
KJK=1 PLFO 101
DO 180 NN=N1,MHARM,N2 PLFO 102
N=N+1 PLFO 103
I=NDI*(N-1)+(IE-NEL1+1) PLFO 104
DO 90 J=1,8 PLFO 105
90 DISP(J)=D(J,I) PLFO 106
FN=NN PLFO 107
FK=FN*PI/TETAO PLFO 108
C FOR EACH TRANSVERSE SECTION PLFO 109
C

```

```

C
DO 130 IY=1,NUMY
FY=IY-1
ETA=XL*FY-1.
E2=ETA*ETA
E3=E2*ETA
PU1=0.5*(1.-ETA)
PU2=0.5*(1.+ETA)
PU3=-1./S12
PU4=-PU3
P1=PU1*DISP(1)+PU2*DISP(2)
P2=PU1*DISP(3)+PU2*DISP(4)
P3=PU3*DISP(1)+PU4*DISP(2)
P4=PU3*DISP(3)+PU4*DISP(4)
PU1=.25*(2.-3.*ETA+E3)
PU2=.25*(2.+3.*ETA-E3)
PU3=.125*S12*(1.-ETA-E2+E3)
PU4=.125*S12*(-1.-ETA+E2+E3)
XW=PU1*DISP(5)+PU2*DISP(6)
P5=XW+PU3*DISP(7)+PU4*DISP(8)
PU1=1.5/S12*(E2-1.)
PU2=-PU1
PU3=.25*(-1.-2.*ETA+3.*E2)
PU4=.25*(-1.+2.*ETA+3.*E2)
P6=PU1*DISP(5)+PU2*DISP(6)+PU3*DISP(7)+PU4*DISP(8)
PU1=6.*ETA/S12
PU2=-PU1
PU3=(3.*ETA-1.)/S12
PU4=(3.*ETA+1.)/S12
P7=PU1*DISP(5)+PU2*DISP(6)+PU3*DISP(7)+PU4*DISP(8)
RR=1./(A*ETA+B)
SPR=SP*RR
CPR=CP*RR
BN=FK*RR
IF (IAx.EQ.0) BN=0.0
C
XX=-BN*P1+CPR*P2+SPR*P5
XNS=D11*P4+D12*XX
XNT=D12*P4+D22*XX
XNST=(P3-CPR*P1+BN*P2)*D33
XX=BN*(BN*P5-SPR*P1)-CPR*P6
XMS=D45*XX-D44*p7
XNT=D55*XX-D45*p7
XMST=D66*(SPR*(P3-CPR*P1)+BN*(CPR*P5-P6))
C
C    SUM UP INTERNAL FORCES AND DISPLACEMENTS
C
DO 120 I=1,NXP
IF (IAx.GT.0) GO TO 100
S=1.0
C=0.0
GO TO 110
100 S=SINKX(N,I)
C=COSKX(N,I)
110 U(I,IY)=U(I,IY)+P1*C
VD(I,IY)=VD(I,IY)+P2*S
PLFO 111
PLFO 112
PLFO 113
PLFO 114
PLFO 115
PLFO 116
PLFO 117
PLFO 118
PLFO 119
PLFO 120
PLFO 121
PLFO 122
PLFO 123
PLFO 124
PLFO 125
PLFO 126
PLFO 127
PLFO 128
PLFO 129
PLFO 130
PLFO 131
PLFO 132
PLFO 133
PLFO 134
PLFO 135
PLFO 136
PLFO 137
PLFO 138
PLFO 139
PLFO 140
PLFO 141
PLFO 142
PLFO 143
PLFO 144
PLFO 145
PLFO 146
PLFO 147
PLFO 148
PLFO 149
PLFO 150
PLFO 151
PLFO 152
PLFO 153
PLFO 154
PLFO 155
PLFO 156
PLFO 157
PLFO 158
PLFO 159
PLFO 160
PLFO 161
PLFO 162
PLFO 163
PLFO 164
PLFO 165
PLFO 166

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```

W(I,IY)=W(I,IY)+XW*S          PLFO 167
SN(I,IY)=SN(I,IY)+XNS*S       PLFO 168
TN(I,IY)=TN(I,IY)+XNT*S       PLFO 169
STN(I,IY)=STN(I,IY)+XNST*C    PLFO 170
SM(I,IY)=SM(I,IY)-XMS*S       PLFO 171
TM(I,IY)=TM(I,IY)-XMT*S       PLFO 172
120 STM(I,IY)=STM(I,IY)-XMST*C PLFO 173
130 CONTINUE                   PLFO 174
C                               PLFO 175
C   PRINT INTERNAL FORCES FOR EACH ELEMENT PLFO 176
C
160 IF (NN.NE.MHARM) GO TO 180    PLFO 177
170 I=NPI(IE)                    PLFO 178
J=NPJ(IE)                      PLFO 179
PRINT 210, IE,I,J,NN            PLFO 180
PRINT 220                        PLFO 181
CALL OPRINT (SN,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 182
PRINT 230                        PLFO 183
CALL OPRINT (TN,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 184
PRINT 240                        PLFO 185
CALL OPRINT(STN,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 186
PRINT 250                        PLFO 187
CALL OPRINT( SM,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 188
PRINT 260                        PLFO 189
CALL OPRINT( TM,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 190
PRINT 270                        PLFO 191
CALL OPRINT(STM,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 192
PRINT 280                        PLFO 193
CALL OPRINT( U,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 194
PRINT 290                        PLFO 195
CALL OPRINT( VD,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 196
PRINT 300                        PLFO 197
CALL OPRINT( W,14,13,XP,NUMY,II,IJ,IL,IO) PLFO 198
C                               PLFO 199
C   CALCULATE GIRDER MOMENTS           PLFO 200
C
IF (MCHECK.LE.0) GO TO 180      PLFO 201
IF (NN.NE.MHARM) GO TO 180      PLFO 202
PLW=PWT(IE)                     PLFO 203
S=DNAI(IE)                      PLFO 204
C=DNAJ(IE)                      PLFO 205
HH=R2-R1                         PLFO 206
VV=Z(I)-Z(J)                     PLFO 207
I=NGIEL(1,IE)                   PLFO 208
J=NGIEL(2,IE)                   PLFO 209
XX=XDIV(IE)                      PLFO 210
CALL MOMP( TN,TM,PLW,IE,NUMY)    PLFO 211
180 CONTINUE                      PLFO 212
NOFPL=IEPL                       PLFO 213
190 CONTINUE                      PLFO 214
GO TO 10                          PLFO 215
200 RETURN                         PLFO 216
C                               PLFO 217
C   210 FORMAT (1H1,48H INTERNAL FORCES PER UNIT LENGTH FOR ELEMENT NO.I4,PLFO 220
118H BETWEEN JOINTS I3,6H AND I3,9H AFTERIS,11H HARMONICS) PLFO 221
220 FORMAT (///10X,5H N(S))        PLFO 222

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230 FORMAT (////10X,9H N(THETA))
240 FORMAT (////10X,11H N(S-THETA))
250 FORMAT (////10X,5H M(S))
260 FORMAT (////10X,9H M(THETA))
270 FORMAT (////10X,11H M(S-THETA))
280 FORMAT (////10X,2H U)
290 FORMAT (////10X,2H V)
300 FORMAT (////10X,2H W)
END

```

```

PLFO 223
PLFO 224
PLFO 225
PLFO 226
PLFO 227
PLFO 228
PLFO 229
PLFO 230
PLFO 231

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```

SUBROUTINE MOMP(M(XN,XM,W,I,NY))
C ***** FIND THE GIRDER MOMENTS BY INTEGRATING THE MEMBRANE STRESSES AND PLATE BENDING MOMENTS IN EACH GIRDER *****
C
COMMON /PERM/ NOXMP,NBOX,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(30),
10,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 80 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 10
  DEH=-DEV*HS(I)/VS(I)
  GO TO 20
10 DEH=HS(I)/SC
20 X1=DNAI(I)
  IF (N2.NE.0) GO TO 40
  DO 30 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(IMOMP
    1X,NN+1))
30 X1=X2
  GO TO 80
40 NN=1
  HH=0.
50 HH=HH+DEH
  AHH=ABS(HH)
  AXDIV=ABS(XDIV(I))
  IF (AHH.GT.AXDIV) GO TO 60
  X2=X1+DEV
  CALL ADDM (J,N1,X1,X2,DEL,DEH,XN(IX,NN),XN(IX,NN+1),XM(IX,NN),XM(IMOMP
    1X,NN+1))
  X1=X2
  NN=NN+1
  GO TO 50
60 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))
  MOMP 1
  MOMP 2
  MOMP 3
  MOMP 4
  MOMP 5
  MOMP 6
  MOMP 7
  MOMP 8
  MOMP 9
  MOMP 10
  MOMP 11
  MOMP 12
  MOMP 13
  MOMP 14
  MOMP 15
  MOMP 16
  MOMP 17
  MOMP 18
  MOMP 19
  MOMP 20
  MOMP 21
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  MOMP 30
  MOMP 31
  MOMP 32
  MOMP 33
  MOMP 34
  MOMP 35
  MOMP 36
  MOMP 37
  MOMP 38
  MOMP 39
  MOMP 40
  MOMP 41
  MOMP 42
  MOMP 43
  MOMP 44
  MOMP 45
  MOMP 46
  MOMP 47
  MOMP 48
  MOMP 49
  MOMP 50
  MOMP 51
  MOMP 52
  MOMP 53
  MOMP 54

```

```

      X1=X3
  70 NN=NN+1
      IF (NN.GT.NSC) GO TO 80
      X2=X1+DEV
      CALL ADDM (J,N2,X1,X2,DEL,DEF,XN(IX,NN),XN(IX,NN+1),XM(IX,NN),XM(IX,NN+1))
      X1=X2
      GO TO 70
  80 CONTINUE
      RETURN
      END

```

MOMP 55  
MOMP 56  
MOMP 57  
MOMP 58  
MOMP 59  
MOMP 60  
MOMP 61  
MOMP 62  
MOMP 63  
MOMP 64  
MOMP 65

```

SUBROUTINE ADDM (J,N,X1,X2,XL,XH,XN1,XN2,XM1,XM2)          ADDM  1
C
C ***** INTEGRATE THE STRESSES BY TRAPEZOIDAL RULE ***** ADDM  2
C
COMMON /PERM/ NOXMP,NBX,X,NGIEL(30,2),BOXMOM(14,10),XDIV(30),DNAI(3ADD 3
10),DNAJ(30),MCpx(14),COMP(14,10),TENS(14,10),HS(30),VS(30),XMP(14)ADD 4
F1=XN1+XL/2.                                              ADDM  5
XM=F1*(X2+2.*X1)/3.                                     ADDM  6
F2=XN2*XL/2.                                              ADDM  7
XM=XM+F2*(X1+2.*X2)/3.                                  ADDM  8
F=F1+F2                                              ADDM  9
XM=XM+0.5*(XM1+XM2)*XH                                  ADDM 10
BOXMOM(J,N)=BOXMOM(J,N)+XM                               ADDM 11
IF (F.LT.0.) GO TO 10                                    ADDM 12
TENS(J,N)=TENS(J,N)+F                                  ADDM 13
GO TO 20                                              ADDM 14
10 COMP(J,N)=COMP(J,N)+F                               ADDM 15
20 RETURN                                              ADDM 16
END                                              ADDM 17
                                         ADDM 18
                                         ADDM 19
                                         ADDM 20
                                         ADDM 21

```

```

      SUBROUTINE PINVAL (IND,D,M,N,X,MX,K1,K2,NCYC,IO,L)
      DIMENSION IND(M), D(M,N), X(N), IN(2), JN(2)
      DATA IN(1),IN(2)/1,8/
      JN(1)=K1
      JN(2)=K2
      DD 10 K=1,NCYC
      J1=IN(K)
      J2=JN(K)
      IF ( IO.EQ.0) PRINT 30, (X(I),I=J1,J2)
      IF ( IO.EQ.1) PRINT 40, (X(I),I=J1,J2)
      DD 10 I=L,MX,4
      10 PRINT 20, (INC(I),(D(I,J),J=J1,J2))
      RETURN
C
      20 FORMAT (I6,1P7E16.7)
      30 FORMAT (6H0JOINT,7(6H     X=F10.3))
      40 FORMAT (6H0JOINT,7(6HTHETA=F10.5))
      END
      PINV 1
      PINV 2
      PINV 3
      PINV 4
      PINV 5
      PINV 6
      PINV 7
      PINV 8
      PINV 9
      PINV 10
      PINV 11
      PINV 12
      PINV 13
      PINV 14
      PINV 15
      PINV 16
      PINV 17
      PINV 18

```

```

SUBROUTINE OPRINT (A,M,N,X,NY,K1,K2,NCYC,IO)
DIMENSION A(M,N), X(M), IN(2), JN(2)
DATA IN(1),IN(2)/1,8/
JN(1)=K1
JN(2)=K2
DO 10 K=1,NCYC
J1=IN(K)
J2=IN(K)
IF (IO.EQ.0) PRINT 30, (X(I),I=J1,J2)
IF (IO.EQ.1) PRINT 40, (X(I),I=J1,J2)
DO 10 I=1,NY
10 PRINT 20, (I,(A(J,I),J=J1,J2))
RETURN
C
20 FORMAT (I6,1P7E16.7)
30 FORMAT (6H0SECT.,7(6H      X=F10.3))
40 FORMAT (6H0SECT.,7(6HTHETA=F10.5))
END

```

OPRT 1  
OPRT 2  
OPRT 3  
OPRT 4  
OPRT 5  
OPRT 6  
OPRT 7  
OPRT 8  
OPRT 9  
OPRT 10  
OPRT 11  
OPRT 12  
OPRT 13  
OPRT 14  
OPRT 15  
OPRT 16  
OPRT 17  
OPRT 18

## OVERLAY(MASTER,7,0)

PROGRAM FORCE

```

C **** FORC 1
C **** FORC 2
C **** FORC 3
C **** FORC 4
C **** FORC 5
C **** FORC 6
C **** FORC 7
C **** FORC 8
C **** FORC 9
C **** FORC 10
C **** FORC 11
C **** FORC 12
C **** FORC 13
C **** FORC 14
C **** FORC 15
C **** FORC 16
C **** FORC 17
C **** FORC 18
C **** FORC 19
C **** FORC 20
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C **** FORC 28
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C **** FORC 38
C **** FORC 39
C **** FORC 40
C **** FORC 41
C **** FORC 42
C **** FORC 43
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C **** FORC 46
C **** FORC 47
C **** FORC 48
C **** FORC 49
C **** FORC 50
C **** FORC 51
C **** FORC 52
C **** FORC 53

```

COMMON TETAD,R,NPL,NEL,NJT,NDIAPH,NXP,MHARM,NCHECK,MCHECK,NBT,NFMDFORC  
1,KFOR,I0,MI,INTRES,PI,MX,N1,N2,IAX,DIAPHX(12),DIADEL(12),KODIA(12)FORC  
2,KDTP(12),CHPLRE,MPC1,MPCOL,MPC,INDMP(60).  
COMMON /PARAM/ NUMEL,NUMNP,NEQ,NUMSPR,NP,NUMELT(8),NUMNPT(8),NEQN(FORC  
18),NUSPRG(8),NPT(8),NPR(80)  
COMMON /FBENT/ EFM(10),E(10),LM(6),SA(6,6),ASA(6,6),T(3,3),S(6,6),FORC  
1RF(6),JK(3),NPSTP(80),SP(40,3),X(80),Y(80),KODE(80),COAX(80),COAY(FORC  
280),COAAZ(80),RE(200),B(200),SPF(6),IP(120),ID(120),IQ(120),A(120,FORC  
3120)

REWIND 2  
REWIND 4  
REWIND 7  
DO 190 IJK=1,NDIAPH  
IF (KODIA(IJK).NE.3) GO TO 190  
REWIND 9  
IF (IJK.EQ.1) GO TO 20  
DO 10 K=2,IJK  
10 READ (9) HH  
20 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 30 I=1,NMAX  
30 READ (2) (A(I,J),J=1,NMAX)  
DO 50 I=1,NMAX  
B(I)=0.  
DO 40 J=1,NMAX  
40 B(I)=B(I)-A(I,J)\*RE(J)  
50 CONTINUE  
N=NEQ  
READ (4) (IQ(I),I=1,N)  
L=N-NP-1  
DO 60 I=1,NP  
L=L+1  
60 READ (4) (A(I,J),J=1,L)  
L=N-NP+1  
DO 80 I=L,N  
B(I)=0.0

```

K=I-1                                FORC 54
M=I-NMAX                             FORC 55
DO 70 J=1,K                            FORC 56
70 B(I)=B(I)-A(M,J)*B(J)            FORC 57
80 CONTINUE                           FORC 58
C                                     FORC 59
C   OUTPUT JOINT DISPLACEMENTS      FORC 60
C
WRITE (6,200) IJK
DO 90 I=1,N
  J=IQ(I)
90 IP(J)=I
WRITE (6,210)
DO 100 I=1,NUMNP
  IL=NPR(I)
  JX=IP(3*IL-2)
  JY=IP(3*IL-1)
  JZ=IP(3*IL)
100 WRITE (6,220) (I,B(JX),B(JY),B(JZ))
C                                     FORC 61
C   DETERMINE MEMBER END FORCES AND PRINT    FORC 62
C
DO 110 N=1,NEQ
110 RE(N)=0.
WRITE (6,230)
DO 140 N=1,NUMEL
READ (7) LM,SA,ASA,T
DO 130 I=1,6
  RF(I)=0.0
  DO 120 J=1,6
    JJ=LM(J)
    JJJ=IP(JJ)
120 RF(I)=RF(I)+SA(I,J)*B(JJJ)
130 CONTINUE
WRITE (6,240) N,(RF(I),I=1,6)
C                                     FORC 63
C   OBTAIN CONTRIBUTION OF ELEMENT END FORCES TO APPLIED JOINT LOADS    FORC 64
C   AND STORE IN RE(NEQ)                                         FORC 65
C
DO 140 I=1,3
  II=LM(I)
  III=LM(I+3)
  DO 140 J=1,3
    RE(II)=RE(II)+T(J,I)*RF(J)
140 RE(III)=RE(III)+T(J,I)*RF(J+3)
C                                     FORC 66
C   DETERMINE AND PRINT ELASTIC SUPPORT REACTIONS                  FORC 67
C
IF (NUMSPR.EQ.0) GO TO 170
WRITE (6,270)
READ (4) (NPSTP(I),I=1,NUMNP)
READ (4) ((SP(I,J),I=1,NUMSPR),J=1,3)
DO 160 N=1,NUMNP
  MSPR=NPSTP(N)
  IF (MSPR.EQ.0) GO TO 160
  NN=NPR(N)
  FORC 68
  FORC 69
  FORC 70
  FORC 71
  FORC 72
  FORC 73
  FORC 74
  FORC 75
  FORC 76
  FORC 77
  FORC 78
  FORC 79
  FORC 80
  FORC 81
  FORC 82
  FORC 83
  FORC 84
  FORC 85
  FORC 86
  FORC 87
  FORC 88
  FORC 89
  FORC 90
  FORC 91
  FORC 92
  FORC 93
  FORC 94
  FORC 95
  FORC 96
  FORC 97
  FORC 98
  FORC 99
  FORC 100
  FORC 101
  FORC 102
  FORC 103
  FORC 104
  FORC 105
  FORC 106
  FORC 107
  FORC 108
  FORC 109

```

```

DO 150 K=1,3
KK=3*(NN-1)+K
KKK=IP(KK)
SPF(K)=-SP(MSPR,K)*B(KKK)
150 RE(KK)=RE(KK)-SPF(K)
WRITE (6,260) N,(SPF(K),K=1,3)
160 CONTINUE
C
C PRINT APPLIED JOINT LOADS AND REACTIONS
C
170 WRITE (6,250)
DO 180 I=1,NUMNP
IL=NPR(I)
JX=3*IL-2
JY=3*IL-1
JZ=3*IL
180 WRITE (6,260) I,RE(JX),RE(JY),RE(JZ)
190 CONTINUE
RETURN
C
C
C
200 FORMAT(52H1INTERNAL FORCES DISPLACEMENTS FOR DIAPHRAGM NUMBER I5) FORC 131
210 FORMAT(1H1/20H JOINT DISPLACEMENTS// FORC 132
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Na mala que trazem os segredos da vida é o conhecimento

que se une ao amor com alegria e alegria com amor, para

que os amores sejam sempre brilhantes, e os amores

que se apagam sejam facilmente ressuscitados.

O amor é a vida, é a morte, é a vida, é a morte,

é a morte, é a vida, é a morte, é a vida, é a morte,

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é a morte, é a vida, é a morte, é a vida, é a morte,

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16. Abstract  A computer program is presented for the analysis of continuous prismatic folded plate structures, which are circular in plan and may have up to twelve flexible interior diaphragms or supports. The folded plate structure is considered to be an assemblage of orthotropic plate elements that may, in general, be segments of conical frusta, interconnected at longitudinal joints and simply supported at the two ends. Each plate element is idealized by a number of circumferential finite strips. The finite strip method is used to determine the strip stiffness. Interior diaphragms may be defined by flexible beams, and interior supports may be defined by two-dimensional planar frame bents. A direct stiffness harmonic analysis is used to analyze the assembled folded plate system. The interaction forces between the folded plate system and the interior diaphragms or supports are found using a force method by satisfying the required compatibility conditions. Loads and interaction forces may be approximated by up to 100 non-zero terms of the appropriate Fourier series. The final results are found by summing the solutions for the known loads and the redundant forces. Several numerical examples are presented to demonstrate the use of the program. A user's guide and a FORTRAN listing are also appended to the report.			
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