Computer Program for Prismatic Folded Plates with Plate and Beam Elements

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COMPUTER PROGRAM FOR PRISMATIC FOLDED PLATES WITH PLATE AND BEAM ELEMENTS

by

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to

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ABSTRACT

A general computer program has been developed which is capable of analyzing any prismatic cellular or open folded plate structure with transverse diaphragms and planar frames at any section as well as longitudinal beams. The structure may be subjected to surface loads, line loads, concentrated loads as well as known displacements. The solution is based on the finite element method in conjunction with the direct stiffness method. All final nodal displacements, reactions, and internal forces and moments in frame elements and within finite elements are printed out at points selected by the user.

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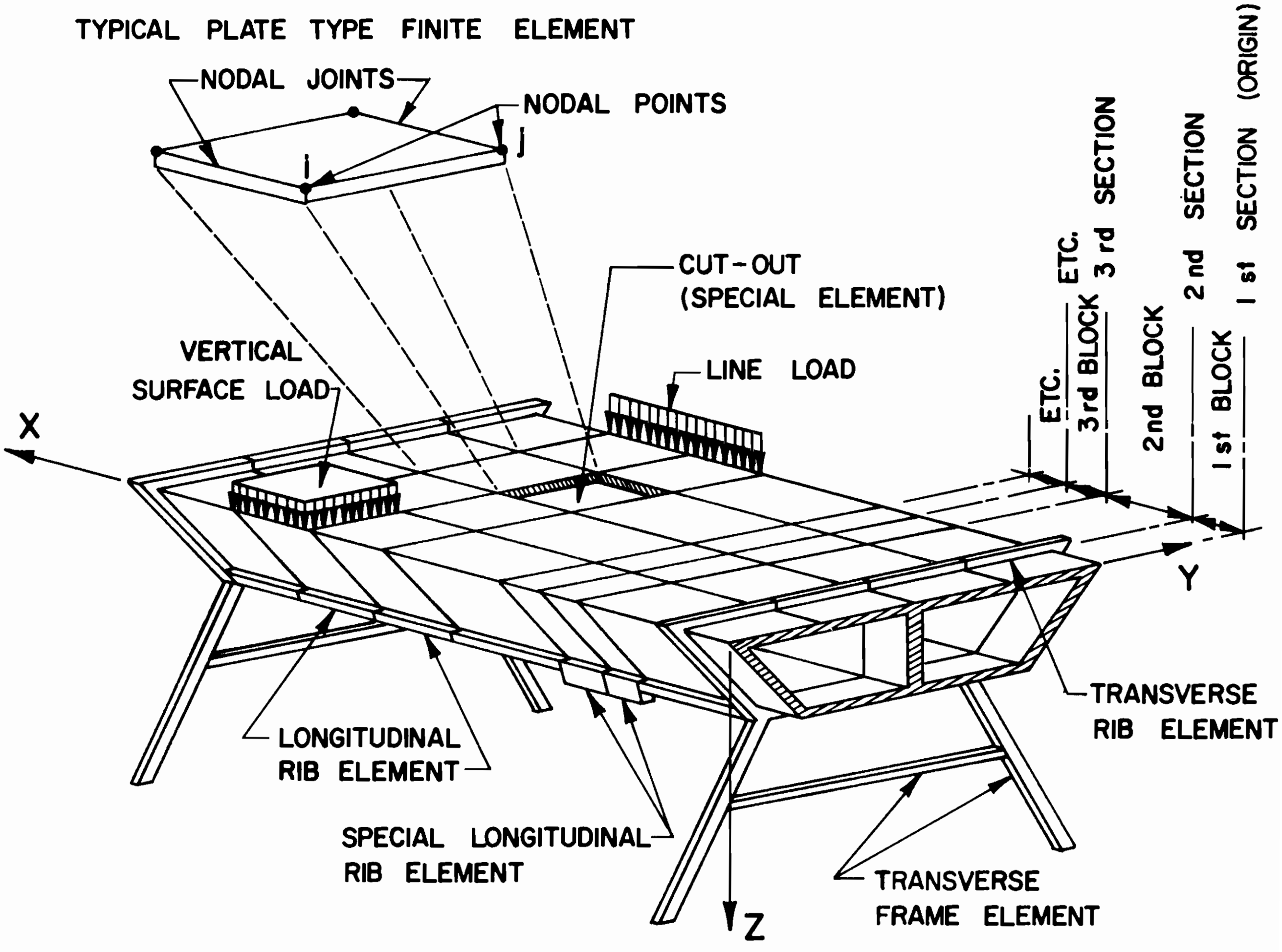
1. INTRODUCTION

The purpose of this report is to present a computer program by means of which it is possible to analyze prismatic structures composed of rectangular plate elements integrated into a three-dimensional frame.

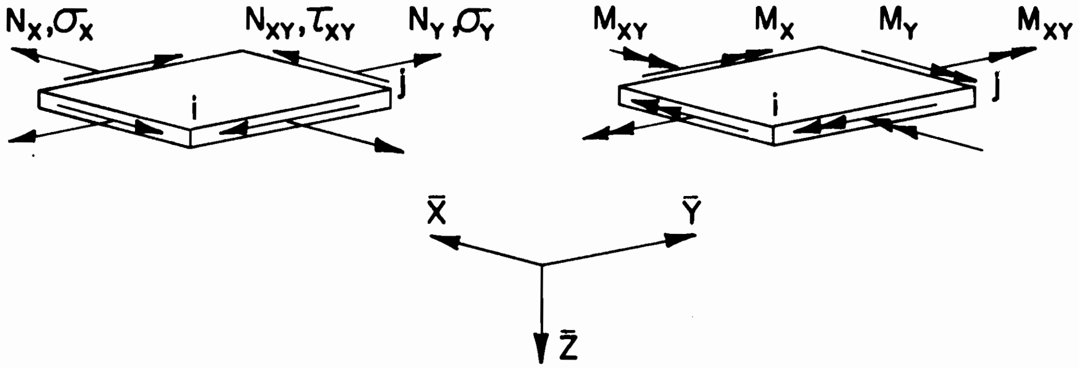
The need for analyzing folded plate or shell structures as well as bridges which are reinforced by transverse or longitudinal ribs as well as transverse diaphragms and single or multiple column bent supports, becomes important whenever it appears that the interaction between the plate structure proper and its supporting structural elements may be of considerable significance for the overall structural behavior of the integrated system. For example the state of stress in a cylindrical shell continuous over transverse rigid frame supports will depend largely on the stiffness of these transverse frames.

Analytically, the problem is extremely difficult, and only the finite element method of analysis seems to be versatile enough to cope with the problem in its broadest sense.

The computer program to be presented below is an extension of the program FINPLA which has been previously reported [2]. In its original version, the program was capable of treating prismatic folded plate structures subjected to any type of loading and boundary conditions. In its present version, it is possible to add transverse diaphragms and beam and column elements at any section of the structure as well as longitudinal ribs or beam elements, Fig. 1.



a) DEFINITIONS OF TERMS



b) INTERNAL FORCES & MOMENTS OF PLATE TYPE FINITE ELEMENT

FIG. 1 TYPICAL PRISMATIC PLATE STRUCTURE

2. METHOD OF ANALYSIS

2.1 Finite Element Analysis

The finite element method has been extensively described in numerous technical papers and textbooks. The rectangular plate finite element used in this analysis has been developed by Abu Ghazeleh [3] and has been described in detail in a report by Scordelis [2].

This finite element is an incompatible displacement model with six degrees of freedom at each of its four corner nodes, three for the in-plane, and three for the plate bending stiffness. The incompability appears as angular discontinuity at the nodes because of the assumed average rotation for the in-plane rotational degree of freedom. Constant strain states and rigid body modes of displacement are included.

For additional information refer to the mentioned references [2] [3].

2.2 Direct Stiffness Method

Once the element stiffnesses have been computed they can be transformed into a common global coordinate system and assembled into the structure stiffness matrix according to the principles of the well-known direct stiffness method. This method applies to two-dimensional elements as well as to one-dimensional beam elements. Care has to be taken only as to where the appropriate stiffness contributions have to be added.

If transverse diaphragms are subdivided into finite elements such that new nodal points are being created, Fig. 6, then the program performs a substructure assembly of the diaphragm stiffness only, and the added degrees of freedom are condensed out by means of a static condensation process before the stiffness contributions of other structural elements are added. By saving the eliminated portion of the diaphragm stiffness matrix on tape, later, after the displacements of all regular nodal points have been calculated, the displacements of the interior diaphragm nodes also can be determined.

2.3 Beam Type Elements

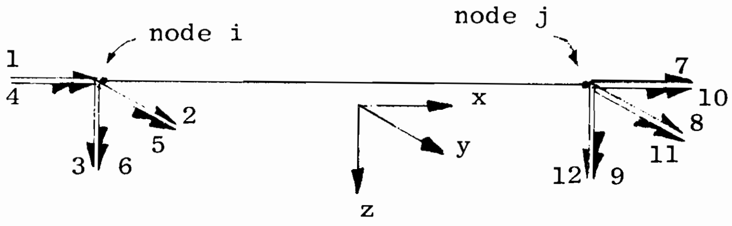
Three different classes of beam type elements are defined:

(1) transverse ribs, which are stiffeners of plate type finite elements and are connected to the nodal points i and j of a plate element as shown in Fig. 2;

(2) transverse frame elements, which may or may not be connected to nodal points already defined by plate type finite elements, Fig. 3;

(3) longitudinal rib elements, which must be connected to any two consecutive nodal points on a longitudinal joint, Fig. 4.

Neglecting shear deformations, the element coordinate stiffness for any beam type element is given on the next page. The twelve degrees of freedom are ordered in accordance with the following numbering scheme in conjunction with a right-hand element coordinate system,



where x is the element axis pointing from node i to node j and y and z are the principal axes of the cross-section.

$$[k] = \left[\begin{array}{cccccccccccc}
\frac{EA}{L} & 0 & 0 & 0 & 0 & 0 & -\frac{EA}{L} & 0 & 0 & 0 & 0 & 0 \\
0 & \frac{12EI_z}{L^3} & 0 & 0 & 0 & \frac{6EI_z}{L^2} & 0 & -\frac{12EI_z}{L^3} & 0 & 0 & 0 & \frac{6EI_z}{L^2} \\
0 & 0 & \frac{12EI_y}{L^3} & 0 & -\frac{6EI_y}{L^2} & 0 & 0 & 0 & -\frac{12EI_y}{L^3} & 0 & -\frac{6EI_y}{L^2} & 0 \\
0 & 0 & 0 & \frac{GJ_x}{L} & 0 & 0 & 0 & 0 & 0 & -\frac{GJ_x}{L} & 0 & 0 \\
0 & 0 & -\frac{6EI_y}{L^2} & 0 & \frac{4EI_y}{L} & 0 & 0 & 0 & \frac{6EI_y}{L^2} & 0 & \frac{2EI_y}{L} & 0 \\
0 & \frac{6EI_z}{L^2} & 0 & 0 & 0 & \frac{4EI_z}{L} & 0 & -\frac{6EI_z}{L^2} & 0 & 0 & 0 & \frac{2EI_z}{L} \\
-\frac{EA}{L} & 0 & 0 & 0 & 0 & 0 & \frac{EA}{L} & 0 & 0 & 0 & 0 & 0 \\
0 & -\frac{12EI_z}{L^3} & 0 & 0 & 0 & -\frac{6EI_z}{L^2} & 0 & \frac{12EI_z}{L^3} & 0 & 0 & 0 & -\frac{6EI_z}{L^2} \\
0 & 0 & -\frac{12EI_y}{L^3} & 0 & \frac{6EI_y}{L^2} & 0 & 0 & 0 & \frac{12EI_y}{L^3} & 0 & \frac{6EI_y}{L^2} & 0 \\
0 & 0 & 0 & -\frac{GJ_x}{L} & 0 & 0 & 0 & 0 & 0 & \frac{GJ_x}{L} & 0 & 0 \\
0 & 0 & -\frac{6EI_y}{L^2} & 0 & \frac{2EI_y}{L} & 0 & 0 & 0 & \frac{6EI_y}{L^2} & 0 & \frac{4EI_y}{L} & 0 \\
0 & \frac{6EI_z}{L^2} & 0 & 0 & 0 & \frac{2EI_z}{L} & 0 & -\frac{6EI_z}{L^2} & 0 & 0 & 0 & \frac{4EI_z}{L}
\end{array}\right]$$

Beam Element Stiffness Matrix

For a transverse rib element, whose axis by definition is parallel to the i-j edge of a plate element, and which has the eccentricities of connection and the rotation of the element principal axes shown in Fig. 2, the transformation from element to global coordinates is given by

$$\begin{Bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{Bmatrix} = \begin{bmatrix} 0 & ca & sa & -e_{\bar{z}} & -e_{\bar{x}}\ sa & e_{\bar{x}}ca \\ -cp & -sa \cdot sp & ca \cdot sp & 0 & -s\ ca \cdot \cos\gamma & -s\ sa \cdot \cos\gamma \\ sp & -sa \cdot cp & ca \cdot cp & 0 & -s\ ca \cdot \sin\gamma & -s\ sa \cdot \sin\gamma \\ 0 & 0 & 0 & 0 & ca & sa \\ 0 & 0 & 0 & -cp & -sa \cdot sp & ca \cdot sp \\ 0 & 0 & 0 & sp & -sa \cdot cp & ca \cdot cp \end{bmatrix} \begin{Bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \\ r_6 \end{Bmatrix}$$

in which

$$sa = \sin\alpha \qquad ca = \cos\alpha$$

$$sp = \sin\varphi \qquad cp = \cos\varphi$$

$$s = \sqrt{e_{\bar{x}}^2 + e_{\bar{z}}^2}$$

$$\gamma = \text{arc tan}\ \frac{e_{\bar{x}}}{e_{\bar{y}}} - \varphi$$

Writing the above transformation as

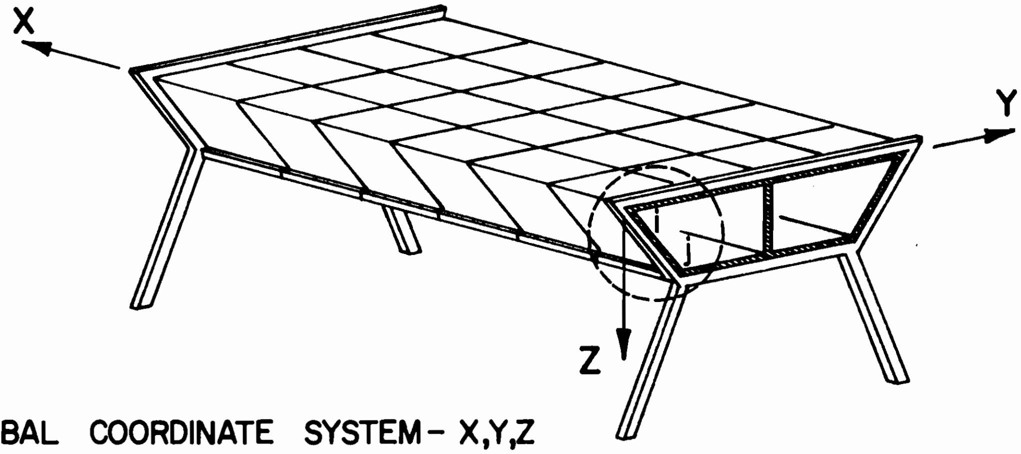
$$\{v_i\} = [a_i]\ \{r_i\}$$

the element stiffness in global coordinates becomes

$$[\bar{k}] = [a]^T\ [k]\ [a]$$

with

$$[a] = \begin{bmatrix} a_i & 0 \\ 0 & a_i \end{bmatrix}$$



GLOBAL COORDINATE SYSTEM – X,Y,Z

PLATE ELEMENT COORDINATES – $\bar{x},\bar{y},\bar{z}$

RIB ELEMENT AXIS – x

PRINCIPAL AXES OF RIB – y , z

ECCENTRICITIES OF CONNECTION $e_{\bar{x}}$, $e_{\bar{z}}$

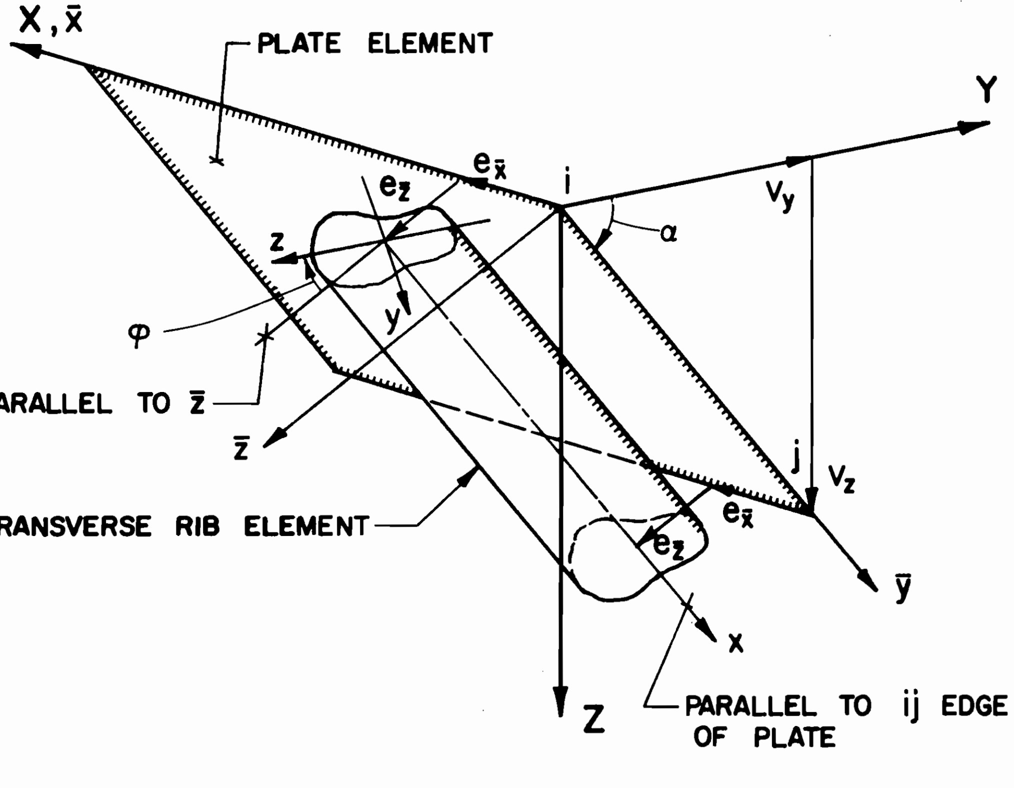


FIG. 2 TRANSVERSE RIB ELEMENT CONNECTED TO NODAL POINTS i & j OF PLATE SYSTEM

For a transverse frame element whose axis by definition lies in a plane normal to the span direction, X , Fig. 3, the transformation matrix becomes

$$\begin{Bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{Bmatrix} = \begin{bmatrix} 0 & ca & sa & s_1 & -e_x \cdot sa & e_x ca \\ -cp & -sa \cdot sp & ca \cdot sp & s_2 \cdot sp & -ca(e_y cp + e_x sp) & -sa(e_y cp + e_x sp) \\ sp & -sa \cdot cp & ca \cdot cp & s_2 \cdot cp & ca(e_y sp - e_x cp) & sa(e_y sp - e_x cp) \\ 0 & 0 & 0 & 0 & ca & sa \\ 0 & 0 & 0 & -cp & -sa \cdot sp & ca \cdot sp \\ 0 & 0 & 0 & sp & -sa \cdot cp & ca \cdot cp \end{bmatrix} \begin{Bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \\ r_6 \end{Bmatrix}$$

or simply,

$$\{v_i\} = [a_i]\ \{r_i\}$$

with the abbreviations

$$sa = \sin \alpha \qquad ca = \cos \alpha$$

$$sp = \sin \varphi \qquad cp = \cos \varphi$$

$$s_1 = \sqrt{e_y^2 + e_z^2}\ [\sin(\alpha - \gamma)]$$

$$s_2 = \sqrt{e_y^2 + e_z^2}\ [\cos(\alpha - \gamma)]$$

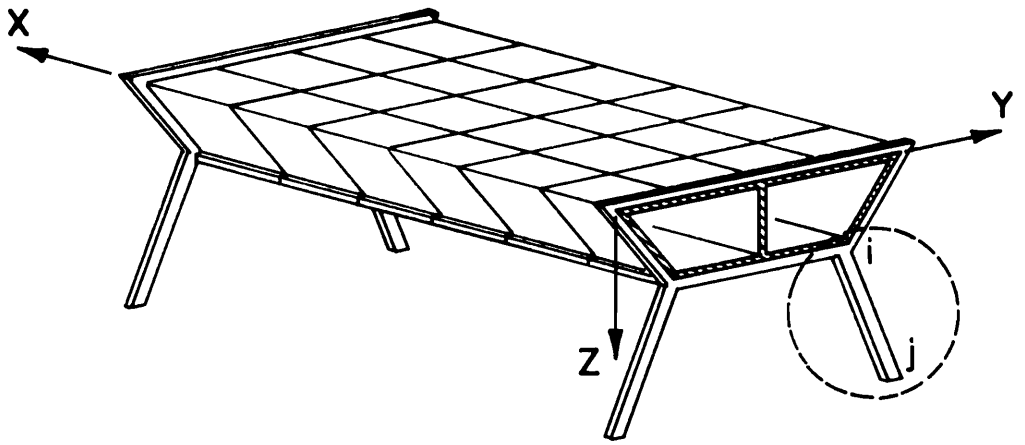
$$\gamma = \arctan \frac{e_z}{e_y}$$

The global element stiffness in this case is

$$[\bar{k}] = [a]^T\ [k]\ [a]$$

with

$$[a] = \begin{bmatrix} a_i & 0 \\ 0 & a_j \end{bmatrix}$$



GLOBAL COORDINATE SYSTEM – X, Y, Z

FRAME ELEMENT AXIS – x

PRINCIPAL AXES OF FRAME ELEMENT – y, z

ECCENTRICITIES OF CONNECTION – e_x, e_y, e_z

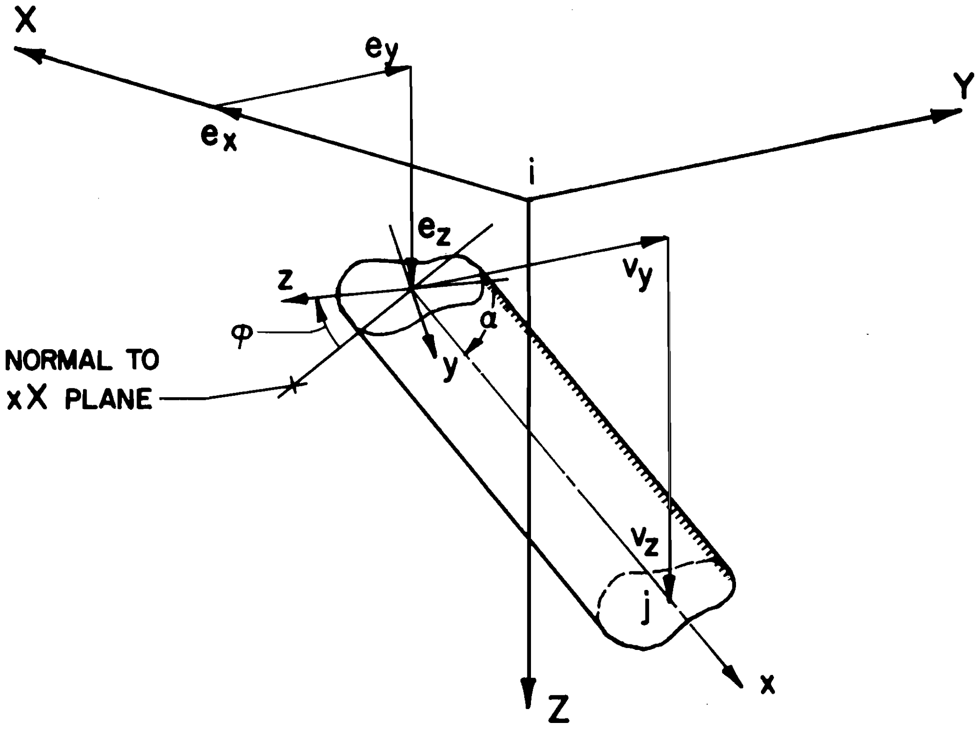


FIG. 3 TRANSVERSE FRAME ELEMENT CONNECTED TO NODAL POINT i OF PLATE SYSTEM

where $[a_j]$ is the degenerate case of $[a_i]$ with $e_X = e_Y = e_Z = 0$.

For a longitudinal rib element whose longitudinal axis by definition is parallel to the global X axis, Fig. 4, the transformation matrix is given by

$$\begin{Bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & e_Z & -e_Y \\ 0 & \cos\varphi & \sin\varphi & -s\sin\alpha & 0 & 0 \\ 0 & -\sin\varphi & \cos\varphi & s\cos\alpha & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & \cos\varphi & \sin\varphi \\ 0 & 0 & 0 & 0 & -\sin\varphi & \cos\varphi \end{bmatrix} \begin{Bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \\ r_6 \end{Bmatrix}$$

in which

$$s = \sqrt{e_Y^2 + e_Z^2}$$

$$\alpha = \text{arc tan}\,\frac{e_Z}{e_Y} - \varphi$$

The global element stiffness is again

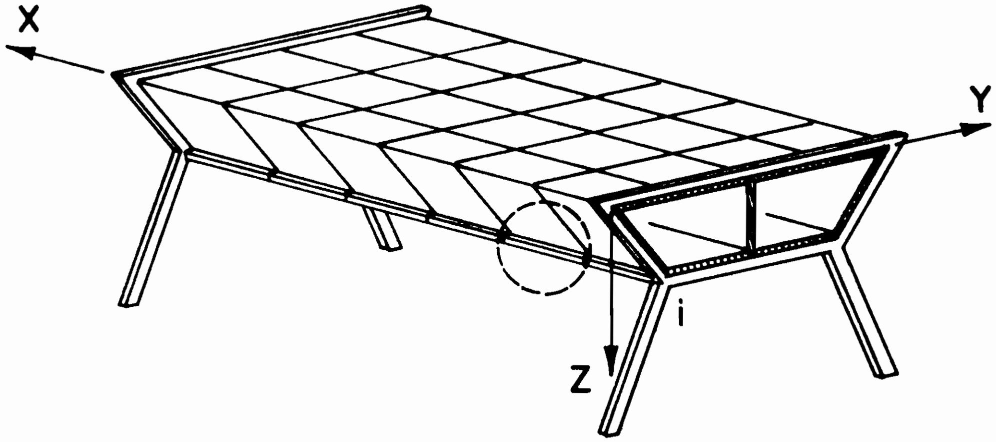
$$[\bar{k}] = [a]^T\,[k]\,[a]$$

with

$$[a] = \begin{bmatrix} a_i & 0 \\ 0 & a_i \end{bmatrix}$$

2.4 Solution Process

The general scheme of the total solution process is illustrated schematically in Fig. 5. In this flow chart it can be seen that the



GLOBAL COORDINATE SYSTEM – X,Y,Z

RIB ELEMENT AXIS – x

PRINCIPAL AXES OF RIB – y,z

ECCENTRICITIES OF CONNECTION – e_y, e_z

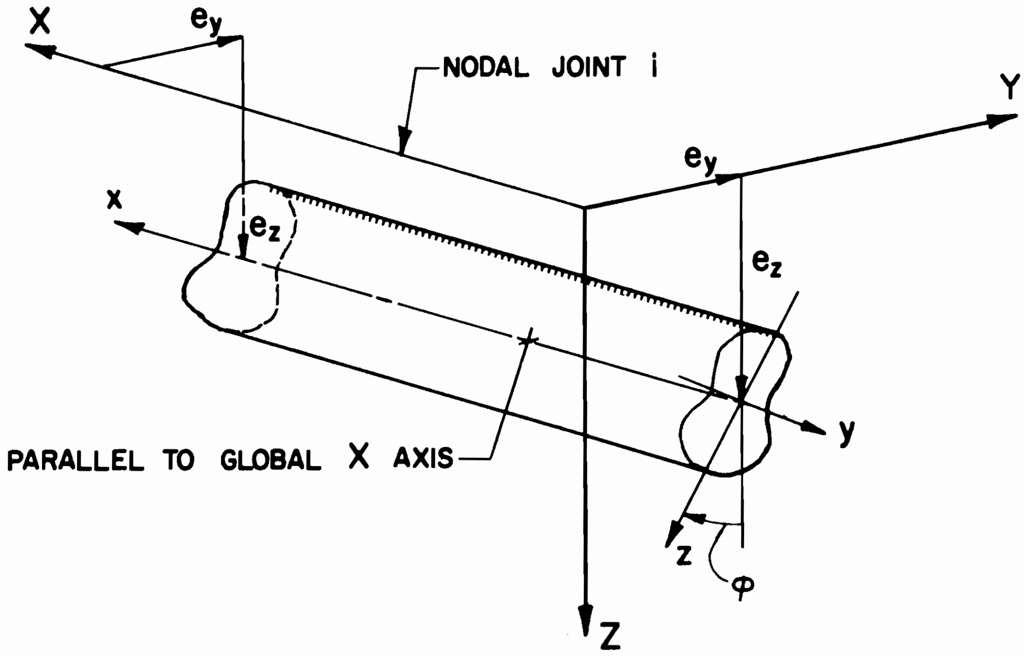


FIG. 4 LONGITUDINAL RIB ELEMENT CONNECTED TO NODAL JOINT i

execution times for multiple load cases are greatly reduced because the structure stiffness has to be reduced only once for the first load case, and the time for reducing additional load vectors and solving for the unknown displacements is small compared to the reduction of the stiffness matrix. The equation solver itself is based on the basic Gauss algorithm and takes advantage of the bandedness of the equations and of zero coefficients within the band. If a complete row of coefficients is zero, for example if a boundary condition has been applied, then this equation is skipped automatically.

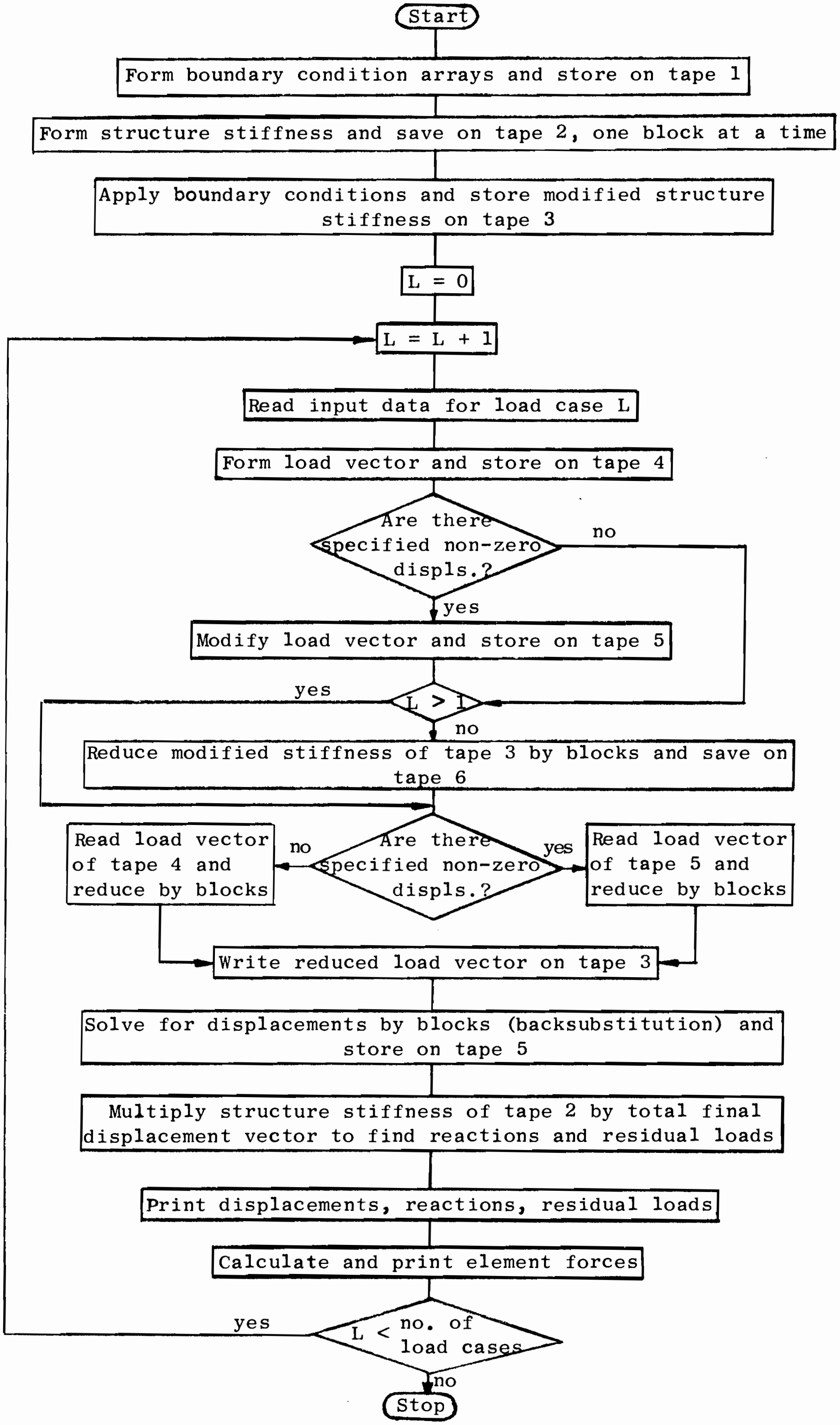


FIG. 5. FLOW CHART OF SOLUTION PROCESS

3. PROGRAM DESCRIPTION

The program has been written in Fortran IV language for the CDC 6400 computer of the Computer Center at Berkeley, California, It consists of one main program called FINPLA and the 13 subroutines INPUT, ELSTIF, TOSTIF, FORMK, STORE, SPECIAL, LOADS, BANSOL, OUTPUT, ELDIS, INTFOS, FL, SSDISK. The order of the subroutines is irrelevant because no overlay system has been utilized. The Fortran listings of the main program and the first 11 subroutines are given in Appendix A together with short descriptions on comment cards at the beginning of each.

Subroutine FL is written in Compass language and serves two purposes. If called as CALL LWA(N), it stores into the number designated by N the last word address of the program, i.e. the storage required by the program, excluding blank common area. If called as CALL RFL(M), it resets the field length dynamically. Thus, having calculated the required blank common area, one would set

CALL RFL(M)

where M = N+L

N = program length

L = blank common length

This subroutine adjusts the total storage area for each problem to be analyzed. If for a different computer system, an equivalent subroutine is not available, a fixed amount of blank common has to be calculated as shown in the next chapter, and dimensioned for in the main program.

Subroutine SSDISK is also a Compass subroutine which provides random access to the scratch area of the disk. To open the random file and provide the SSDISK subroutines access to the index and buffer arrays, the routine OPDISK has to be called before calls are made to the other random routines. To write information on the disk, one calls WRDISK, and to read a record which has been written on the disk, one calls RDDISK.

In addition, seven tapes are used for temporary storage purposes.

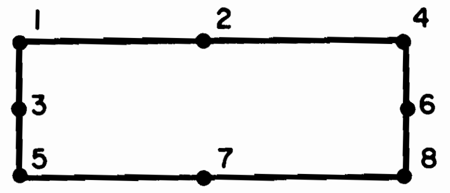
4. PROGRAM USAGE

4.1 Capabilities and Restrictions

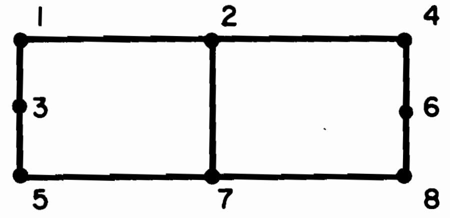
The program has been written primarily for prismatic plate structures which can be described by defining just one longitudinal segment at the origin having a typical cross-section which then repeats itself as one proceeds along the span. For example, defining the first block of the structure shown in Fig. 1a, by specifying its nodal point numbering and finite element configuration, supplies sufficient information to build up the rest of the structure provided the X-coordinates of all sections separating the various structure segments along the span direction are known.

However, variations of the typical or "regular" block are permitted but have to be treated as so-called "special" elements. For example, the cut-out in the 6th block of the structure, Fig. 1a, can be input as a special element with zero thickness or zero elastic modulus.

Transverse diaphragms at up to 10 sections may be assembled out of rectangular finite elements. Several approaches for discretizing the transverse diaphragm of a box beam are illustrated in Fig. 6. In most cases, a diaphragm element will extend either through the total height, Fig. 6b, or through the total width of the diaphragm, Fig. 6c. But the diaphragm may be further subdivided such that additional nodal points are created, Fig. 6d. As long as these additional nodal points are assigned numbers following the last ordinary nodal point number, they will not increase the band width of the structure stiffness matrix.

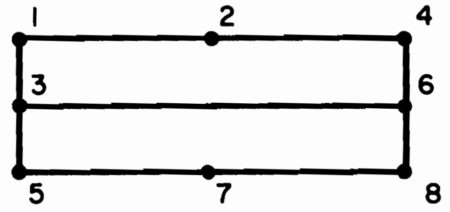


a) NODAL POINT NUMBERING OF PLATE SYSTEM



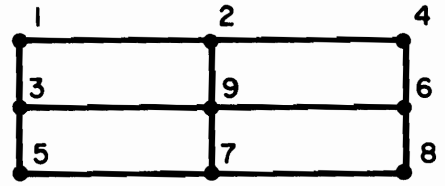
(NODES 3 & 6 NOT CONNECTED TO DIAPHRAGM)

b) TWO ELEMENTS EXTENDING THROUGH TOTAL DIAPHRAGM HEIGHT

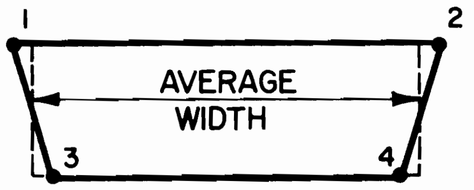


(NODES 2 & 7 NOT CONNECTED TO DIAPHRAGM)

c) TWO ELEMENTS EXTENDING THROUGH TOTAL DIAPHRAGM WIDTH



d) FURTHER DIAPHRAGM SUBDIVISION INTO 4 ELEMENTS



e) APPROXIMATION OF NON-RECTANGULAR DIAPHRAGM ELEMENT

FIG. 6 FINITE ELEMENT IDEALIZATION OF TRANSVERSE DIAPHRAGMS

If the shape of a diaphragm is not rectangular, it may be approximated in some cases using rectangular elements as long as the stiffnesses formed with "average heights" or "average widths" is not much different from those of the actual diaphragm, Fig. 6e.

A planar frame may be assembled at up to 10 sections, using one-dimensional beam elements, which may leave the geometric domain of the plate system (for example free standing columns), thus introducing additional nodal points. Frame elements may also be introduced as braces. If used as stiffeners of plates they are referred to as transverse ribs.

By defining a diaphragm or planar frame at one typical or "regular" section, it is implied that it is repeated identically at all other sections specified as such, unless this implication is overridden by the use of the special element option.

Longitudinal beam elements may be connected to any nodal joints within an arbitrary set of structure segments. Variations of the regular types can be again introduced by the special element option.

These various special element options give the user freedom in defining his structure and permit the treatment of very irregular structures. However, the user must bear in mind that the program becomes less efficient, the less the input system resembles a regular prismatic structure.

The loading may consist of surface loads (dead load, horizontal and vertical load) which are uniformly distributed over a finite element, again implying that the loads specified for some block, are applied to all blocks of the structure, unless this assumption is overridden by the special element option. Line loads along nodal joints between two specified sections and concentrated nodal point loads may be applied anywhere on the structure. But transverse line loads have to be lumped at the nodal points (for example, using the tributary area concept) before being input. Also dead load of diaphragms and beam elements has to be input in the form of concentrated nodal point loads.

Boundary conditions, including nonzero displacements, may be specified for any points on the structure. For a given set of boundary conditions, there is no restriction on the number of load cases that may be analyzed for a given structure. It should be stressed again that the execution time for each additional load case is greatly reduced compared to that for the first load case.

There is no restriction on the number of nodal points within a cross section, but as for limitations regarding maximum number of plate elements, plate types, etc., see the input specifications, Section 4.3.

4.2 Definitions

In order to aid the efficient use of the program, exact definitions of various terms used in this chapter and mainly in the input specifications are summarized below.

Sign Conventions

Use of three right-hand coordinate systems is made: a global, a plate element, and a beam element coordinate system. The global coordinate system, Fig. 1, has its origin at one end of the structure, the X-axis pointing towards the other end, the Z-axis pointing downwards, and the Y-axis following from the right-hand rule. This coordinate system is used for loads, displacements, and plate projections. The $\bar{x}$-axis of the plate element coordinates, Fig. 1, is identical with the global X-axis, the $\bar{y}$-axis points from node i to node j, and the $\bar{z}$-axis follows from the right-hand rule. Internal forces and moments of plate elements are expressed in these coordinates. The x-axis of the beam element coordinates, Figs. 2 and 3, points from node i to node j, or in the case of longitudinal ribs, Fig. 4, along the global X-axis, and the y and z-axes are the principal axes of the element cross section.

Block

A segment cut out of the plate system by two transverse sections, Fig. 1. The block which is repeated often within the structure (the longitudinal width may be variable), may be defined as the regular block.

Section

A plane separating two adjacent blocks or forming the end faces of the structure and containing all nodal points in this plane. Note that $N_{\text{sections}} = N_{\text{blocks}} + 1$.

Finite Element

A rectangular element whose position within the structure is defined by two nodal joints i and j, and by its block between two consecutive sections.

Nodal Point

A point at which finite elements or beam elements are interconnected. Each nodal point is assigned a number in a regular section. A nodal joint is the line parallel to the global X-axis and passing through a nodal point. There is no limit on the maximum number of nodal points.

Bandwidth

The bandwidth of the structure stiffness matrix is a function of the number of nodal points in a section and of the maximum nodal point difference in a regular finite element, but independent of the nodal point difference in beam and diaphragm elements. The nodal points should be numbered such as to keep the maximum difference within an element at a minimum.

Finite Element Type

A finite element characterized by its horizontal and vertical projections, V_Y and V_Z, within a section, Fig. 2, by its thickness and material properties, but not by its length along the span.

Rib Element

One-dimensional beam element connecting two nodal points pre-defined by plate finite elements. A transverse rib element has an x-axis which lies in a transverse section and is parallel to the i-j edge of the associated plate type finite element connecting the same two nodal points, Fig. 2. A longitudinal rib belongs to a specified block and must be associated with the nodal joint to which it is connected, Fig. 4.

Frame Element

One-dimensional beam element lying in the plane of a transverse section (or at some eccentricity parallel to it) and connecting any two nodal points which may or may not be predefined by the plate system (for example, columns), Fig. 3.

Beam Element Connections

The end points of transverse ribs may be eccentric with respect to the nodal points in the $\bar{x}$ and $\bar{z}$-directions, and the element principal axes may be rotated about an angle, φ , Fig. 2. Both ends must have the same eccentricities. If a frame element is connected with one end point to the plate system, this end point should be node i and may be eccentric in the X , Y , and Z-directions, and the principal axes may be rotated, Fig. 3. A longitudinal rib may be connected to a nodal joint with eccentricies in the Y and Z-directions, and the principal axes may be rotated, Fig. 4. Both ends must have the same eccentricities.

Beam Element Type

A beam element type is characterized by its section properties, eccentricities of connection, and orientation within a section or block.

Diaphragm

An assembly of rectangular finite elements within any designated section. The creation of additional interior nodal points by subdividing the diaphragm is permissible, Fig. 11b.

Special Element

A one- or two-dimensional element with a different type than the corresponding element in the regular block, diaphragm, or frame; for example, if the material or section properties are different, Fig. 1.

Applied Group Displacement

A specified displacement component applied simultaneously to a designated group of nodal points of a given section.

Prescribed Line Displacement

A specified displacement component applied simultaneously to all nodal points along a given nodal joint between two designated sections. These two sections may be identical if the displacement is applied to only one nodal point.

4.3 Input Specifications

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 (8A10)

Col. 1 to 80 - Title of problem to be printed with output = TITLE(I)

2) Control Card (F10.3,9I4)

Col. 1 to 10 - Span length = SPAN

Col. 11 to 14 - Number of finite element types = NFEL, max. = 90

Col. 15 to 18 - Number of nodal points in typical cross section = NPTS Do not count points created by subdividing transverse diaphragms, but count all those created by any frame elements. No restriction on maximum number.

Col. 19 to 22 - Number of blocks along x-axis = NUMELX, max. = 40

Col. 23 to 26 - Number of finite elements in one block = NUMELY, max. = 30

Col. 27 to 30 - Number of sections with transverse ribs = NTRIB, max. = 20

Col. 31 to 34 - Number of blocks with longitudinal ribs = NLRIB, max. = 40

Col. 35 to 38 - Number of sections with frames = NFRAME, max. = 10

Col. 29 to 42 - Number of sections with diaphragms = NDIAPH, max. = 10

3) X-Coordinate Cards (10F7.2)

X-Coordinates of sections along X-axis = XS(I)

Start with the origin X = 0.0.

If there are more than 10 sections, use second card.

4) Plate Element Type Cards (7X,I3,5F10.3) - One Card for Each Type

Col. 8 to 10 - Type number = I

Col. 11 to 20 - Horizontal projection = H(I)

Col. 21 to 30 - Vertical projection = V(I)

Col. 31 to 40 - Thickness = TH(I)

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

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

5) Plate Element Cards (4I4) - One Card for Each Element in Regular Block

Col. 1 to 4 - Element number = I

Col. 5 to 8 - Nodal point I = NPI(I)

Col. 9 to 12 - Nodal point J = NPJ(I)

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

6) <u>Special Plate Element Indicator Card</u> (7X,I3)

Col. 8 to 10 - Number of special elements with plate types different from those of the corresponding elements in the regular block = NPE, max. = 60

7) <u>Special Plate Element Cards</u> (4I4) - One Card for Each Special Element - No Cards Required if No Such Elements

Col. 1 to 4 - Special element number = I

Col. 5 to 8 - Number of corresponding element in regular block = NFL(I)

Col. 9 to 12 - Block number = IBLK(I)

Col. 13 to 16 - Type number for this special element = IPET(I)

8) <u>Transverse Rib Cards</u> - No Cards Required if No Such Ribs

First Card (3I4)

Col. 1 to 4 - Number of transverse rib element types = NTRT, max. = 60

Col. 5 to 8 - Number of transverse rib elements at regular section with such ribs = NTRE, max. = 30

Col. 9 to 12 - Number of special transverse rib elements = NTRS, max. = 30

Second Card (10I3)

Numbers of sections with transverse ribs = NSTR(I) - Use second card if necessary

Transverse Rib Element Type Cards (2I5,7F10.3) - One Card for Each Type

Col. 1 to 5 - Type number = I

Col. 6 to 10 - Corresponding plate element type number = NPT(I)

Col. 11 to 20 - Eccentricity of connection in global X-direct.= ETX(I)

Col. 21 to 30 - Eccentricity of connection normal to corresponding plate element = FTY(I)

Col. 31 to 40 - Rotation of element principal axes about element x-axis (in radian) = ETR(I)

Col. 41 to 50 - EA, axial rigidity = TREA(I)

Col. 51 to 60 - EI_Y, bending rigidity about local y-axis = TREIY(I)

Col. 61 to 70 - EI_Z, bending rigidity about local z-axis = TREIZ(I)

Col. 71 to 80 - GJ_X, torsional rigidity = TRGJX(I)

Transverse Rib Element Cards (3I4) - One Card for Each Element in Regular Section with Transverse Ribs

Col. 1 to 4 - Rib element number = I

Col. 5 to 8 - Type number = NTRTY(I)

Col. 9 to 12 - Corresponding plate element number = NTRP(I)

Special Transverse Rib Element Cards (4I4) - One Card for Each Special Element - No Cards Required if No Such Elements

Col. 1 to 4 - Special element number = I

Col. 5 to 8 - Number of corresponding element in regular section = NTRSE(I)

Col. 9 to 12 - Section number = NTRSS(I)

Col. 13 to 16 - Type number for this special rib element = NTRST(I)

9) Longitudinal Rib Cards - No Cards Required if No Such Ribs

First Card (3I4)

Col. 1 to 4 - Number of longitudinal rib element types = NLRT, max. = 50

Col. 5 to 8 - Number of longitudinal rib elements in regular block with such ribs = NLRE, max. = 20

Col. 9 to 12 - Number of special rib elements = NLRS, max. = 30

Second Card (20I3)

Numbers of blocks with longitudinal ribs = NBLR(I)

Longitudinal Rib Element Type Cards (7X,I3,7F10.3) - One Card for Each Type

Col. 8 to 10 - Type number = I

Col. 11 to 20 - Eccentricity of beam centroidal axis from nodal joint in global y-direction = FLY(I)

Col. 21 to 30 - Eccentricity of beam centroidal axis from nodal joint in global Z-direction = ELZ(I)

Col. 31 to 40 - Rotation of principal axes about element axis (in radian) = ELR(I)

Col. 41 to 50 - EA, axial rigidity = TLEA(I)

Col. 51 to 60 - EI_Y, bending rigidity about local y-axis = TLEIY(I)

Col. 61 to 70 - EI_Z, bending rigidity about local z-axis = TLEIZ(I)

Col. 71 to 80 - GJ_X, torsional rigidity = TLGJX(I)

Longitudinal Rib Element Cards (3I4) - One Card for Each Element in Regular Block with Longitudinal Ribs

Col. 1 to 4 - Rib element number = I

Col. 5 to 8 - Type number = NLRTY(I)

Col. 9 to 12 - Number of joint to which it is connected = NLRJ(I)

Special Longitudinal Rib Element Cards (4I4) - One Card for Each Special Element - No Cards Required if No Such Elements

Col. 1 to 4 - Special element number = I

Col. 5 to 8 - Number of corresponding element in regular ribbed block = NLRSE(I)

Col. 9 to 12 - Block number = NLRSB(I)

Col. 13 to 16 - Type number for this special rib element = NLRST(I)

10) <u>Frame Cards</u> - No Cards Required if No Frame Elements

First Card (3I4)

Col. 1 to 4 - Number of frame element types = NFT, max. = 40

Col. 5 to 8 - Number of elements in regular frame = NFE, max. = 10

Col. 9 to 12 - Number of special frame elements = NFS, max. = 30

Second Card (10I3)

Numbers of sections with transverse frames = NSF(I)

Frame Element Type Cards (I4,6F6.3,4F10.3) - One Card for Each Type

Col. 1 to 4 - Type number = I

Col. 5 to 10 - Global X-eccentricity of node i connection = EFX(I)

Col. 11 to 16 - Global Y-eccentricity of node i connection = EFY(I)

Col. 17 to 22 - Global Z-eccentricity of node i connection = EFZ(I)

Col. 23 to 28 - Rotation of element principal axes about element axis (in radian) = EFR(I)

Col. 29 to 34 - Horizontal projection of node j with respect to i = FH(I)

Col. 35 to 40 - Vertical projection of node j with respect to i = FV(I)

Col. 41 to 50 - EA, axial rigidity = FEA(I)

Col. 51 to 60 - EI_Y, bending rigidity about local y-axis = FEIY(I)

Col. 61 to 70 - EI_Z, bending rigidity about local z-axis = FEIZ(I)

Col. 71 to 80 - GJ_X, torsional rigidity = FGJX(I)

Frame Element Cards (4I4) - One Card for Each Element in Regular Frame

Col. 1 to 4 - Frame element number = I

Col. 5 to 8 - Type number = NFTY(I)

Col. 9 to 12 - Nodal point i = NFI(I)

Col. 13 to 16 - Nodal point j = NFJ(I)

If one end is connected to the plate system, this end should be called node i.

Special Frame Element Cards (4I4) - One Card for Each Special Element - No Cards Required if No Such Elements

Col. 1 to 4 - Special element number = I

Col. 5 to 8 - Number of corresponding element in regular frame = NFSF(I)

Col. 9 to 12 - Frame number = NFSF(I)

Col. 13 to 16 - Type number for this special frame element = NFST(I)

11) Diaphragm Cards - No Cards Required if No Diaphragms

First Card (3I4)

Col. 1 to 4 - Number of diaphragm element types = NDT, max. = 40

Col. 5 to 8 - Number of elements in regular diaphragm = NDE, max. = 20

Col. 9 to 12 - Number of special diaphragm elements = NDS, max. = 20

Second Card (5I3)

Numbers of sections with diaphragms = NSD(I)

Diaphragm Element Type Cards (7X,I3,5F10.3) - One Card for Each Type

Col. 8 to 10 - Type number = I

Col. 11 to 20 - Element height = DIAH(I)

Col. 21 to 30 - Horizontal width = DIAW(I)

Col. 31 to 40 - Thickness = DIATH(I)

Col. 41 to 50 - Modulus of elasticity = DIAE(I)

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

Diaphragm Element Cards (6I4) - One Card for Each Element of Regular Diaphragm

Col. 1 to 4 - Diaphragm element number = I

Col. 5 to 8 - Type number = NDTY(I)

Col. 9 to 12 - Nodal point i (upper left) = NPID(I)

Col. 13 to 16 - Nodal point j (upper right) = NPJD(I)

Col. 17 to 20 - Nodal point k (lower left) = NPKD(I)

Col. 21 to 24 - Nodal point l (lower right) = NPLD(I)

If additional nodal points are created by diaphragm subdivisions these points are assigned numbers following those assigned to ordinary nodal points defined by plate or frame elements.

Special Diaphragm Element Cards (4I4) - One Card for Each Special Diaphragm Element - No Cards Required if No Such Elements

Col. 1 to 4 - Special element number = I

Col. 5 to 8 - Number of corresponding element in regular diaphragm = NDSE(I)

Col. 9 to 12 - Diaphragm number = NDSD(I)

Col. 13 to 16 - Type number for this special diaphragm element = NDST(I)

12) Internal Force Output Cards

Block Cards (3I4) - One Card for Each Block

Col. 1 to 4 - Block number = I

Col. 5 to 8 - Number of longitudinal subdivisions within individual plate elements for internal force output = NSEGX(I), max. = 4

Col. 9 to 12 - Number of transverse subdivisions within individual plate elements for internal force output = NSEGY(I), max. = 4

Two 0's give no results in that block -

Two 4's give results at 25 (= (4+1)**2) points throughout each element in that block

Diaphragm Cards (3I4) - One Card for Each Diaphragm - No Cards Required if No Diaphragms

Col. 1 to 4 - Diaphragm number = I

Col. 5 to 8 - Number of vertical subdivisions within individual diaphragm elements for internal force output = NSEGV(I), max. = 4

Col. 9 to 12 - Number of horizontal subdivisions within individual diaphragm elements for internal force output = NSEGH(I), max. = 4

13) <u>Applied Group Displacement Cards</u>

First Card (7X,I3)

Col. 8 to 10 - Number of applied group displacements = NTAD, max. = 25

Displacement Component Cards - Each Applied Displacement Component Requires a Set of Two Cards - If All Nodes are Likewise Affected, Only One Card - No cards if NTAD = 0

First Card (4I4,4X,F10.3)

Col. 1 to 4 - Displacement component number = I

Col. 5 to 8 - Component indicator = INDT(I), which is equal to

1 - prescribed displacement in X-direction

2 - prescribed displacement in Y-direction

3 - prescribed displacement in Z-direction

4 - prescribed rotation about X-axis

5 - prescribed rotation about Y-axis

6 - prescribed rotation about Z-axis

Col. 9 to 12 - Number of affected nodal points = NAN(I)
If this equals the total number of nodal points, NPTS (see control card), omit the second card

Col. 13 to 16 - Section number of applied group displacement = NSAD(I)

Col. 21 to 30 - Displacement magnitude = DTIN(I)

Second Card (20I3) - Affected Nodal Points = NAD(I,J)

14) Prescribed Displacement Cards

First Card (7X,I3)

Col. 8 to 10 - Number of prescribed line (or single node) displacements = NPD, max. = 30

Prescribed Displacement Cards (4I4,4X,F10.3) - One Card for Each Prescribed Displacement - No Cards if No Such Prescribed Displacements

Col. 1 to 4 - Nodal joint number = NJPD(I)

Col. 5 to 8 - Number of section where prescribed displacement starts = NSDS(I)

Col. 9 to 12 - Number of section where prescribed displacement ends = NSDE(I) - For a single node displacement the last two entries are identical

Col. 13 to 16 - Component indicator (values as in preceding cards) = INPD(I)

Col. 21 to 30 - Prescribed displacement value = PDIS(I)

15) Load Case Card (7X,I3)

Col. 8 to 10 - Number of load cases for this structure = NLC
No restriction on maximum number

16) Surface Load Cards

First Card (2I4)

Col. 1 to 4 - Number of elements in a block with regular surface loads = NESL

Col. 5 to 8 - Number of elements with other than regular surface loads = NSSL

Element Cards (7X,I3,3F10.3) - One Card for Each Element in Block with Regular Surface Loads - No Cards Required if No Regular Surface Loads

Col. 8 to 10 - Element number = NELSL(I)

Col. 11 to 20 - Dead load (P/plate area) = DL(I)

Col. 21 to 30 - Load in Y-direction (P/vertical projected area) = YL(I)

Col. 31 to 40 - Load in Z-direction (P/horizontal projected area) = ZL(I)

Special Element Cards (2I5,3F10.3) - One Card for Each Element with Other than Regular Surface Loads - No Cards Required if No Such Surface Loads

Col. 1 to 5 - Block number = NBLSL(I)

Col. 6 to 10 - Element number = NSLSL(I)

Col. 11 to 20 - Dead load (P/plate area) = SDL(I)

Col. 21 to 30 - Load in Y-direction (P/vertical projected area) = SYL(I)

Col. 31 to 40 - Load in Z-direction (P/horizontal projected area) = SZL(I)

Dead load of rib, frame, and diaphragm elements has to be input in form of concentrated joint loads (tributary area concept)

17) Distributed and Concentrated Joint Load Cards

First Card (7X,I3)

Col. 8 to 10 - Number of concentrated or distributed line loads along the nodal joints = NCL

For transverse line loads use tributary concept

Load Cards (4I4,4X,F10.3) - One Card for Each Load - No Cards Required if No Such Loads

Col. 1 to 4 - Nodal joint number = NJL(I)

Col. 5 to 8 - Number of section where loading starts = NSA(I)

Col. 9 to 12 - Number of section where loading ends = NSO(I)

For a concentrated joint load the two last entries are identical

Col. 13 to 16 - Component indicator = NID(I), which is equal to

1 - applied load in X-direction

2 - applied load in Y-direction

3 - applied load in Z-direction

4 - applied moment about X-axis

5 - applied moment about Y-axis

6 - applied moment about Z-axis

Col. 21 to 30 - Load intensity = FF(I)

For concentrated load input total value

Repeat the decks 16) and 17) for each load case. Repeat the decks 1) through 17) for the next problem. Two blank cards are added following the last problem in order to terminate the job execution.

4.4 Output Description and Interpretation

The output of each correctly executed job contains the following information:

1) The complete set of input data is printed out with proper headings for an easy check for input errors.
2) The displacements of all nodal points of the structure are printed out and are positive in the global coordinate system defined above.
3) Similarly all reactions are printed out which have nonzero values whenever the corresponding displacement components have been specified as input.
4) As a check on the accuracy of the equation solver, the "residual" loads are printed out, i.e., the quantities

$$R_r = Kr - R$$

where

K = structure stiffness matrix

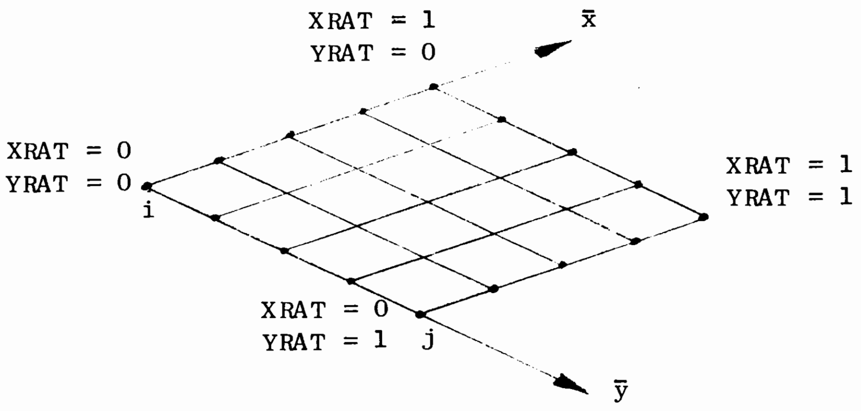
r = final nodal displacement vector

R = input load vector, containing also all calculated reactions

The residuals are theoretically zero and should be practically very small quantities. If they are not very small compared to the input loads, then this will indicate that there must be an error in the input data or that the set of equations is ill-conditioned.

5) For all beam type elements, the end shears V_y and V_z, the axial force S as well as the end moments M_y, M_z, T are printed out grouped according to their classification as longitudinal or transverse rib elements or frame elements.

6) While the user has no option to influence the output mentioned so far, he can determine where to output internal forces and moments in the plate type finite elements. If no results are desired in some block I, zero's have to be input for the quantities NSEGX(I) and NSEGY(I) (see input specifications, section 12). Two 1's give results at the nodal points only. Additional subdivisions may be selected up to NSEGX = NSEGY = 4, in which case results at 25 points will be printed with proper coordinate labels XRAT and YRAT varying from zero to one as shown:

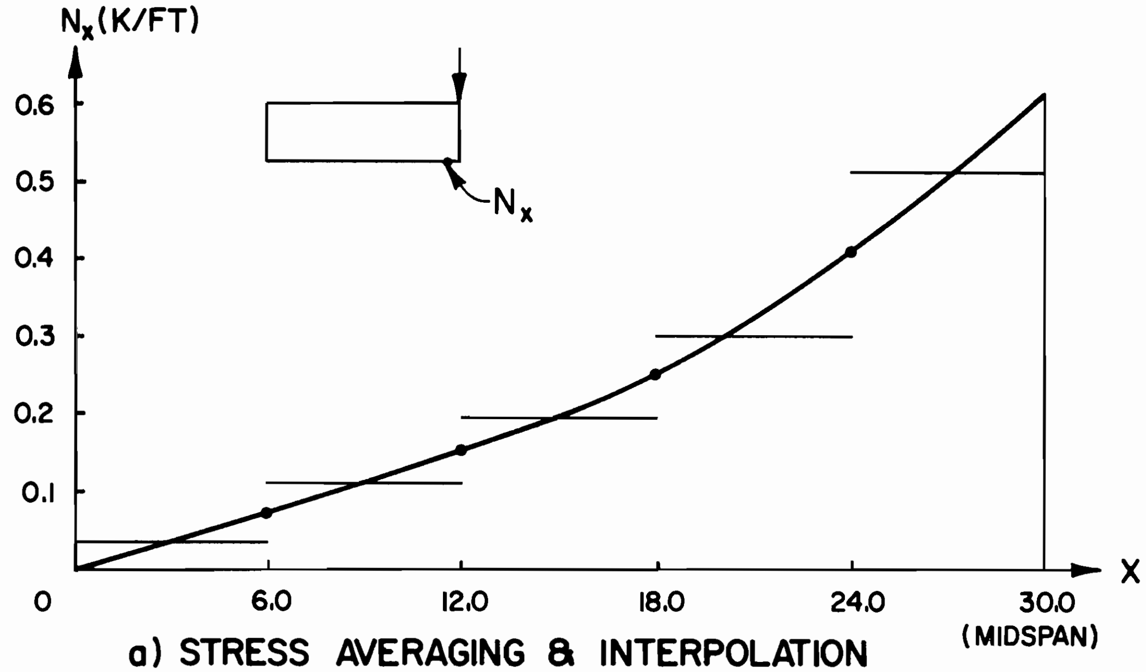


For plate type finite elements the $\bar{x}$-axis is identical with the global X-axis, and for diaphragm elements, the $\bar{x}$-axis points downward.

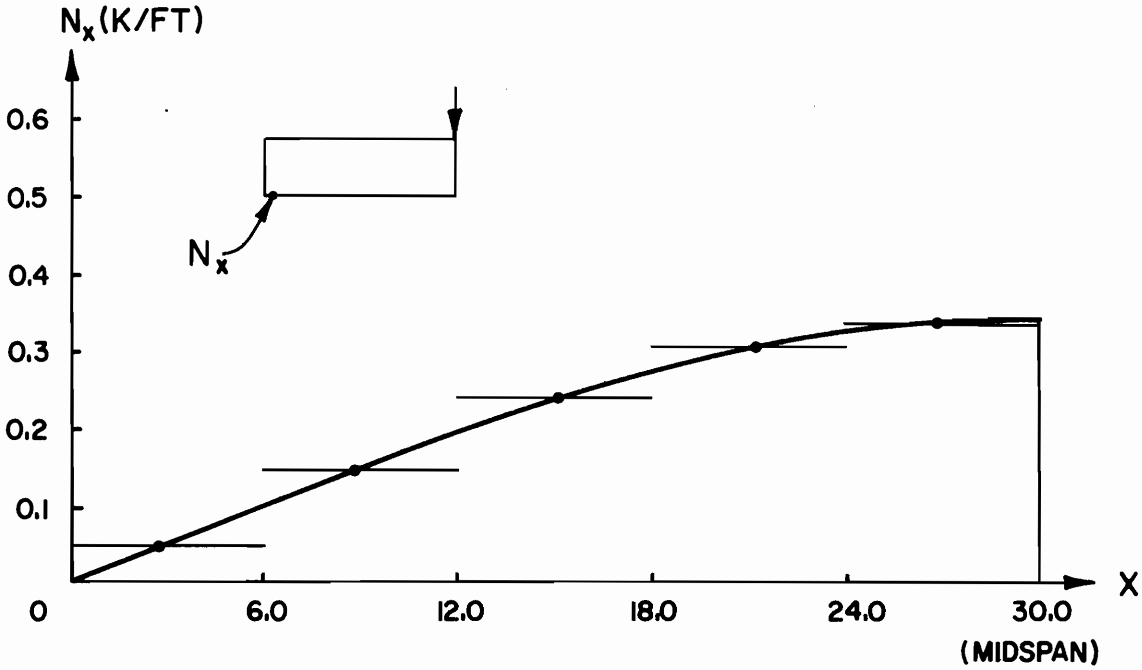
It should be noted, however, that only results along the element edges are meaningful, because of the displacement functions used in deriving the finite element stiffness. Output quantities consist of the three membrane stress resultants N_x , N_y , N_{xy} , and the three bending moments M_x , M_y , M_{xy} as shown in Fig. 1b, as well as the three membrane stresses σ_x , σ_y , τ_{xy} which are just the stress resultants divided by the element thickness.

7) For each executed problem, the elapsed time is printed out separately for (1) input setup and calculation of all element stiffnesses, (2) assembly and modification of the structure stiffness, and then for each load case, (3) load input setup, (4) solution of equations, and (5) calculation of internal forces and output of all results.

The interpretation of output stress resultants in finite elements needs some explanation. Plotting, for example, the direct output of the normal stress resultant N_x in the bottom plate of an eccentrically loaded box girder (see also Example 4, Figs. 11 and 12) longitudinally, the stepped functions of Fig. 7 are obtained with the characteristic jumps between adjacent elements. Due to the selected type of displacement functions, stresses are constant with x , or almost constant, within one element. In striving for a meaningful output evaluation, two methods are recommended, both of which are about equally useful. The first method consists of averaging the stresses between adjacent elements and thence fitting a curve between these averages, Fig. 7a. The other method fits the curve between the mid-element values as



a) STRESS AVERAGING & INTERPOLATION



b) INTERPOLATION OF MID-ELEMENT STRESSES

FIG. 7 INTERPRETATION OF OUTPUT RESULTS

illustrated in Fig. 7b. Both methods require extrapolation of the midspan value which is often of prime interest. Unfortunately, for curves with peaks, the extrapolation is usually so sensitive that it can only supply estimates of the peak values. It might in some cases not even be clear, if the N_x-curve has a positive or a negative curvature at midspan. But the following general rule might be helpful in overcoming this difficulty: The N_x-curve for a girder loaded by a concentrated load has always a peak, Fig. 7a, while for an unloaded girder, it always has a horizontal tangent at midspan, Fig. 7b. If a transverse diaphragm is present at the point of load application, then the curves of all girders tend to have small peaks.

In view of the difficulty of extrapolating important stress quantities, and considering the large amount of tedious work involved, it is recommended that the structure blocks next to a concentrated load or reaction at an interior support be subdivided longitudinally at least once and preferably more often. Not only does the extrapolation procedure become more accurate with this fine mesh, but also, for sufficient subdivisions, the direct output of stress for the last block may already be an acceptable estimate of the actual peak value for practical purposes since the peak itself (theoretically a singularity) has no meaning for practical application. Transversely, the stress discontinuity between elements is much smaller than longitudinally, because stresses vary linearly over the width of one element. Often, there is no discontinuity at all.

Concluding, it must be cautioned that the finite element method on which this program is based, although an efficient numerical tool in solving difficult problems, is only approximate, and careful engineering judgment has to be used in interpreting the results. However, in refining the mesh layout of a given structure, the results are known to converge towards the theoretically correct values.

4.5 Storage Requirements and Execution Time Estimate

Program FINPLA, if compiled by the FUN compiler of the CDC 6400 of the University of California Computer Center, requires together with all subroutines a central memory area of about $67{,}000_8 \approx 28{,}000_{10}$, not counting the blank common area. This additional storage requirement can be calculated as follows.

For the execution of subroutine INPUT,

$$\begin{aligned} \text{COMMON}_1 &= 3*\text{NT} + 25*\text{NPTS} \\ &= (18*\text{NX} + 25)*\text{NPTS} \end{aligned}$$

where

NX = number of sections

NPTS = number of nodal points in a section, counting also all nodes defined by frame elements

For the execution of subroutine FORMK,

$$\begin{aligned} \text{COMMON}_2 &= \text{NL} + \text{NT} + 2*\text{NH} \\ &= \text{NL} + (6*\text{NX} + 24)*\text{NPTS} \end{aligned}$$

where

$$\text{NL} = \text{MAX}\,(6*\text{NPTS}*\text{MB},\ 36*\text{NPTS}'*\text{NPTS}')$$

$$\begin{aligned} \text{MB} &= \text{half bandwidth} \\ &\approx \left(\begin{matrix}\text{max. nodal point difference} \\ \text{for any element}\end{matrix} + \text{NPTS} + 1\right)*6 \end{aligned}$$

$$\text{NPTS}' = \text{NPTS} + \text{all interior nodes of diaphragms}$$

$$\text{If NPTS}' = \text{NPTS, then NL} = 6*\text{NPTS}*\text{MB}$$

For the execution of subroutine BANSOL,

$$\begin{aligned} \text{COMMON}_3 &= \text{NH} + \text{NH*MB} \\ &= \text{12*NPTS*(MB + 1)} \end{aligned}$$

If an automatic change of field length is not desired or possible, the maximum common area required is usually given by (especially if no interior diaphragm nodes are used)

$$\text{COMMON} = \text{12*NPTS*(MB + 1)}$$

which may have to be converted into octal units.

Execution times largely depend on the computer. The estimate given below is based on experience with the CDC 6400. The solution of equations requires approximately

$$T_1 = 2\cdot 10^{-5}(\text{NT})(\text{MB})^2 \text{ seconds} \tag{1}$$

where

NT = total number of nonzero equations

MB = half bandwidth

The larger the system, the larger is also the percentage of total execution time spent in solving the equations. Up to about 70%, this percentage is approximately $p = 40 + T_1$ so that the estimate for the total execution time becomes

$$T_2 = \frac{2\cdot 10^{-5}(\text{NT})(\text{MB})^2}{40 + 2\cdot 10^{-5}(\text{NT})(\text{MB})^2} \cdot 100 \tag{2}$$

For example, a system with 462 equations and a bandwidth of 54 would approximately require

$$T_1 = 2\cdot 10^{-5}(462)(54)^2 \approx 27 \text{ seconds}$$

for solving the equations and

$$T_2 = \frac{27}{40 + 27} \cdot 100 \approx 40 \text{ seconds}$$

for the overall execution. The actual times in an example of this size were 30.3 and 36.4 seconds, respectively.

While the estimate (1) is valid for virtually any size of equation system, the estimate (2) holds only up to about $T_2 = 50$ seconds, because for longer runs, not enough data are available.

5. EXAMPLES

5.1 Plane Stress Problem

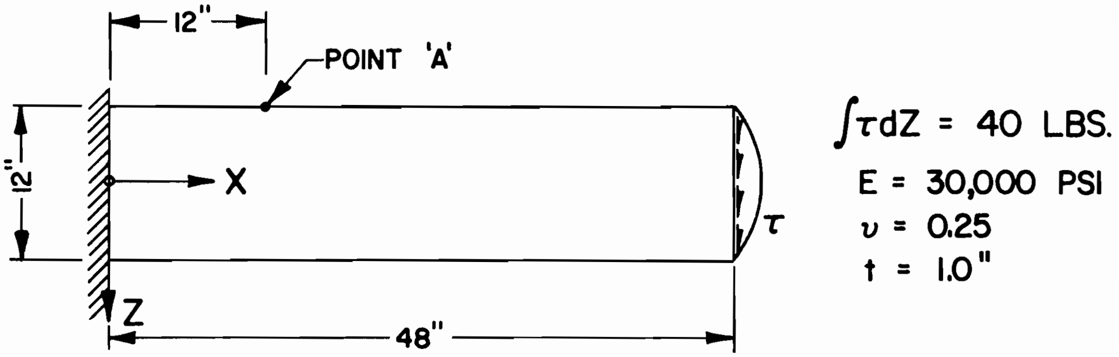
The cantilever of Fig. 8a has been analyzed using the three mesh layouts shown in Fig. 8b. Results are summarized in Table 1.

Table 1. Results for Cantilever, Fig. 8

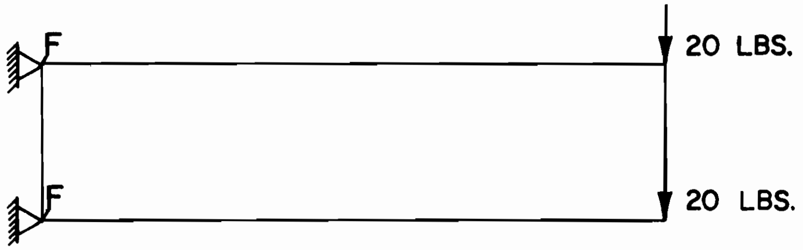
	End Deflection, inch	Top Fibre Stress at Point A, psi
FINPLA, mesh a	0.11906	17.23
FINPLA, mesh b	0.35582	64.92
FINPLA, mesh c	0.35290	62.21
Theoretical Solution (incl. shear deformation)	0.35583	60.00

5.2 Plate Bending Problem

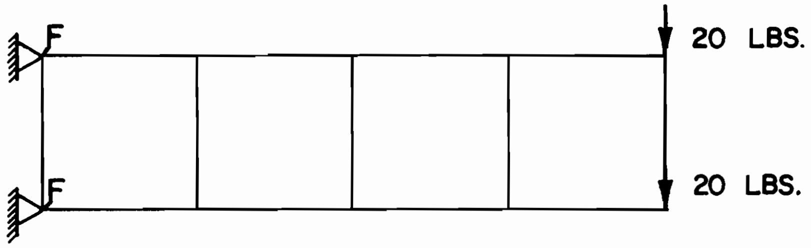
The square plate of Fig. 9a has been analyzed using the four mesh layouts shown in Fig. 9b. The results are summarized in Table 2 and are compared with the theoretical solution [4] as well as with the solution using Felippa's Q19 element [5]. Table 2 presents also the results of analyzing the plate with a hole, Fig. 9c, using the fine mesh idealization. Note that the hole has to be input as a special finite element with zero stiffness and zero loading, and the results given in Table 2 are those for the midside of the hole edge.



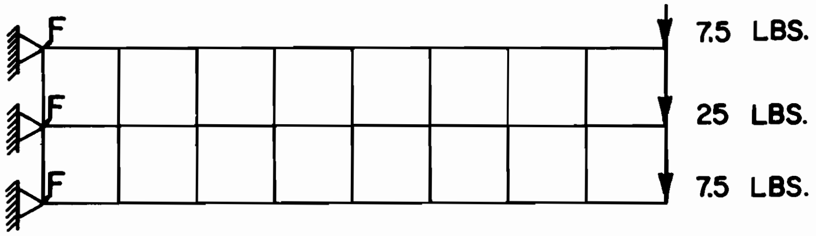
a) CANTILEVER



MESH a – 1 ELEMENT AT 12" x 48"



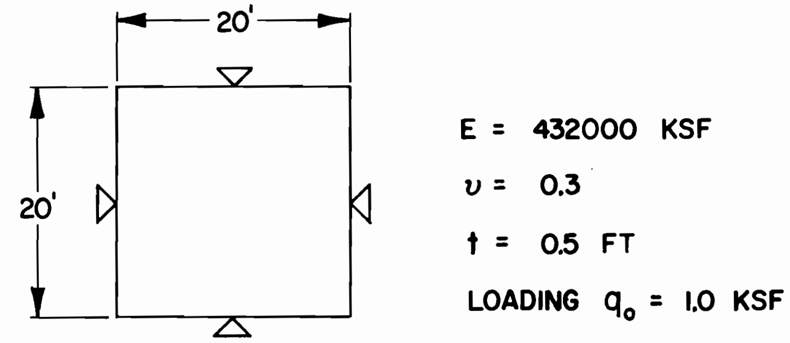
MESH b – 4 ELEMENTS AT 12" x 12"



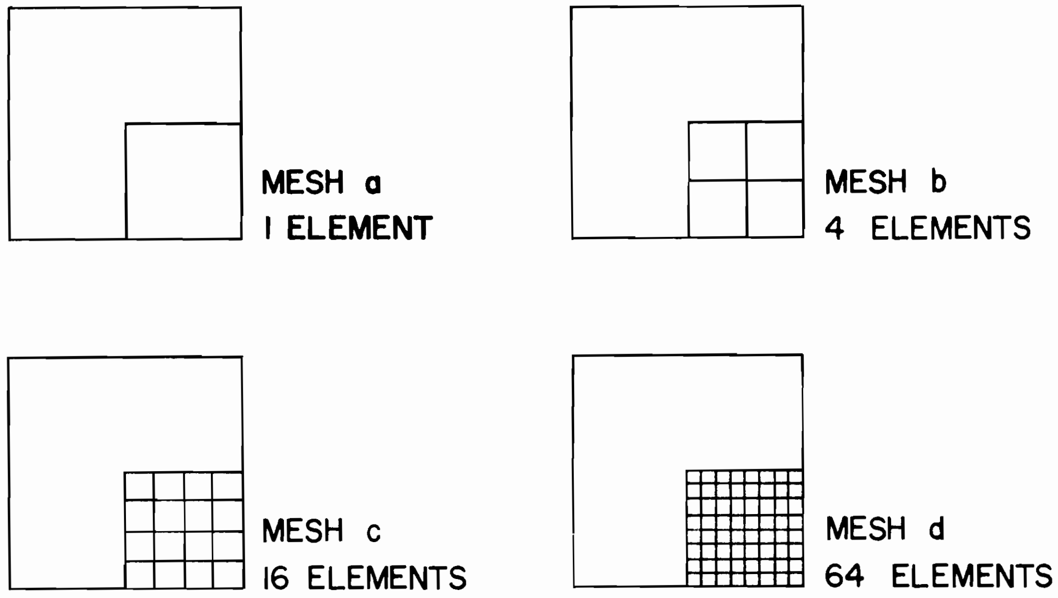
MESH c – 16 ELEMENTS AT 6" x 6"

b) MESH LAYOUTS

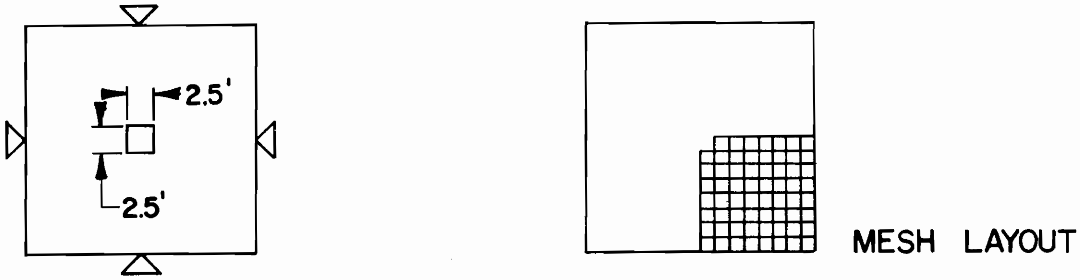
FIG. 8 EXAMPE 1 – PLANE STRESS PROBLEM



a) PLATE SIMPLY SUPPORTED ALONG FOUR SIDES

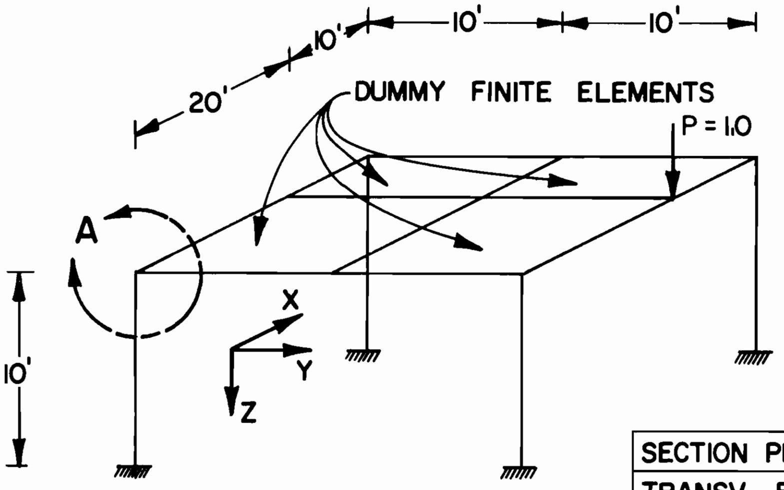


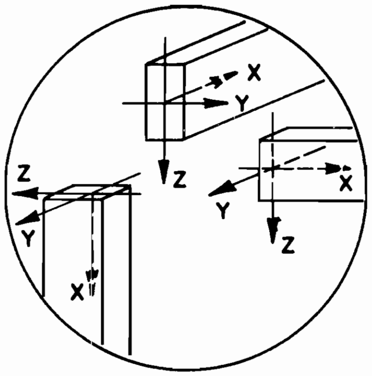
b) MESH LAYOUTS



c) PLATE WITH HOLE

FIG. 9 EXAMPLE 2 - PLATE BENDING PROBLEM



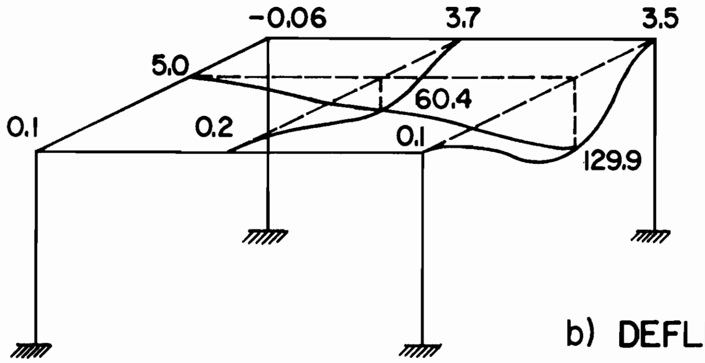


DETAIL A

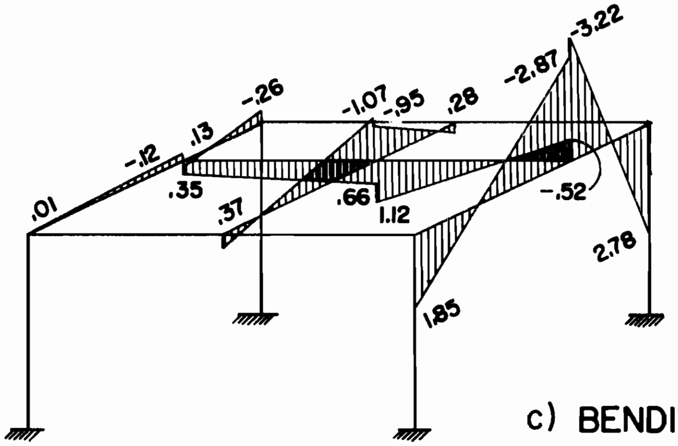
ELEMENT COORDINATES

SECTION PROPERTIES	EA	EI_y	EI_z	GJ_x
TRANSV. BEAMS	2	4	1	1
LONGIT. BEAMS	1	1	0.5	0.5
COLUMNS	2	4	1	1

a) 3-D FRAME



b) DEFLECTIONS



c) BENDING MOMENTS M_y

FIG. 10 EXAMPLE 3 - 3-D FRAME

Table 2. Results for Square Plate, Fig. 9

	Center Deflection, ft	Center Moment, ft-lb
FINPLA, mesh a	0.0774	15.11
FINPLA, mesh b	0.1156	16.18
FINPLA, mesh c	0.1275	18.33
FINPLA, mesh d	0.1304	18.94
Felippa, mesh c	0.1273	18.48
Theoretical Solution	0.1312	19.16
Plate with Hole FINPLA, mesh d	0.1427*)	32.22*)

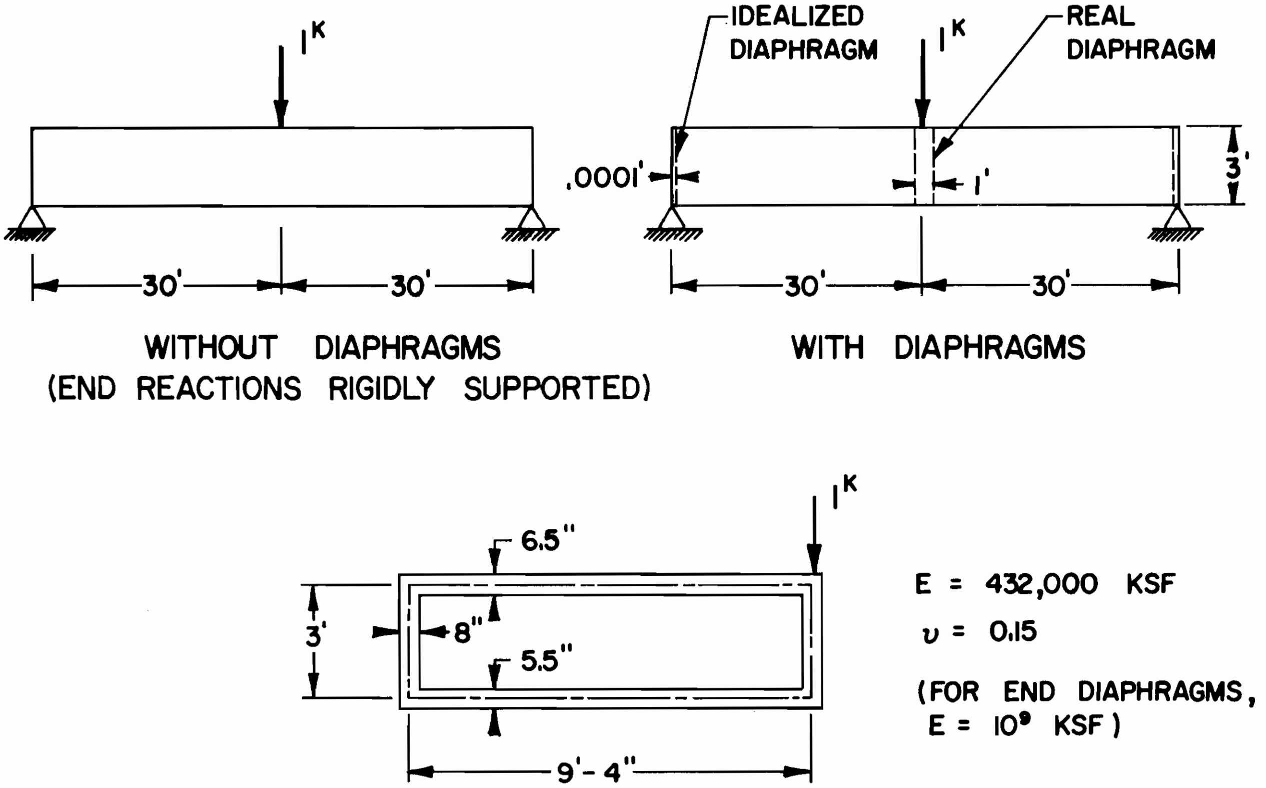
*) at midside of hole edge

5.3 Three-Dimensional Frame

The 3D-frame shown in Fig. 10a has been analyzed with FINPLA by defining dummy finite elements, i.e., elements with zero stiffness. The results, some of which are shown in Fig. 10b and 10c agreed with the results of a standard frame program to all figures that were printed out. Note that by defining the dummy finite elements as shown, this structure is made up of 6 longitudinal rib elements, 6 transverse rib elements, and 4 frame elements, but the transverse beams could also be treated as frame elements if desired.

5.4 Box Girder

The box girder of Fig. 11a has been analyzed with and without diaphragms. The idealized end diaphragms (with zero bending and infinite in-plane stiffness) have been simulated by finite elements with very small thickness and very large elastic modulus. The box with diaphragms

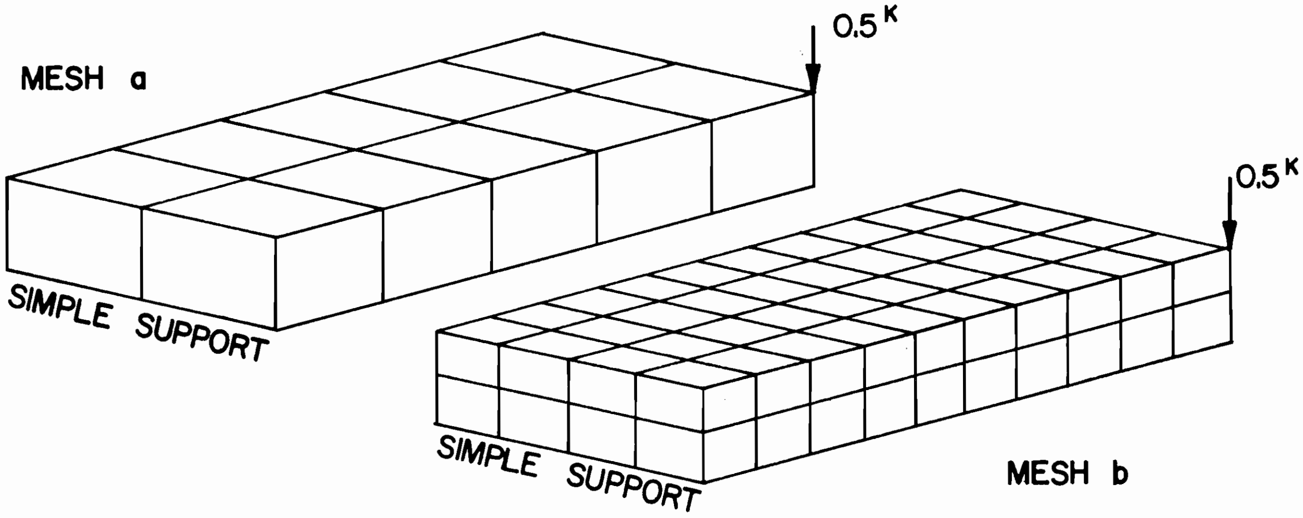


E = 432,000 KSF

ν = 0.15

(FOR END DIAPHRAGMS,
E = 10^9 KSF)

a) BOX GIRDER



b) MESH LAYOUTS FOR HALF STRUCTURE

FIG. 11 EXAMPLE 4 – BOX GIRDER

has been analyzed with several mesh layouts, two of which are shown in Fig. 11b.

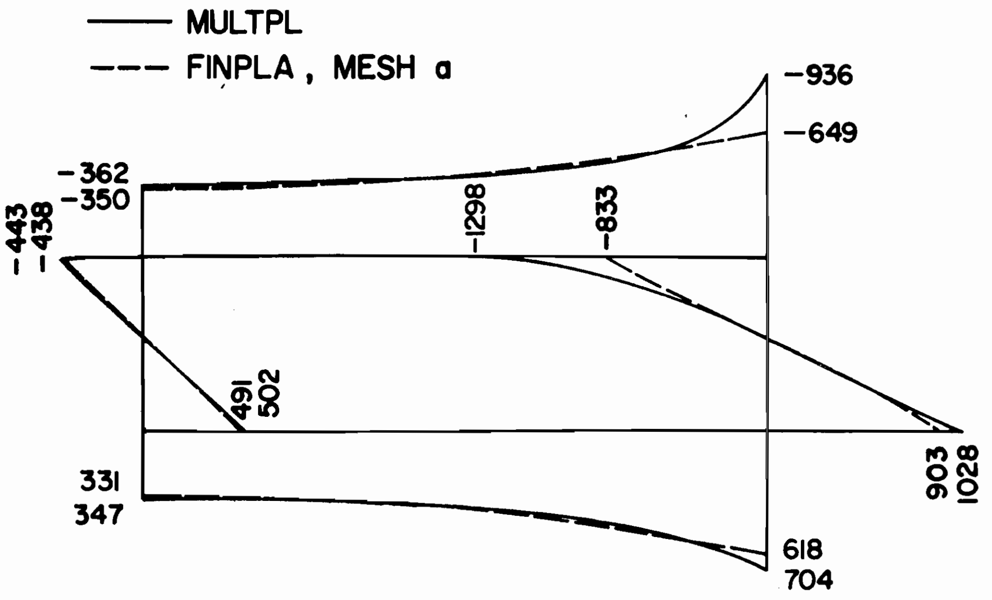
Midspan deflections are summarized in Table 3 and longitudinal stress resultants N_x at midspan are shown in Fig. 12. They have been extrapolated as outlined earlier. For comparison also, the results of two computer programs, MULTPL and MUPDI, are shown. These computer programs are based on the elasticity solution of folded plate structures with or without transverse rigid diaphragms, and have been described elsewhere [1] [2].

Table 3. Midspan Deflections of Box Girder

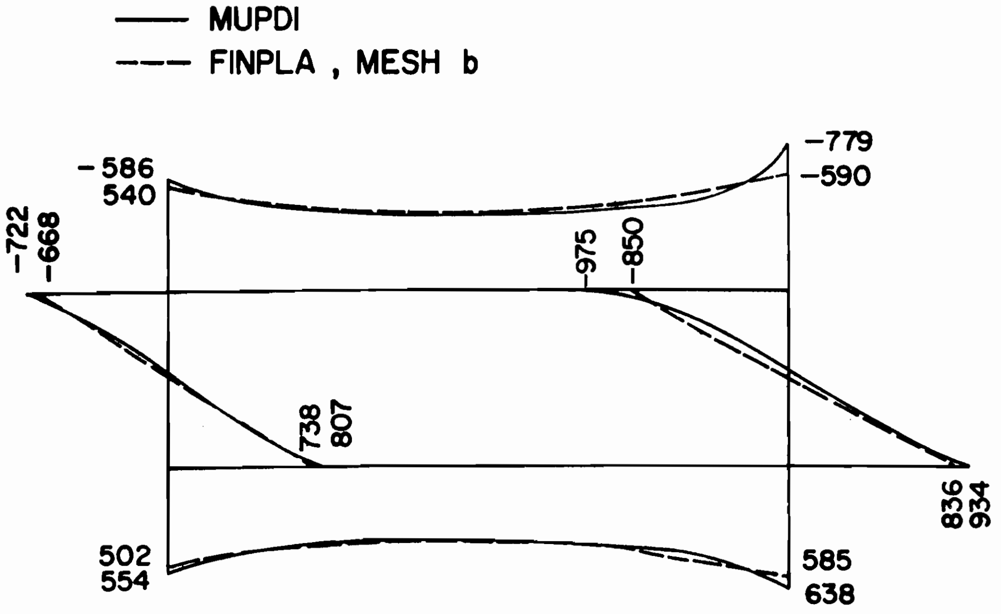
		Midspan Deflection, ft	
		Unloaded Web	Loaded Web
Without Dia-phragms	FINPLA mesh a	$.3957 \cdot 10^{-3}$	$.4887 \cdot 10^{-3}$
	MULTPL	$.4197 \cdot 10^{-3}$	$.5167 \cdot 10^{-3}$
With Diaphragms	FINPLA mesh a	$.4159 \cdot 10^{-3}$	$.4700 \cdot 10^{-3}$
	FINPLA mesh b	$.4353 \cdot 10^{-3}$	$.4906 \cdot 10^{-3}$
	MUPDI	$.4439 \cdot 10^{-3}$	$.4933 \cdot 10^{-3}$

5.5 Two-Span Box Girder Bridge

The continuous box girder bridge shown in Fig. 13 has been analyzed for three load cases: (1) dead load only; (2) a settlement of 1 inch at the base of the center column; and (3) two standard AASHO-trucks positioned as shown in Fig. 13. For the first two load cases, symmetry allows an input of only one quarter of the structure, Fig. 14a, but because of the different boundary condition for the center column, the



a) BOX WITHOUT DIAPHRAGM



b) BOX WITH DIAPHRAGM

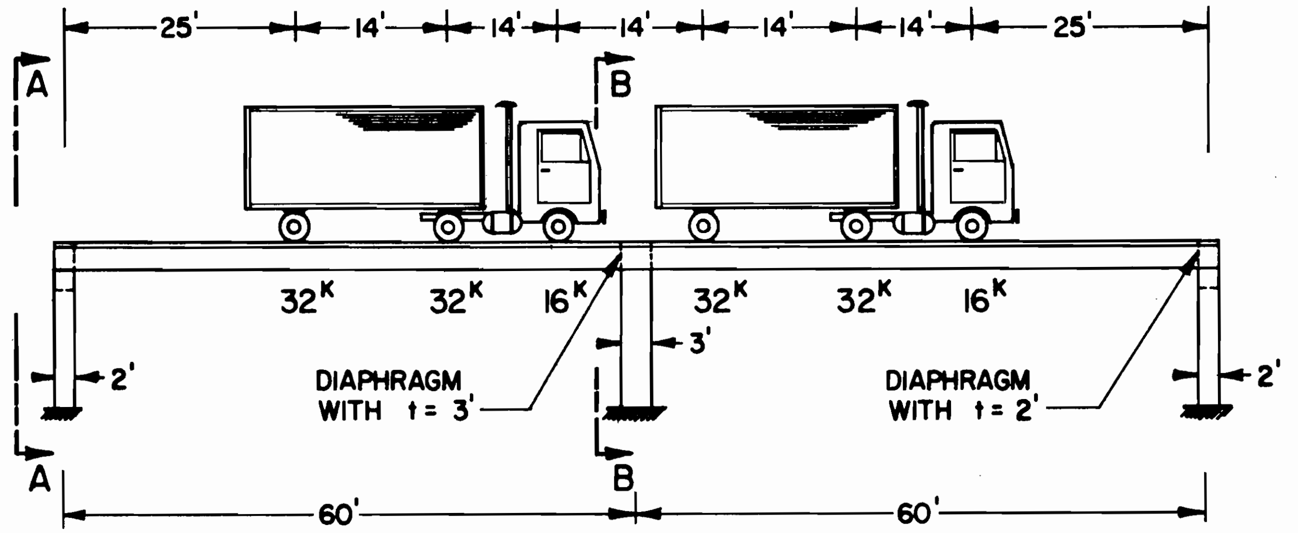
FIG. 12 MIDSPAN RESULTS FOR N_X (K/FT) OF BOX GIRDER multiple load case option cannot be used. For the third load case, the entire bridge has to be input, Fig. 14b. The complete set of input data for the third load case is given in Appendix B. The change in the column arrangement has to be handled by defining dummy columns with zero stiffness as shown in Fig. 14, and by changing the frame element types by use of the special element option.

The trapezoidal diaphragm elements have been approximated with rectangular elements of 10.5 ft. width as discussed earlier.

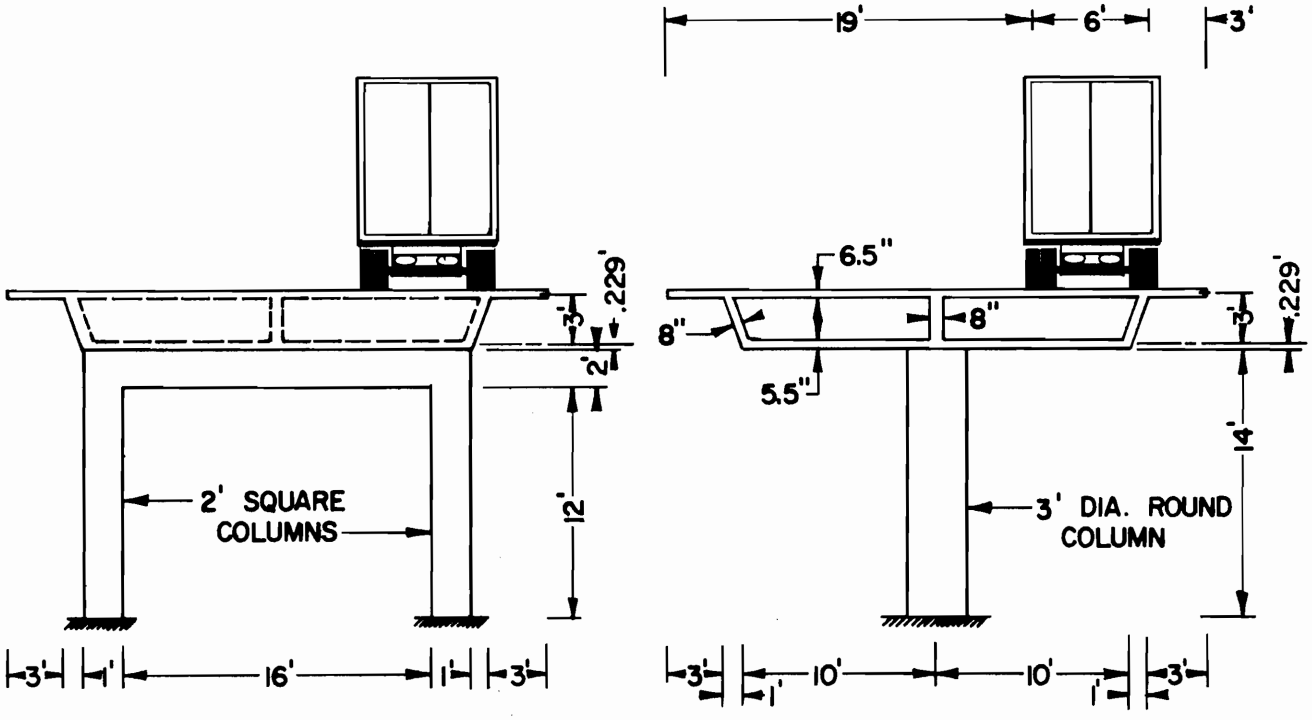
Some results are shown in Figs. 15 and 16. Longitudinal stress resultants N_x are shown for all three load cases at the sections $x = 25$ ft. and $x = 56.5$ ft., which is only 3.5 ft. away from the center support. It is interesting to note that the severe truck loading produces less than half of the dead load stresses, while the one inch settlement of the center column almost cancels the negative support moment. Note that the irregularity of the N_x-distribution at $x = 56.5$ in the top deck is due to the fact that nodal joint 6 is not connected to the diaphragms.

Some vertical deflections have been plotted in Fig. 16. The axial shortening of the columns under dead load is small but visible. Under the truck loading, the diaphragm over the center column undergoes an average rotation of about 0.00037 radian, which causes joint 8 to deflect .0051 ft. over the support. The bending moment in the center column due to the truck loading is 138.1 ft-kip.

The third load case involved the solution of $(12)(19)(6) = 1368$ equations, with a band width of $(2 + 1 + 12)(6) = 90$. The total execution time was 3 minutes 54.0 seconds, of which 166.6 seconds were needed to solve the equations. This surprisingly low figure was due to the



a) ELEVATION

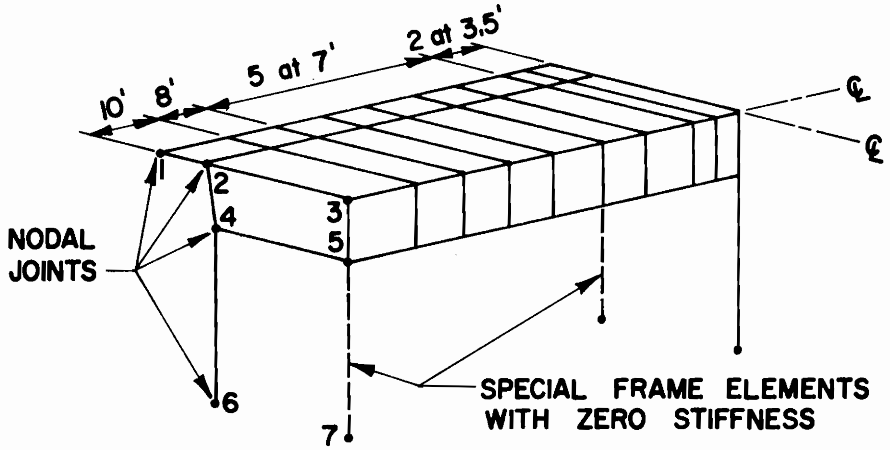


SECTION A-A

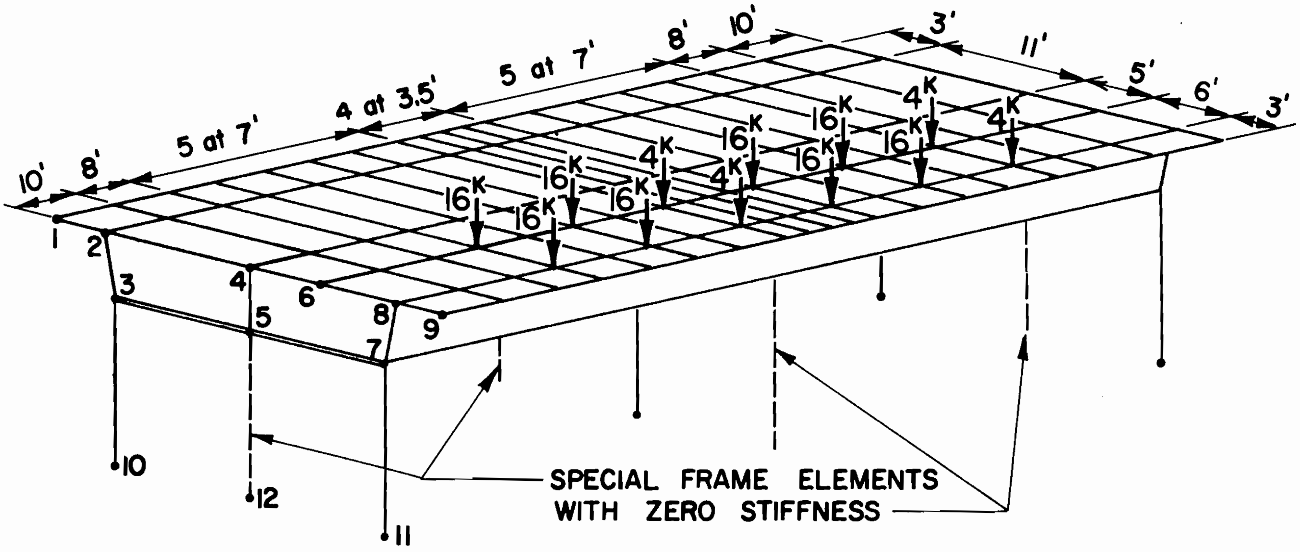
SECTION B-B

b) SECTIONS

FIG. 13 EXAMPLE 5 - BOX GIRDER BRIDGE

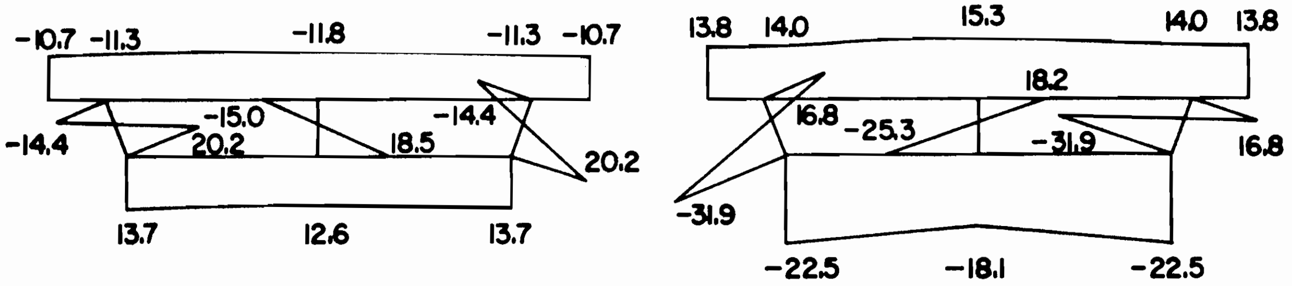


a) QUARTER-STRUCTURE FOR LOAD CASES 1 & 2



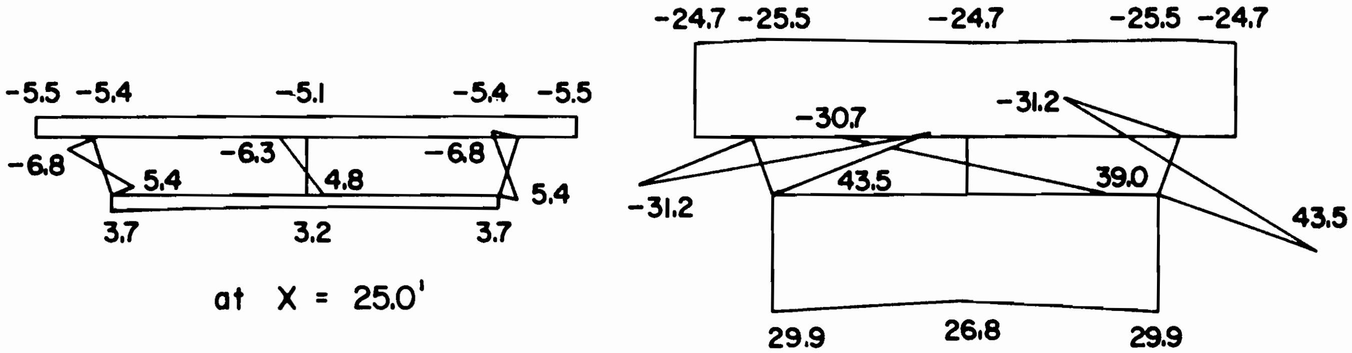
b) FULL STRUCTURE FOR TRUCK LOADING

FIG. 14 MESH LAYOUTS FOR EXAMPLE 5



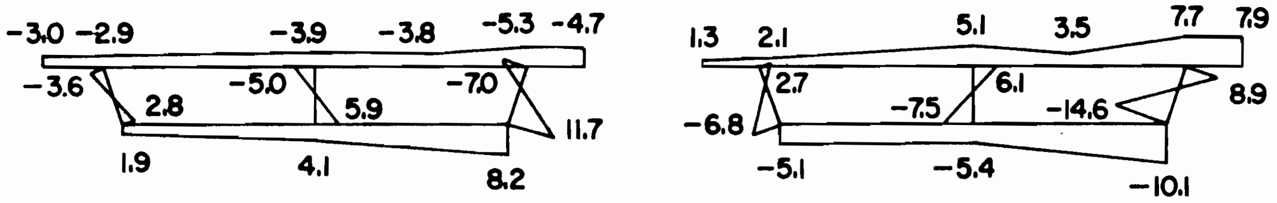
at X = 25.0 at X = 56.5

a) DEAD LOAD



at X = 25.0' at X = 56.5'

b) ONE INCH SETTLEMENT OF CENTER COLUMN



at X = 25.0' at X = 56.5'

c) TRUCK LOADING

FIG. 15 STRESS RESULTANTS N (K/FT) FOR EXAMPLE 5

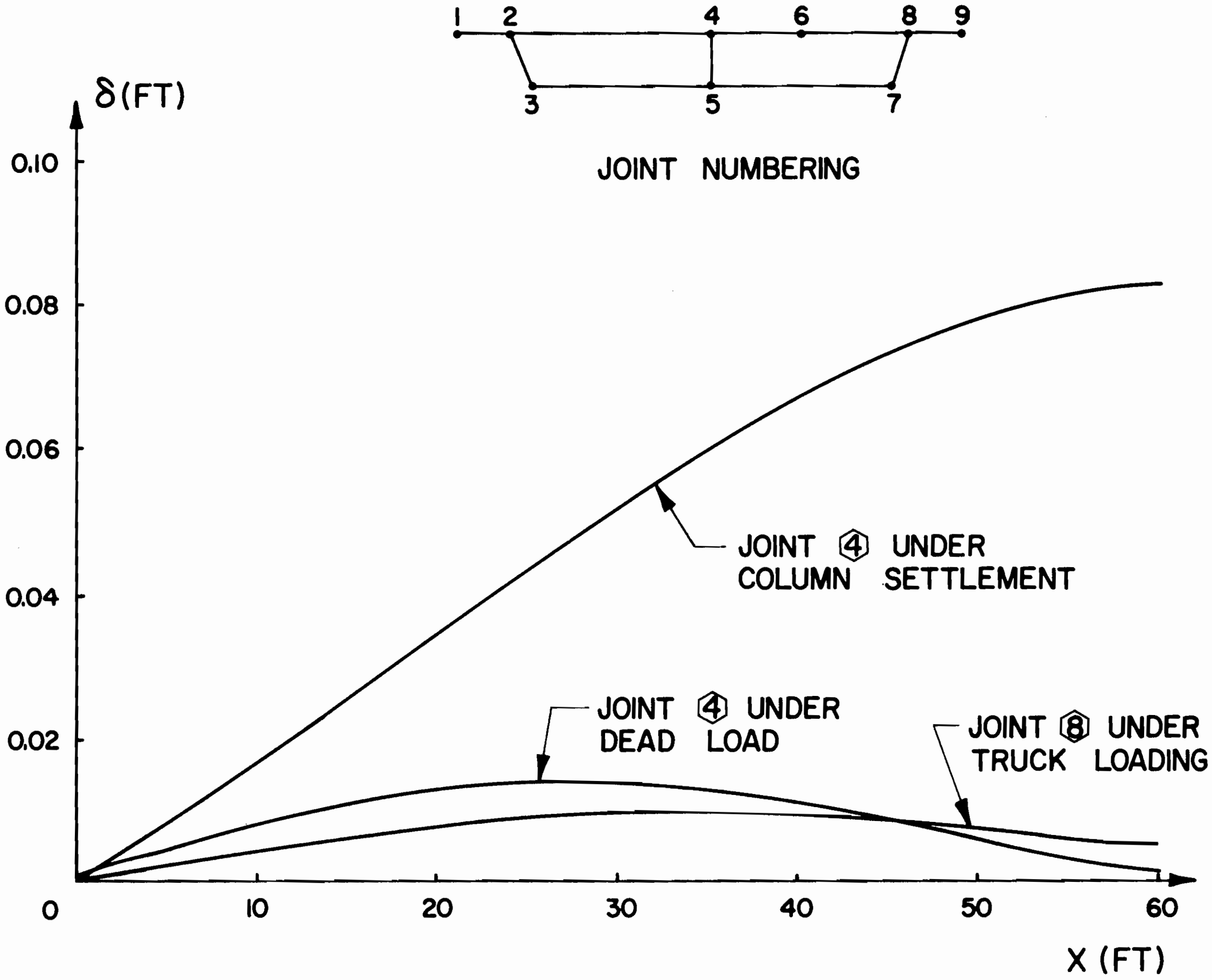


FIG. 16 LONGITUDINAL VARIATION OF VERTICAL DEFLECTIONS FOR EXAMPLE 5

many zero-equations. All frame end points are either dummy (no stiffness coefficients are ever formed) or subject to boundary conditions, so that actually only 1368 - (3)(19)(6) = 1026 equations had to be solved. This example illustrates the fact that dummy nodal points may be introduced without increasing the execution time.

A number of equilibrium checks were performed on this example. First, the entire structure was taken as a free body and the total forces and moments in the global X, Y, Z directions produced by the applied loads were compared with the column base reactions. These were found to be in exact agreement, thus satisfying statics. Second, a portion of the structure from the left end to a section at x = 25.0 ft. was taken as a free body and the total force in the global X direction and the total moment at the section about the global Y-axis produced by the applied loads and the column base reactions were compared with those found by integrating the internal stresses in the finite elements at this section. The results of these comparisons as well as those for a section at x = 56.5 ft. are shown in Table 4.

Table 4. Statics Checks on Example 5

Load Case	Dead Load		Column Settlement		Truck Loading	
At Section	x = 25.0'	x = 56.5'	x = 25.0'	x = 56.5'	x = 25.0'	x = 56.5'
Net External Axial Force (Kip)	-19.3	-19.3	-43.2	-43.2	-10.7	-10.7
Internal Axial Compression (Kip)	-194.6	-272.8	-89.4	-422.0	-131.8	-174.6
Internal Axial Tensile Force (Kip)	177.2	244.2	46.6	381.2	121.0	151.6
Net Internal Axial Force (Kip)	-17.4	-28.6	-42.8	-40.8	-10.8	-23.0
External Moment (FT-K)	547.6	-573.7	248.4	1075.2	399.7	-310.9
Internal Moment (FT-K)	504.1	-623.1	240.7	1095.6	352.0	-382.3
Error %	-8	+9	-3	+2	-12	+23

Agreement for the axial forces is in general quite good. As can be seen, agreement for the moment is fair in most cases except in the third load case at x = 56.5 ft., only 3.5 ft. away from the center column. The error in the moment comparison, 23%, seems to be quite large and is partially due to the steep moment gradient at this section. Recognizing the coarse finite element mesh selected to represent the structure, one could not expect a much better agreement.

These comparisons which are typical for finite element analyses of structures, show once more the need for careful engineering judgment in the interpretation of output results. The finite element method of analysis gives only approximate results, the accuracy of which can be increased by refining the mesh representation of the structure to be analyzed.

6. ACKNOWLEDGEMENT

The computer program described in this report was developed as part of a continuing research project in the Department of Civil Engineering, University of California at Berkeley, under the sponsorship of the Division of Highways, Department of Public Works, State of California, and the Bureau of Public Roads, Federal Highway Administration, United States Department of Transportation. The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsors.

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The support of the University of California Computer Center, which provided the computer facilities, is gratefully acknowledged.

7. REFERENCES

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3. B. N. Abu Ghazaleh, "Analysis of Plate Type Prismatic Structures," Ph.D. thesis presented to the Division of Structural Engineering and Structural Mechanics, University of California, Berkeley, Jan. 1966.

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Appendix A

FORTRAN IV Listing of Program

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.

```
      PROGRAM FINPLA (INPUT,OUTPUT,TAPE 1,TAPE 2,TAPE 3,TAPE 4,
     1                TAPE 5,TAPE 6,TAPE 7)
C
C
C***********************************************************************
C
C     COMMON AND DIMENSION STATEMENTS
C
      COMMON/SETUP/NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH,
     1             INDAV,NLC,XS(41),A(40),NPE,NDT,NDE,NDS,NSD(10),
     2             NFT,NFE,NFS,NSF(10),NTRT,NTRE,NTRS,NSTR(20),NLRT,
     3             NLRE,NLRS,NBLR(40),IFLAG,NA,MBAND,ISPD,NX,LOCD,
     4             LOCL,LOCF,LOCT
      COMMON/PLATE/H(90),V(90),TH(90),E(90),FNU(90),B(90),
     1             NPI(30),NPJ(30),KPL(30),NEL(30),IBLK(60),IPET(60),
     2             NSEGX(40),NSEGY(40)
      COMMON/DIAPH/DIAH(40),DIAW(40),DIATH(40),DIAE(40),DIAN(40),
     1             NDTY(20),NPID(20),NPJD(20),NPKD(20),NPLD(20),
     2             NDSE(20),NDSD(20),NDST(20),NSEGV(10),NSEGH(10)
      COMMON STORE(1)
      DIMENSION TITLE(8),INDX(1120),BUFFER(512)
C
C     READ AND PRINT CONTROL CARDS
C
      CALL LWA(NNN)
      NNM=0
    1 READ 1000, (TITLE(I), I=1,8)
      CALL SECOND(T1)
      READ 1001, SPAN,NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH
      IF(SPAN.EQ.0.) GO TO 999
      PRINT 2000, (TITLE(I), I=1,8)
      PRINT 2001, SPAN,NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH
      CALL OPDISK (1120,INDX,512,BUFFER)
C
C     CALL INPUT SUBROUTINE
C
      NX=NUMELX+1
      NEQ=6*NPTS
      NT=NX*NEQ
      N1=NT+1
      N2=N1+NT
      NNP=NNN+3*NT+25*NPTS
      IF(NNP.GT.NNM) GO TO 68
      NNQ=NNP+1000
      IF(NNQ.GT.NNM) GO TO 70
   68 NNM=NNP
      CALL RFL(NNM)
   70 CALL INPUT(STORE(1),STORE(N1),STORE(N2),NT,NPTS)
      CALL SECOND(T2)
C
C     DETERMINE BANDWIDTH
C
      IJ=0
      DO 75 I=1,NUMELY
      II=IABS(NPI(I)-NPJ(I))
      IF(II.GT.IJ) IJ=II
```

```
   75 CONTINUE
      MBAND=6*(IJ+NPTS+1)
      NQ=NEQ
      MB=MBAND
C
C     CHECK FOR ADDITIONAL STORAGE REQUIREMENTS
C     DUE TO INTERIOR DIAPHRAGM NODES
C
      IF(NDIAPH.LE.0) GO TO 85
      NN=NPTS
      DO 80 I=1,NDE
      IF(NPID(I).GT.NN) NN=NPID(I)
      IF(NPJD(I).GT.NN) NN=NPJD(I)
      IF(NPKD(I).GT.NN) NN=NPKD(I)
   80 IF(NPLD(I).GT.NN) NN=NPLD(I)
      NQ=6*NN
      IF(NQ.GT.MB) MB=NQ
C
C     CALL FORMK SUBROUTINE
C
   85 NH=12*NPTS
      NL=NQ*MB
      N1=NH+1
      N2=N1+NEQ*NQ
      NZ=NQ-NEQ
      NNP=NNN+NL+NT+2*NH
      IF(NNP.LE.NNM) GO TO 86
      NNM=NNP
      CALL RFL(NNM)
   86 CALL FORMK (STORE(1),STORE(N1),STORE(N2),NQ,MB,NH,NZ)
      CALL SECOND(T3)
      T4=T2-T1
      T5=T3-T2
      PRINT 2005, T4, T5
C
C     CALL LOADS SUBROUTINE FOR EACH LOAD CASE  L
C
      LC=1
      DO 90 L=1,NLC
      NL=NEQ*MBAND
      N1=NL+1
      N2=N1+NT
      N3=N2+NH
      N4=1
      N5=N4+NEQ
      N6=N5+NEQ
      N7=N6+NEQ
      N8=N7+NEQ
      N9=N8+NEQ
      N10=N9+NEQ
      N11=N10+NEQ
      N12=N11+NEQ
      CALL LOADS (L,STORE(1),STORE(N1),STORE(N2),STORE(N3),STORE(N4),
     1            STORE(N5),STORE(N6),STORE(N7),STORE(N8),STORE(N9),
     2            STORE(N10),STORE(N11),STORE(N12),STORE(N4),
     3            STORE(N5),STORE(N6),STORE(N7),STORE(N8),
```

```
      4              NT,NEQ,MBAND,NH)
       CALL SECOND(T1)
C
C      CALL BANSOL SUBROUTINE TO SOLVE EQUATIONS FOR DISPLACEMENTS
C
       N1=NH+1
       NNP=NNN+NH+NH*MBAND
       IF(NNP.LE.NNM) GO TO 87
       NNM=NNP
       CALL RFL(NNM)
    87 CALL BANSOL (STORE(1),STORE(N1),NH,NEQ,MBAND,LC,NX,ISPD)
       CALL SECOND(T2)
C
C      CALL OUTPUT SUBROUTINE
C
       N1=1+NL
       N2=N1+NH
       N3=N2+NH
       N4=N3+NH
       NNP=NNN+NL+7*NEQ
       IF(NNP.GT.NNM) GO TO 88
       NNQ=NNP+1000
       IF(NNQ.GT.NNM) GO TO 89
    88 NNM=NNP
       CALL RFL(NNM)
    89 CALL OUTPUT (STORE(1),STORE(N1),STORE(N2),STORE(N3),STORE(N4),
      1              STORE(1),NEQ,MBAND,NH,NZ,NQ)
       T4=T1-T3
       CALL SECOND(T3)
       T5=T2-T1
       T6=T3-T2
       PRINT 2006, L,T4,T5,T6
       LC=2
    90 CONTINUE
       GO TO 1
   999 STOP
C
C      FORMAT STATEMENTS
C
  1000 FORMAT(8A10)
  1001 FORMAT(F10.3,9I4)
  2000 FORMAT(1H1,20X,8A10)
  2001 FORMAT(////,
      1 54H SPAN LENGTH                                            =,F10.3/,
      2 54H NUMBER OF FINITE ELEMENT TYPES                         =,I5/,
      3 54H NUMBER OF NODAL POINTS IN A CROSS SECTION              =,I5/,
      4 54H NUMBER OF BLOCKS ALONG THE X-AXIS                      =,I5/,
      5 54H NUMBER OF FINITE ELEMENTS IN A CROSS SECTION           =,I5/,
      6 54H NUMBER OF TRANSVERSE SECTIONS WITH TRANSVERSE RIBS     =,I5/,
      7 54H NUMBER OF BLOCKS WITH LONGITUDINAL RIBS                =,I5/,
      8 54H NUMBER OF TRANSVERSE SECTIONS WITH FRAME SUPPORTS      =,I5/,
      9 54H NUMBER OF TRANSVERSE SECTIONS WITH DIAPHRAGMS          =,I5//)
  2005 FORMAT(//////18H   EXECUTION TIMES//,48H INPUT SETUP AND CALC. OF
      1ELEMENT STIFFNESSES - ,F10.3,7H   SEC./,33H FORMATION OF STRUCTURE
      2 STIFFNESS,12X,3H - ,F10.3,7H   SEC.)
  2006 FORMAT(//////36H   EXECUTION TIMES FOR LOAD CASE NO.,I5//,17H LOAD
```

```
1 INPUT SETUP,19X,3H - ,F10.3,7H   SEC./,22H SOLUTION OF EQUATIONS,
2 14X,3H - ,F10.3,7H   SEC./,39H CALC. OF INTERNAL FORCES AND OUTPU
3T - ,F10.3,7H   SEC.)
 END
```

```
      SUBROUTINE INPUT (INDCR,DISPL,NAD,NT,NL)
C
C***********************************************************************
C     THIS SUBROUTINE READS AND PRINTS ALL INPUT DATA EXCEPT LOAD
C     INFORMATION. IT SETS UP THE DISPL-ARRAY CONTAINING ALL BOUNDARY
C     CONDITIONS AND PRESCRIBED DISPLACEMENTS. THE ARRAY INDCR
C     INDICATES IF FOR A GIVEN DEGREE OF FREEDOM THE DISPLACEMENT OR
C     EXTERNAL FORCE IS SPECIFIED. DISPL AND INDCR ARE WRITTEN ON
C     TAPE 1. FINALLY, ELEMENT STIFFNESSES OF ALL TWO- AND ONE-
C     DIMENSIONAL ELEMENTS ARE CALCULATED AND STORED ON DISK.
C***********************************************************************
C
C
C     COMMON, DIMENSION, AND EQUIVALENCE STATEMENTS
C
      DIMENSION INDCR(NT),DISPL(NT),ST(300),NAD(25,NL)
      DIMENSION INDT(25),NAN(25),NSAD(25),DTIN(25),NJPD(30),NSDS(30),
     1          NSDE(30),INPD(30),PDIS(30)
C
      COMMON/SETUP/NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH,
     1              INDAV,NLC,XS(41),A(40),NPE,NDT,NDE,NDS,NSD(10),
     2              NFT,NFE,NFS,NSF(10),NTRT,NTRE,NTRS,NSTR(20),NLRT,
     3              NLRE,NLRS,NBLR(40),IFLAG,NA,MBAND,ISPD,NX,LOCD,
     4              LOCL,LOCF,LOCT
      COMMON/PLATE/H(90),V(90),TH(90),E(90),FNU(90),B(90),
     1              NPI(30),NPJ(30),KPL(30),NEL(30),IBLK(60),IPET(60),
     2              NSEGX(40),NSEGY(40)
      COMMON/DIAPH/DIAH(40),DIAW(40),DIATH(40),DIAE(40),DIAN(40),
     1              NDTY(20),NPID(20),NPJD(20),NPKD(20),NPLD(20),
     2              NDSE(20),NDSD(20),NDST(20),NSEGV(10),NSEGH(10)
      COMMON/FRAME/EFX(40),EFY(40),EFZ(40),EFR(40),FH(40),FV(40),
     1              FEA(40),FEIY(40),FEIZ(40),FGJX(40),
     2              NFTY(10),NFI(10),NFJ(10),NFSE(30),NFSF(30),NFST(30)
      COMMON/TRIBS/NPT(60),ETX(60),ETY(60),ETR(60),
     1              TREA(60),TREIY(60),TREIZ(60),TRGJX(60),
     2              NTRTY(30),NTRP(30),NTRSE(30),NTRSS(30),NTRST(30)
      COMMON/LRIBS/ELY(50),ELZ(50),ELR(50),
     1              TLEA(50),TLEIY(50),TLEIZ(50),TLGJX(50),
     2              NLRTY(30),NLRJ(30),NLRSE(30),NLRSB(30),NLRST(30)
      COMMON/STIFFT/T(24,24)
C
      EQUIVALENCE (T,ST)
C
C***********************************************************************
C     READ AND PRINT INPUT DATA
C***********************************************************************
C
C
C     INFORMATION ON PLATE SYSTEM
C
      READ 1000, (XS(I), I=1,NX)
      PRINT 2000
      PRINT 1000, (XS(I), I=1,NX)
C
      DO 1 J=1,NFEL
    1 READ 1001,   I,H(I),V(I),TH(I),E(I),FNU(I)
```

```
      PRINT 2001
      PRINT 2002
      PRINT 2003, (I,H(I),V(I),TH(I),E(I),FNU(I), I=1,NFEL)
C
      DO 2 J=1,NUMELY
    2 READ 1002,  I,NPI(I),NPJ(I),KPL(I)
      PRINT 2004
      PRINT 2005
      PRINT 2006, (I,NPI(I),NPJ(I),KPL(I), I=1,NUMELY)
C
      READ 1001, NPE
      IF(NPE.LE.0) GO TO 5
      DO 3 J=1,NPE
    3 READ 1002,  I,NEL(I),IBLK(I),IPET(I)
      PRINT 2007
      PRINT 2008
      PRINT 2009, (I,NEL(I),IBLK(I),IPET(I), I=1,NPE)
C
C     INFORMATION ON TRANSVERSE RIBS
C
    5 IF(NTRIB.LE.0) GO TO 15
      READ 1002, NTRT,NTRE,NTRS
      READ 1003, (NSTR(I), I=1,NTRIB)
      PRINT 2010
      PRINT 2011, NTRT,NTRE,NTRS
      PRINT 2012, (NSTR(I), I=1,NTRIB)
C
      READ 1004, (I,NPT(I),ETX(I),ETY(I),ETR(I),
     1            TREA(I),TREIY(I),TREIZ(I),TRGJX(I), J=1,NTRT)
      PRINT 2014
      PRINT 2015
      PRINT 2016, (I,NPT(I),ETX(I),ETY(I),ETR(I),
     1            TREA(I),TREIY(I),TREIZ(I),TRGJX(I), I=1,NTRT)
C
      DO 12 J=1,NTRE
   12 READ 1002,  I,NTRTY(I),NTRP(I)
      PRINT 2017
      PRINT 2018
      PRINT 2019, (I,NTRTY(I),NTRP(I), I=1,NTRE)
C
      IF(NTRS.LE.0) GO TO 15
      DO 13 J=1,NTRS
   13 READ 1002,  I,NTRSE(I),NTRSS(I),NTRST(I)
      PRINT 2020
      PRINT 2021
      PRINT 2022, (I,NTRSE(I),NTRSS(I),NTRST(I), I=1,NTRS)
C
C     INFORMATION ON LONGITUDINAL RIBS
C
   15 IF(NLRIB.LE.0) GO TO 20
      READ 1002, NLRT,NLRE,NLRS
      READ 1003, (NBLR(I), I=1,NLRIB)
      PRINT 2023
      PRINT 2011, NLRT,NLRE,NLRS
      PRINT 2024
      PRINT 1003, (NBLR(I), I=1,NLRIB)
```

```
C
      READ 1001, (I,ELY(I),ELZ(I),ELR(I),TLEA(I),TLEIY(I),
     1              TLEIZ(I),TLGJX(I), J=1,NLRT)
      PRINT 2014
      PRINT 2025
      PRINT 2026, (I,ELY(I),ELZ(I),ELR(I),TLEA(I),TLEIY(I),
     1              TLEIZ(I),TLGJX(I), I=1,NLRT)
C
      DO 17 J=1,NLRE
   17 READ 1002,  I,NLRTY(I),NLRJ(I)
      PRINT 2027
      PRINT 2028
      PRINT 2029, (I,NLRTY(I),NLRJ(I), I=1,NLRE)
C
      IF(NLRS.LE.0) GO TO 20
      DO 18 J=1,NLRS
   18 READ 1002,  I,NLRSE(I),NLRSB(I),NLRST(I)
      PRINT 2020
      PRINT 2030
      PRINT 2022, (I,NLRSE(I),NLRSB(I),NLRST(I), I=1,NLRS)
C
C     INFORMATION ON TRANSVERSE FRAMES
C
   20 IF(NFRAME.LE.0) GO TO 30
      READ 1002, NFT,NFE,NFS
      READ 1003, (NSF(I), I=1,NFRAME)
      PRINT 2031
      PRINT 2032, NFT,NFE,NFS
      PRINT 2033, (NSF(I), I=1,NFRAME)
C
      READ 1005, (I,EFX(I),EFY(I),EFZ(I),EFR(I),FH(I),FV(I),
     1              FEA(I),FEIY(I),FEIZ(I),FGJX(I), J=1,NFT)
      PRINT 2034
      PRINT 2035
      PRINT 2036, (I,EFX(I),EFY(I),EFZ(I),EFR(I),FH(I),FV(I),
     1              FEA(I),FEIY(I),FEIZ(I),FGJX(I), I=1,NFT)
C
      DO 27 J=1,NFE
   27 READ 1002,  I,NFTY(I),NFI(I),NFJ(I)
      PRINT 2037
      PRINT 2038
      PRINT 2039, (I,NFTY(I),NFI(I),NFJ(I), I=1,NFE)
C
      IF(NFS.LE.0) GO TO 30
      DO 28 J=1,NFS
   28 READ 1002,  I,NFSE(I),NFSF(I),NFST(I)
      PRINT 2040
      PRINT 2041
      PRINT 2042, (I,NFSE(I),NFSF(I),NFST(I), I=1,NFS)
      DO 29 I=1,NFS
      J=NFSF(I)
   29 NFSF(I)=NSF(J)
C
C     DIAPHRAGM INPUT INFORMATION
C
   30 IF(NDIAPH.LE.0) GO TO 40
```

```
      READ 1002, NDT,NDE,NDS
      READ 1003, (NSD(I), I=1,NDIAPH)
      PRINT 2043
      PRINT 2044, NDT,NDE,NDS
      PRINT 2045, (NSD(I), I=1,NDIAPH)
C
      DO 37 J=1,NDT
   37 READ 1001,  I,DIAH(I),DIAW(I),DIATH(I),DIAE(I),DIAN(I)
      PRINT 2046
      PRINT 2047
      PRINT 2048, (I,DIAH(I),DIAW(I),DIATH(I),DIAE(I),DIAN(I), I=1,NDT)
C
      READ 1002, (I,NDTY(I),NPID(I),NPJD(I),NPKD(I),NPLD(I), J=1,NDE)
      PRINT 2049
      PRINT 2050
      PRINT 2051, (I,NDTY(I),NPID(I),NPJD(I),NPKD(I),NPLD(I), I=1,NDE)
C
      IF(NDS.LE.0) GO TO 40
      DO 39 J=1,NDS
   39 READ 1002,  I,NDSE(I),NDSD(I),NDST(I)
      PRINT 2052
      PRINT 2053
      PRINT 2042, (I,NDSE(I),NDSD(I),NDST(I), I=1,NDS)
      DO 38 I=1,NDS
      J=NDSD(I)
   38 NDSD(I)=NSD(J)
C
C     INTERNAL FORCE OUTPUT SPECIFICATIONS
C
   40 DO 42 J=1,NUMELX
   42 READ 1002,  I,NSEGX(I),NSEGY(I)
      PRINT 2054
      PRINT 2055
      PRINT 2056, (I,NSEGX(I),NSEGY(I), I=1,NUMELX)
      PRINT 2057
      DO 45 I=1,NUMELX
      IF(NSEGX(I).LE.4.AND.NSEGY(I).LE.4) GO TO 45
      PRINT 2058, I
      NSEGX(I)=4
      NSEGY(I)=4
   45 CONTINUE
C
      IF(NDIAPH.LE.0) GO TO 55
      DO 46 J=1,NDIAPH
   46 READ 1002,  I,NSEGV(I),NSEGH(I)
      PRINT 2059
      PRINT 2056, (I,NSEGV(I),NSEGH(I), I=1,NDIAPH)
      DO 50 I=1,NDIAPH
      IF(NSEGV(I).LE.4.AND.NSEGH(I).LE.4) GO TO 50
      PRINT 2060, I
      NSEGV(I)=4
      NSEGH(I)=4
   50 CONTINUE
C
C     APPLIED GROUP DISPLACEMENT INFORMATION
C
```

```
   55 READ 1001, NTAD
      IF(NTAD.LE.0) GO TO 80
      DO 70 K=1,NTAD
      READ 1006, I,INDT(I),NAN(I),NSAD(I),DTIN(I)
      NN=NAN(I)
      IF(NN.EQ.NPTS) GO TO 60
      READ 1003, (NAD(I,J), J=1,NN)
      GO TO 70
   60 DO 65 J=1,NPTS
   65 NAD(I,J)=J
   70 CONTINUE
      PRINT 2061
      PRINT 2062
      DO 75 I=1,NTAD
      PRINT 2063, I,INDT(I),NAN(I),NSAD(I),DTIN(I)
      NN=NAN(I)
      PRINT 2064, (NAD(I,J), J=1,NN)
   75 CONTINUE
      PRINT 2065
C
C     PRESCRIBED LINE DISPLACEMENT  INFORMATION
C
   80 READ 1001, NPD
      IF(NPD.LE.0) GO TO 85
      READ 1006, (NJPD(I),NSDS(I),NSDE(I),INPD(I),PDIS(I), I=1,NPD)
      PRINT 2066
      PRINT 2067
      PRINT 2068, (NJPD(I),NSDS(I),NSDE(I),INPD(I),PDIS(I), I=1,NPD)
   85 READ 1001, NLC
C
C***********************************************************************
C     SET UP DISPLACEMENT AND INDICATOR ARRAY
C***********************************************************************
C
      DO 90 I=1,NT
      INDCR(I)=0
   90 DISPL(I)=0.0
C
C     INCLUDE APPLIED GROUP DISPLACEMENTS
C
      IF(NTAD.LE.0) GO TO 105
      DO 100 I=1,NTAD
      NP=NSAD(I)*NPTS-NPTS
      NN=NAN(I)
      DO 95 J=1,NN
      IJ=(NP+NAD(I,J))*6-6+INDT(I)
      DISPL(IJ)=DTIN(I)
   95 INDCR(IJ)=1
  100 CONTINUE
C
C     INCLUDE PRESCRIBED LINE DISPLACEMENTS
C
  105 IF(NPD.LE.0) GO TO 120
      DO 115 I=1,NPD
      JA=NSDS(I)
      JE=NSDE(I)
```

```
      DO 110 J=JA,JE
      NP=J*NPTS-NPTS+NJPD(I)
      IJ=NP*6-6+INPD(I)
      DISPL(IJ)=PDIS(I)
  110 INDCR(IJ)=1
  115 CONTINUE
C
C     CHECK FOR SPECIFIED NON-ZERO DISPLACEMENTS
C
  120 ISPD=0
      DO 122 I=1,NT
      IF(DISPL(I).EQ.0.) GO TO 122
      ISPD=1
      GO TO 124
  122 CONTINUE
C
C     WRITE DISPLACEMENT AND INDICATOR ARRAY ON TAPE 1
C
  124 REWIND 1
      NPT6=6*NPTS
      NP=1
      DO 125 I=1,NX
      NN=NP+NPT6-1
      WRITE (1) (DISPL(J), J=NP,NN)
      WRITE (1) (INDCR(J), J=NP,NN)
  125 NP=NP+NPT6
C
C***********************************************************************
C     DETERMINE BLOCK LENGTHS AND PLATE WIDTHS
C***********************************************************************
C
      NA=1
      A(1)=XS(2)
      IF(NX.LE.2) GO TO 137
      DO 135 I=3,NX
      II=I-1
      AA=XS(I)-XS(II)
      DO 130 J=1,NA
      IF(AA.NE.A(J)) GO TO 130
      GO TO 135
  130 CONTINUE
      NA=NA+1
      A(NA)=AA
  135 CONTINUE
  137 DO 140 I=1,NFEL
  140 B(I)=SQRT(H(I)*H(I)+V(I)*V(I))
C
C***********************************************************************
C     CALCULATE PLATE AND BEAM ELEM. STIFFNESSES AND STORE THEM ON DISK
C***********************************************************************
C
C     PLATE ELEMENTS
C
      LOCD=0
      LOCL=0
      LOCF=0
```

```
      LOCT=0
      NLOC=1
      DO 150 I=1,NA
      DO 150 J=1,NFEL
      CALL TOSTIF(H(J),A(I),TH(J),FNU(J),E(J),V(J),0)
      II=0
      DO 145 K=1,24
      DO 145 L=K,24
      II=II+1
  145 ST(II)=T(K,L)
      CALL WRDISK(NLOC,ST,300)
  150 NLOC=NLOC+1
C
C     DIAPHRAGM ELEMENTS
C
      IF(NDIAPH.LE.0) GO TO 165
      LOCD=NLOC-1
      DO 160 I=1,NDT
      CALL TOSTIF(DIAW(I),0.0,DIATH(I),DIAN(I),DIAE(I),DIAH(I),1)
      II=0
      DO 155 K=1,24
      DO 155 L=K,24
      II=II+1
  155 ST(II)=T(K,L)
      CALL WRDISK(NLOC,ST,300)
  160 NLOC=NLOC+1
C
C     LONGITUDINAL RIB ELEMENTS
C
  165 IF(NLRIB.LE.0) GO TO 178
      LOCL=NLOC-1
      DO 175 I=1,NLRIB
      IB=NBLR(I)
      S=XS(IB+1)-XS(IB)
      DO 175 J=1,NLRT
      CALL ELSTIF(0.,0.,S,0.,ELY(J),ELZ(J),ELR(J),TLEA(J),TLEIY(J),
     1             TLEIZ(J),TLGJX(J),0,1)
      II=0
      DO 170 K=1,12
      DO 170 L=K,12
      II=II+1
  170 ST(II)=T(K,L)
      CALL WRDISK(NLOC,ST,78)
  175 NLOC=NLOC+1
C
C     TRANSVERSE FRAME ELEMENTS
C
  178 IF(NFRAME.LE.0) GO TO 188
      LOCF=NLOC-1
      DO 185 I=1,NFT
      CALL ELSTIF(FH(I),FV(I),0.,EFX(I),EFY(I),EFZ(I),EFR(I),
     1             FEA(I),FEIY(I),FEIZ(I),FGJX(I),1,1)
      II=0
      DO 180 K=1,12
      DO 180 L=K,12
      II=II+1
```

```
  180 ST(II)=T(K,L)
      CALL WRDISK(NLOC,ST,78)
  185 NLOC=NLOC+1
C
C     TRANSVERSE RIB ELEMENTS
C
  188 IF(NTRIB.LE.0) GO TO 200
      LOCT=NLOC-1
      DO 195 I=1,NTRT
      IP=NPT(I)
      CALL ELSTIF(H(IP),V(IP),0.,ETX(I),ETY(I),0.,ETR(I),
     1            TREA(I),TREIY(I),TREIZ(I),TRGJX(I),2,1)
      II=0
      DO 190 K=1,12
      DO 190 L=K,12
      II=II+1
  190 ST(II)=T(K,L)
      CALL WRDISK(NLOC,ST,78)
  195 NLOC=NLOC+1
C
C***********************************************************************
C     FORMAT STATEMENTS
C***********************************************************************
C
 1000 FORMAT(10F7.2)
 1001 FORMAT(7X,I3,7F10.3)
 1002 FORMAT(6I4)
 1003 FORMAT(20I3)
 1004 FORMAT(2I5,7F10.3)
 1005 FORMAT(I4,6F6.3,4F10.3)
 1006 FORMAT(4I4,4X,F10.3)
C
 2000 FORMAT(//////,44H X-COORDINATES OF SECTIONS ALONG THE X-AXIS  //)
 2001 FORMAT(1H1,40X,37H PROPERTIES OF FINITE ELEMENT TYPES     //)
 2002 FORMAT(118H    TYPE NUMBER      H-PROJECTION        V-PROJECTION
     1        THICKNESS          ELASTIC MODULUS   POISSON-S RATIO   /)
 2003 FORMAT(I10,3X,3E20.5,6X,E16.5,E18.5)
 2004 FORMAT(1H1,36X,49H PROPERTIES OF PLATE ELEMENTS IN REGULAR BLOCK
     1   //)
 2005 FORMAT(29X,64H ELEMENT NUMBER   NODAL POINT I   NODAL POINT J    E
     1LEMENT TYPE   /)
 2006 FORMAT(23X,4I15)
 2007 FORMAT(1H1,23X,83H SPECIAL ELEMENTS OF DIFFERENT TYPE THAN THE COR
     1RESP. ELEMENTS IN REGULAR BLOCK      //)
 2008 FORMAT(19X,94H SPECIAL ELEMENT NO.    CORRESP.REGULAR ELEMENT
     1  BLOCK NUMBER      SPECIAL ELEMENT TYPE    /)
 2009 FORMAT(27X,I3,22X,I3,22X,I3,19X,I3)
 2010 FORMAT(1H1,49X,22H TRANSVERSE RIB INPUT  ////)
 2011 FORMAT(54H NUMBER OF RIB ELEMENT TYPES                         =I5
     1/54H NUMBER OF RIB ELEMENTS AT REGULAR SECTION WITH RIBS =I5,
     2/54H NUMBER OF SPECIAL RIB ELEMENTS                      =I5/////)
 2012 FORMAT(41H NUMBERS OF SECTIONS WITH TRANSVERSE RIBS   //20I6)
 2014 FORMAT(///////50X,19H RIB ELEMENT TYPES  //)
 2015 FORMAT(12X,48H CORRESP.PLATE      ECCENTRICITIES OF CONNECTION,
     1 19X,24H RIB ELEMENT RIGIDITIES /,112H    TYPE NO.  TYPE NUMBER
     2X-DIRECT.   NORM.TO PL.    ROTATION        EA         EI-Y
```

```
     3 EI-Z           GJ-X    /)
 2016 FORMAT(I9,I11,3X,3F13.4,4E13.4)
 2017 FORMAT(1H1,34X,52H RIB ELEMENTS IN REGULAR SECT. WITH TRANSVERSE R
     1IBS  //)
 2018 FORMAT(30X,12H ELEMENT NO.,13X,9H TYPE NO.,7X,27H CORRESP.PLATE EL
     1EMENT NO.  /)
 2019 FORMAT(13X,3I24)
 2020 FORMAT(///////,50X,20HSPECIAL RIB ELEMENTS//)
 2021 FORMAT(24X,75H SPECIAL ELE.NO.  CORRESP.REGULAR ELE.   SECTION NUM
     1BER   SPECIAL ELE. TYPE /)
 2022 FORMAT(14X,4I20)
 2023 FORMAT(1H1,48X,24H LONGITUDINAL RIB INPUT  ////)
 2024 FORMAT(44H NUMBERS OF BLOCKS WITH LONGITUDINAL RIBS  - //)
 2025 FORMAT(25X,29H ECCENTRICITIES OF CONNECTION ,19X,24H RIB ELEMENT R
     1IGIDITIES /,10X,97H TYPE NO.   Y-DIRECT.   Z-DIRECT.    ROTATION
     2         EA         EI-Y         EI-Z         GJ-X  /)
 2026 FORMAT(I17,3F13.4,4E13.4)
 2027 FORMAT(1H1,34X,48H RIB ELEMENTS IN REGULAR BLOCK WITH LONGIT. RIBS
     1 //)
 2028 FORMAT(32X,12H ELEMENT NO.,11X,9H TYPE NO.,6X,23H CONNECTED TO JOI
     1NT NO. /)
 2029 FORMAT(17X,3I22)
 2030 FORMAT(24X,75H SPECIAL ELE.NO.  CORRESP.REGULAR ELE.     BLOCK NUM
     1BER   SPECIAL ELE. TYPE  /)
 2031 FORMAT(1H1,48X,24H TRANSVERSE FRAME INPUT  ////)
 2032 FORMAT(38H NUMBER OF FRAME ELEMENT TYPES       =I5/,
     1        38H NUMBER OF ELEMENTS IN REGULAR FRAME =I5/,
     2        38H NUMBER OF SPECIAL FRAME ELEMENTS    =I5/////)
 2033 FORMAT(32H NUMBERS OF SECTIONS WITH FRAMES //10I10)
 2034 FORMAT(/////,49X,21H FRAME ELEMENT TYPES  //)
 2035 FORMAT(15X,25H ECCENTRICITIES OF NODE I  ,10X,16H ELE.PROJECTIONS,
     1 18X,19H ELEMENT RIGIDITIES /,119H TYPE NO X-DIRECT. Y-DIRECT. Z-D
     2IRECT. ROTATION  Y-DIRECT. Z-DIRECT.       EA           EI-Y
     3  EI-Z         GJ-X    /)
 2036 FORMAT(I5,6F10.4,2X,4E13.4)
 2037 FORMAT(1H1,45X,33H FRAME ELEMENTS IN REGULAR FRAME  //)
 2038 FORMAT(30X,60H  ELEMENT NO.      TYPE NO.     NODAL PT. I    NODAL
     1 PT. J   /)
 2039 FORMAT(23X,4I15)
 2040 FORMAT(///////,48X,24H SPECIAL FRAME ELEMENTS //)
 2041 FORMAT(27X,67H ELEMENT NO.    CORRESP.REG.ELE.    FRAME NUMBER
     1  ELEMENT TYPE  /)
 2042 FORMAT(15X,4I18)
 2043 FORMAT(1H1,46X,28H TRANSVERSE DIAPHRAGM INPUT  ////)
 2044 FORMAT(42H NUMBER OF DIAPHRAGM ELEMENT TYPES         =I5/,
     1        42H NUMBER OF ELEMENTS IN REGULAR DIAPHRAGM =I5/,
     2        42H NUMBER OF SPECIAL DIAPHRAGM ELEMENTS    =I5)
 2045 FORMAT(/////36H NUMBERS OF SECTIONS WITH DIAPHRAGMS  //10I10)
 2046 FORMAT(/////,48X,25H DIAPHRAGM ELEMENT TYPES  //)
 2047 FORMAT(13X,98H TYPE NO.       ELEMENT HEIGHT  HORIZONTAL WIDTH    T
     1HICKNESS      ELASTIC MODULUS  POISSON-S RATIO  /)
 2048 FORMAT(I19,4X,5E17.4)
 2049 FORMAT(1H1,45X,31H ELEMENTS OF REGULAR DIAPHRAGM  //)
 2050 FORMAT(23X,71H ELEMENT NO.   TYPE NO.     NODE I      NODE J
     1NODE K      NODE L   /)
 2051 FORMAT(19X,6I12)
```

```
 2052 FORMAT(///////,46X,28H SPECIAL DIAPHRAGM ELEMENTS   //)
 2053 FORMAT(27X,68H ELEMENT NO.  CORRESP.REG.ELE.    DIAPHRAGM NO.
     1ELEMENT TYPE     /)
 2054 FORMAT(1H1,42X,37H INTERNAL FORCE OUTPUT SPECIFICATION  //)
 2055 FORMAT(31X,62H BLOCK NUMBER      NO.OF LONGIT.SUBDIV.  NO.OF TRANS
     1V.SUBDIV.   /)
 2056 FORMAT(17X,3I22)
 2057 FORMAT(///37X,46H TWO 0-S GIVE NO RESULTS IN THAT BLOCK         /,
     1          37X,46H TWO 1-S GIVE RESULTS AT THE NODAL POINTS ONLY
     2 //////)
 2058 FORMAT(///34H *** NO. OF SUBDIVISIONS OF BLOCK ,I3,51H  GREATER TH
     1AN 4  -   SET AUTOMATICALLY EQUAL TO 4  )
 2059 FORMAT(31X,62H DIAPHRAGM NO.      NO. OF VERT. SUBDIV.  NO.OF HORIZ
     1. SUBDIV.   /)
 2060 FORMAT(///38H *** NO. OF SUBDIVISIONS OF DIAPHRAGM ,I3,51H  GREATE
     1R THAN 4  -   SET AUTOMATICALLY EQUAL TO 4   )
 2061 FORMAT(1H1,43X,34H APPLIED GROUP DISPLACEMENT INPUT   ///)
 2062 FORMAT(118H        DISPL. NO.      COMPONENT NO.  NO.OF AFFECTED N
     1.PTS   SECTION NO.  DISPL.MAGNITUDE    AFFECTED NODAL POINTS    /)
 2063 FORMAT(I14,3I18,F20.5)
 2064 FORMAT(90X,10I3)
 2065 FORMAT(////23H COMPONENT INDICATOR - ,
     1 46H - 1 - PRESCRIBED DISPLACEMENT IN X-DIRECTION /, 23X,
     2 46H - 2 - PRESCRIBED DISPLACEMENT IN Y-DIRECTION /, 23X,
     3 46H - 3 - PRESCRIBED DISPLACEMENT IN Z-DIRECTION /, 23X,
     4 46H - 4 - PRESCRIBED ROTATION ABOUT X-AXIS       /, 23X,
     5 46H - 5 - PRESCRIBED ROTATION ABOUT Y-AXIS       /, 23X,
     6 46H - 6 - PRESCRIBED ROTATION ABOUT Z-AXIS        )
 2066 FORMAT(///////45X,31H PRESCRIBED LINE DISPLACEMENTS  //)
 2067 FORMAT(7X,108H NODAL JOINT NO.        START SECTION           END
     1SECTION          COMPONENT NO.      DISPLACEMENT VALUE    /)
 2068 FORMAT (I17,3I22,F28.5)
C
  200 RETURN
      END
```

```
      SUBROUTINE ELSTIF (H,V,XXL,EX,EY,EZ,PHI,EA,EIY,EIZ,GJX,IND,IA)
C
C***********************************************************************
C     IF  IA=1, THIS SUBROUTINE CALCULATES THE GLOBAL STIFFNESS OF
C               ONE-DIMENSIONAL ELEMENTS ACCORDING TO THE MATRIX
C               TRANSFORMATION    T = AT * K * A
C     IF  IA=2, THIS SUBROUTINE CALCULATES INTERNAL FORCES OF
C               ONE-DIMENSIONAL ELEMENTS FOR GIVEN END DISPLACEMENTS
C               ACCORDING TO THE MATRIX EQUATION    S = K * A * R
C
C                             -  INPUT  -
C
C     IND       - ELEMENT INDICATOR, EQUAL TO
C                  0  FOR LONGITUDINAL RIB ELEMENTS
C                  1  FOR TRANSVERSE FRAME ELEMENTS
C                  2  FOR TRANSVERSE RIB ELEMENTS
C     H,V       - HORIZONTAL AND VERTICAL ELEMENT PROJECTIONS
C     XXL       - ELEMENT LENGTH (IF LONGITUDINAL RIB)
C     EX,EY,EZ  - ECCENTRICITIES OF END CONNECTION
C     PHI       - ROTATION OF PRINCIPAL AXES ABOUT ELEMENT AXIS (IN RAD.)
C     EA,EIY,EIZ,GJX - ELEMENT RIGIDITIES
C     R         - NODAL DISPLACEMENT VECTOR (FOR IA=2 ONLY)
C***********************************************************************
C
      COMMON/STIFFT/T(24,24)
      COMMON/DISPLT/R(24)
      DIMENSION XK(12,12),A(12,12),S(12)
      EQUIVALENCE (R(13),S)
C
C     INITIALIZATION
C
      DO 5  I=1,12
      DO 5  J=1,12
      A(I,J)=0.0
    5 T(I,J)=0.0
      PI2=1.5707963267949
C
C***********************************************************************
C     ELEMENT COORDINATE TRANSFORMATION MATRICES
C***********************************************************************
C
C     TRANSVERSE RIB ELEMENTS
C
      IF(IND.NE.2) GO TO 15
      XL=SQRT(H*H+V*V)
      IF(H.EQ.0.) GO TO 6
      VH=V/H
      ALPHA=ATAN(VH)
      GO TO 7
    6 ALPHA=PI2
      IF(V.LT.0.) ALPHA=-ALPHA
    7 SA=V/XL
      CA=H/XL
      SI=SQRT(EX*EX+EY*EY)
      IF(EY.EQ.0.) GO TO 8
      VH=EX/EY
```

```
      BETA=ATAN(VH)
      GO TO 9
    8 BETA=PI2
      IF(EX.LT.0.) BETA=-BETA
    9 GAMMA=BETA-PHI
      SG=SIN(GAMMA)*SI
      CG=COS(GAMMA)*SI
      CP=COS(PHI)
      SP=SIN(PHI)
      A(1,2)=CA
      A(1,3)=SA
      A(1,4)=-EY
      A(1,5)=-EX*SA
      A(1,6)=EX*CA
      A(2,1)=-CP
      A(2,2)=-SA*SP
      A(2,3)=CA*SP
      A(2,5)=-CA*CG
      A(2,6)=-SA*CG
      A(3,1)=SP
      A(3,2)=-SA*CP
      A(3,3)=CA*CP
      A(3,5)=-CA*SG
      A(3,6)=-SA*SG
      A(4,5)=CA
      A(4,6)=SA
      A(5,4)=-CP
      A(5,5)=-SA*SP
      A(5,6)=CA*SP
      A(6,4)=SP
      A(6,5)=-SA*CP
      A(6,6)=CA*CP
      DO 10 I=1,6
      DO 10 J=1,6
   10 A(I+6,J+6)=A(I,J)
      GO TO 30
C
C     TRANSVERSE FRAME ELEMENTS
C
   15 IF(IND.NE.1) GO TO 25
      XL=SQRT(H*H+V*V)
      IF(H.EQ.0.) GO TO 16
      VH=V/H
      ALPHA=ATAN(VH)
      GO TO 17
   16 ALPHA=PI2
      IF(V.LT.0.) ALPHA=-ALPHA
   17 SA=SIN(ALPHA)
      CA=COS(ALPHA)
      SI=SQRT(EZ*EZ+EY*EY)
      IF(EY.EQ.0.) GO TO 12
      VH=EZ/EY
      GAMMA=ATAN(VH)
      GO TO 13
   12 GAMMA=PI2
      IF(EY.LT.0.) GAMMA=-GAMMA
```

```
   13 GAMMA=ALPHA-GAMMA
      S1=SI*SIN(GAMMA)
      S2=SI*COS(GAMMA)
      SP=SIN(PHI)
      CP=COS(PHI)
      A(1,2)=CA
      A(1,3)=SA
      A(2,1)=-CP
      A(2,2)=-SA*SP
      A(2,3)=CA*SP
      A(3,1)=SP
      A(3,2)=-SA*CP
      A(3,3)=CA*CP
      A(4,5)=CA
      A(4,6)=SA
      A(5,4)=-CP
      A(5,5)=-SA*SP
      A(5,6)=CA*SP
      A(6,4)=SP
      A(6,5)=-SA*CP
      A(6,6)=CA*CP
      DO 20 I=1,6
      DO 20 J=1,6
   20 A(I+6,J+6)=A(I,J)
      A(1,4)=S1
      A(1,5)=-EX*SA
      A(1,6)=EX*CA
      A(2,4)= S2*SP
      A(2,5)=-EZ*CP-EX*CA*SP
      A(2,6)= EY*CP-EX*SA*SP
      A(3,4)= S2*CP
      A(3,5)= EZ*SP-EX*CA*CP
      A(3,6)=-EY*SP-EX*SA*CP
      GO TO 30
C
C     LONGITUDINAL RIB ELEMENTS
C
   25 XL=XXL
      SP=SIN(PHI)
      CP=COS(PHI)
      SS=SQRT(EY*EY+EZ*EZ)
      IF(EY.EQ.0.) GO TO 26
      VH=EZ/EY
      BETA=ATAN(VH)
      GO TO 27
   26 BETA=PI2
      IF(EZ.LT.0.) BETA=-BETA
   27 ALPHA=BETA-PHI
      SSA=SS*SIN(ALPHA)
      SCA=SS*COS(ALPHA)
      A(1,1)=1.0
      A(1,5)=EZ
      A(1,6)=-EY
      A(2,2)=CP
      A(2,3)=SP
      A(2,4)=-SSA
```

```
      A(3,2)=-SP
      A(3,3)=CP
      A(3,4)=SCA
      A(4,4)=1.0
      A(5,5)=CP
      A(5,6)=SP
      A(6,5)=-SP
      A(6,6)=CP
      DO 28 I=1,6
      DO 28 J=1,6
   28 A(I+6,J+6)=A(I,J)
C
C*********************************************************************
C     ELEMENT STIFFNESS FOR PRISMATIC BEAM IN LOCAL COORDINATES
C     NEGLECTING SHEAR DEFORMATIONS
C*********************************************************************
C
   30 XL2=XL*XL
      XL3=XL*XL2
      T(1,1)=EA/XL
      T(7,7)=T(1,1)
      T(1,7)=-T(1,1)
      T(2,2)=12.*EIZ/XL3
      T(8,8)=T(2,2)
      T(2,8)=-T(2,2)
      T(3,3)=12.*EIY/XL3
      T(9,9)=T(3,3)
      T(3,9)=-T(3,3)
      T(4,4)=GJX/XL
      T(10,10)=T(4,4)
      T(4,10)=-T(4,4)
      T(5,5)=4.*EIY/XL
      T(11,11)=T(5,5)
      T(5,11)=T(5,5)/2.
      T(6,6)=4.*EIZ/XL
      T(12,12)=T(6,6)
      T(6,12)=T(6,6)/2.
      T(2,6)=6.*EIZ/XL2
      T(2,12)=T(2,6)
      T(6,8)=-T(2,12)
      T(8,12)=T(6,8)
      T(3,5)=-6.*EIY/XL2
      T(3,11)=T(3,5)
      T(5,9)=-T(3,5)
      T(9,11)=T(5,9)
      DO 35 I=1,12
      DO 35 J=I,12
   35 T(J,I)=T(I,J)
C
C*********************************************************************
C     FIND STIFFNESS IN GLOBAL COORDINATES
C*********************************************************************
C
      IF(IA.EQ.2) GO TO 60
      DO 40 I=1,12
      DO 40 J=1,12
```

```
      XK(I,J)=0.0
      DO 40 K=1,12
   40 XK(I,J)=XK(I,J)+T(I,K)*A(K,J)
      DO 50 I=1,12
      DO 50 J=I,12
      T(I,J)=0.0
      DO 45 K=1,12
   45 T(I,J)=T(I,J)+A(K,I)*XK(K,J)
   50 T(J,I)=T(I,J)
      GO TO 100
C
C***********************************************************************
C     FIND INTERNAL ELEMENT FORCES
C***********************************************************************
C
   60 DO 70 I=1,12
      XK(I,1)=0.0
      DO 70 J=1,12
   70 XK(I,1)=XK(I,1)+A(I,J)*R(J)
      DO 80 I=1,12
      S(I)=0.0
      DO 80 J=1,12
   80 S(I)=S(I)+T(I,J)*XK(J,1)
C
  100 RETURN
      END
```

```
      SUBROUTINE TOSTIF(H,A,TH,FNU,E,V,IEO)
C
C*********************************************************************
C         THIS SUBROUTINE EVALUATES THE TOTAL 24*24 STIFFNESS
C          OF A RECTANGULAR ELEMENT WITH 6 D.O.F. AT A NODE
C
C
C                             - INPUT -
C
C     H      - HORIZONTAL ELEMENT PROJECTION (ALONG THE Y-AXIS)
C     A      - LONGITUDINAL ELEMENT PROJECTION (ALONG GLOBAL X-AXIS)
C     V      - VERTICAL ELEMENT PROJECTION (ALONG GLOBAL Z-AXIS)
C     TH     - ELEMENT THICKNESS
C     FNU    - POISSON-S RATIO
C     IEO    - INDEX OF ELEMENT ORIENTATION
C              0 - ELEMENT X-AXIS IS IDENTICAL WITH GLOBAL X-AXIS
C                  (ORDINARY PLATE ELEMENTS)
C              1 - ELEMENT Y-AXIS IS IDENTICAL WITH GLOBAL Y-AXIS
C                  (DIAPHRAGM ELEMENTS)
C
C
C                             - OUTPUT -
C
C     T(24,24) - ELEMENT STIFFNESS IN GLOBAL COORDINATES
C
C*********************************************************************
C
      COMMON/STIFFT/T(24,24)
C
      DO 5 I=1,24
      DO 5 J=1,24
    5 T(I,J) = 0.0
      IF(E.EQ.0..OR.TH.EQ.0.) GO TO 100
      ATEMP = A
      IF(IEO.EQ.0) GO TO 7
      AX = H
      A = SQRT(A*A + V*V)
      C=ATEMP/A
      S=V/A
      GO TO 8
    7 AX = SQRT(H*H + V*V)
      C=H/AX
      S=V/AX
C
C*********************************************************************
C        1) IN-PLANE STIFFNESS
C*********************************************************************
C
    8 COMM1 = E*TH/(1. - FNU**2)
      X1 = AX/A
      X2 = AX**2/A
      X3 = AX**3/A
      X4 = AX*A
      X5 = A/AX
      X6 = A**2/AX
      X7 = A**3/AX
```

```
      Y1 = AX/A*(1. - FNU)
      Y2 = A/AX*(1. - FNU)
      Y3 = FNU*AX*A
C
      T(1,1) = 123./350.*X5 + 41./175.*Y1
      T(1,2) = 9./80. + 11./80.*FNU
      T(1,6) = -9./175.*X6 - 393./8400.*AX + 743./8400.*FNU*AX
      T(1,7) = -123./350.*X5 + 57./1400.*Y1
      T(1,8) = -9./80. + 29./80.*FNU
      T(1,12) = 9./175.*X6 + 183./8400.*AX - 533./8400.*FNU*AX
      T(1,13) = -26./175.*X5 - 57./1400.*Y1
      T(1,14) = -T(1,2)
      T(1,18) = -67./2100.*X6 + 183./8400.*AX + 167./8400.*FNU*AX
      T(1,19) = 26./175.*X5 - 41./175.*Y1
      T(1,20) = -T(1,8)
      T(1,24) = 67./2100.*X6 - 393./8400.*AX + 43./8400.*FNU*AX
      T(2,2) = 123./350.*X1 + 41./175.*Y2
      T(2,6) = 9./175.*X2 + 393./8400.*A - 743./8400.*FNU*A
      T(2,7) = -T(1,8)
      T(2,8) = 26./175.*X1 - 41./175.*Y2
      T(2,12) = -67./2100.*X2 + 393./8400.*A - 43./8400.*FNU*A
      T(2,13) = T(1,14)
      T(2,14) = -26./175.*X1 - 57./1400.*Y2
      T(2,18) = 67./2100.*X2 - 183./8400.*A - 167./8400.*FNU*A
      T(2,19) = T(1,8)
      T(2,20) = -123./350.*X1 + 57./1400.*Y2
      T(2,24) = -9./175.*X2 - 183./8400.*A + 533./8400.*FNU*A
      T(6,6) = 2./175.*(X7 + X3) + 83./2100.*X4 - 5./84.*Y3
      T(6,7) = T(1,12)
      T(6,8) = -T(2,12)
      T(6,12) = -2./175.*X7 - 3./350.*X3 + 13./1050.*X4 + 8./1050.*Y3
      T(6,13) = -T(1,18)
      T(6,14) = -T(2,18)
      T(6,18) = 3./350.*(X7 + X3) - X4/70. - 6./1050.*Y3
      T(6,19) = -T(1,24)
      T(6,20) = T(2,24)
      T(6,24) = -3./350.*X7 - 2./175.*X3 + 13./1050.*X4 + 8./1050.*Y3
      T(7,7) = T(1,1)
      T(7,8) = -T(1,2)
      T(7,12) = T(1,6)
      T(7,13) = T(1,19)
      T(7,14) = T(1,8)
      T(7,18) = T(1,24)
      T(7,19) = T(1,13)
      T(7,20) = T(1,2)
      T(7,24) = T(1,18)
      T(8,8) = T(2,2)
      T(8,12) = -T(2,6)
      T(8,13) = T(2,7)
      T(8,14) = T(2,20)
      T(8,18) = -T(2,24)
      T(8,19) = T(1,2)
      T(8,20) = T(2,14)
      T(8,24) = T(6,14)
      T(12,12) = T(6,6)
      T(12,13) = T(6,19)
```

```
      T(12,14) = -T(2,24)
      T(12,18) = T(6,24)
      T(12,19) = T(6,13)
      T(12,20) = T(2,18)
      T(12,24) = T(6,18)
      T(13,13) = T(1,1)
      T(13,14) = T(1,2)
      T(13,18) = -T(1,6)
      T(13,19) = T(1,7)
      T(13,20) = T(1,8)
      T(13,24) = -T(1,12)
      T(14,14) = T(2,2)
      T(14,18) = T(8,12)
      T(14,19) = T(2,7)
      T(14,20) = T(2,8)
      T(14,24) = T(6,8)
      T(18,18) = T(6,6)
      T(18,19) = -T(6,7)
      T(18,20) = T(2,12)
      T(18,24) = T(6,12)
      T(19,19) = T(1,1)
      T(19,20) = -T(1,2)
      T(19,24) = -T(1,6)
      T(20,20) = T(2,2)
      T(20,24) = T(2,6)
      T(24,24) = T(6,6)
C
C***********************************************************************
C       2) BENDING STIFFNESS
C***********************************************************************
C
      COMM2 = E*TH**3/(12.*(1.-FNU**2))
      X1 = AX/A
      X2 = AX**2/A**2
      X3 = AX**3/A**3
      X4 = A/AX
      X5 = A**2/AX**2
      X6 = A**3/AX**3
      Y1 = AX/A**2
      Y2 = AX/A**3
      Y3 = AX**2/A**3
      Y4 = A/AX**2
      Y5 = A/AX**3
      Y6 = A**2/AX**3
      Z1 = FNU/AX
      Z2 = FNU/A
      Z3 = FNU/AX/A
      Z4 = 1./AX/A
C
      T(3,3) = 176./35.*(Y5 + Y2) + 78./25.*Z4 + 0.8*Z3
      T(3,4) = 23./35.*Y3 + 33./14.*Y4 + 7./25./A + 1.3*Z2
      T(3,5) = 23./35.*Y6 + 33./14.*Y1 + 7./25./AX+ 1.3*Z1
      T(3,9) = -176./35.*Y5 + 34./35.*Y2 - 78./25.*Z4 - 0.8*Z3
      T(3,10) = 33./14.*Y4 - 12./35.*Y3 + 7./25./A + 0.1*Z2
      T(3,11) = -23./35.*Y6 + 9./14.*Y1 - 7./25./AX- 1.3*Z1
      T(3,15) = -34./35.*(Y5 + Y2) + 78./25.*Z4 + 0.8*Z3
```

```
T(3,16) = 9./14.*Y4 + 12./35.*Y3 - 7./25./A - 0.1*Z2
T(3,17) = 12./35.*Y6 + 9./14.*Y1 - 7./25./AX- 0.1*Z1
T(3,21) = 34./35.*Y5 - 176./35.*Y2 - 78./25.*Z4 - 0.8*Z3
T(3,22) = 9./14.*Y4 - 23./35.*Y3 - 7./25./A - 1.3*Z2
T(3,23) = -12./35.*Y6 + 33./14.*Y1 + 7./25./AX + 0.1*Z1
T(4,4) = 52./35.*X4 + 8./25.*X1 + 4./35.*X3
T(4,5) = 11./35.*(X5 + X2) + 1.2*FNU + 0.02
T(4,9) = -T(3,10)
T(4,10) = 26./35.*X4 - 2./25.*X1 - 3./35.*X3
T(4,11) = 13./70.*X2 - 11./35.*X5 - FNU/10. - 0.02
T(4,15) = -T(3,16)
T(4,16) = 9./35.*X4 + 2./25.*X1 + 3./35.*X3
T(4,17) = 13./70.*X5 + 13./70.*X2 - 0.02
T(4,21) = T(3,22)
T(4,22) = 18./35.*X4 - 8./25.*X1 - 4./35.*X3
T(4,23) = 11./35.*X2 - 13./70.*X5 + FNU/10. + 0.02
T(5,5) = 52./35.*X1 + 8./25.*X4 + 4./35.*X6
T(5,9) = T(3,11)
T(5,10) = -T(4,11)
T(5,11) = -8./25.*X4 + 18./35.*X1 - 4./35.*X6
T(5,15) = -T(3,17)
T(5,16) = T(4,17)
T(5,17) = 3./35.*X6 + 9./35.*X1 + 2./25.*X4
T(5,21) = -T(3,23)
T(5,22) = -T(4,23)
T(5,23) = -3./35.*X6 + 26./35.*X1 - 2./25.*X4
T(9,9) = T(3,3)
T(9,10) = -T(3,4)
T(9,11) = T(3,5)
T(9,15) = T(3,21)
T(9,16) = -T(4,21)
T(9,17) = -T(5,21)
T(9,21) = T(3,15)
T(9,22) = T(4,15)
T(9,23) = -T(5,15)
T(10,10) = T(4,4)
T(10,11) = -T(4,5)
T(10,15) = -T(4,21)
T(10,16) = T(4,22)
T(10,17) = -T(4,23)
T(10,21) = -T(4,15)
T(10,22) = T(4,16)
T(10,23) = -T(4,17)
T(11,11) = T(5,5)
T(11,15) = T(5,21)
T(11,16) = T(4,23)
T(11,17) = T(5,23)
T(11,21) = T(5,15)
T(11,22) = -T(4,17)
T(11,23) = T(5,17)
T(15,15) = T(3,3)
T(15,16) = -T(3,4)
T(15,17) = -T(3,5)
T(15,21) = T(3,9)
T(15,22) = T(4,9)
T(15,23) = -T(5,9)
```

```
      T(16,16) = T(4,4)
      T(16,17) = T(4,5)
      T(16,21) = -T(4,9)
      T(16,22) = T(4,10)
      T(16,23) = T(4,11)
      T(17,17) = T(5,5)
      T(17,21) = -T(5,9)
      T(17,22) = T(5,10)
      T(17,23) = T(5,11)
      T(21,21) = T(3,3)
      T(21,22) = T(3,4)
      T(21,23) = -T(3,5)
      T(22,22) = T(4,4)
      T(22,23) = -T(4,5)
      T(23,23) = T(5,5)
C
C***********************************************************************
C       3) COMMON MULTIPLYERS
C***********************************************************************
C
      N = 1
      DO 25 I = 1,24
      N = N + 1
      IF(N.LE.3) GO TO 10
      ID = 2
      GO TO 15
   10 ID = 1
   15 IF(N.EQ.6) N = 0
      DO 25 J = I,24
      IF(ID.EQ.2) GO TO 20
      T(I,J) = COMM1*T(I,J)
      GO TO 25
   20 T(I,J) = COMM2*T(I,J)
   25 CONTINUE
C
      DO 30 I = 1,24
      DO 30 J = I,24
   30 T(J,I) = T(I,J)
C
C***********************************************************************
C       4) TRANSFORMATION TO RIGHT-HANDED GLOBAL COORDINATE SYSTEM
C***********************************************************************
C
C     DIAPHRAGM ELEMENTS
C
      IF(IEO.EQ.0) GO TO 35
      DO 32 I=1,4
      II=6*I-6
      DO 31 J=1,24
      TX1=T(J,II+2)
      T(J,II+2)=T(J,II+1)
      T(J,II+1)=TX1*C-T(J,II+3)*S
      T(J,II+3)=TX1*S+T(J,II+3)*C
      TX1=T(J,II+4)
      T(J,II+4)=TX1*C+T(J,II+6)*S
      T(J,II+6)=TX1*S-T(J,II+6)*C
```

```
   31 T(J,II+5)=-T(J,II+5)
   32 CONTINUE
      DO 34 I=1,4
      II=6*I-6
      DO 33 J=1,24
      TX1=T(II+2,J)
      T(II+2,J)=T(II+1,J)
      T(II+1,J)=TX1*C-T(II+3,J)*S
      T(II+3,J)=TX1*S+T(II+3,J)*C
      TX1=T(II+4,J)
      T(II+4,J)=TX1*C+T(II+6,J)*S
      T(II+6,J)=TX1*S-T(II+6,J)*C
   33 T(II+5,J)=-T(II+5,J)
   34 CONTINUE
      GO TO 60
C
C     PLATE ELEMENTS
C
   35 DO 40 I=1,4
      II=6*I-6
      DO 36 J=1,24
      TX1=T(J,II+1)
      T(J,II+1)=T(J,II+2)
      T(J,II+2)=TX1*C-T(J,II+3)*S
      T(J,II+3)=TX1*S+T(J,II+3)*C
      TX1=-T(J,II+5)*S-T(J,II+6)*C
      T(J,II+5)=-T(J,II+5)*C+T(J,II+6)*S
   36 T(J,II+6)=TX1
   40 CONTINUE
      DO 50 I=1,4
      II=6*I-6
      DO 45 J=1,24
      TX1=T(II+1,J)
      T(II+1,J)=T(II+2,J)
      T(II+2,J)=TX1*C-T(II+3,J)*S
      T(II+3,J)=TX1*S+T(II+3,J)*C
      TX1=-T(II+5,J)*S-T(II+6,J)*C
      T(II+5,J)=-T(II+5,J)*C+T(II+6,J)*S
   45 T(II+6,J)=TX1
   50 CONTINUE
C
C***********************************************************************
C       5) RENUMBERING NODAL POINTS FOR STRUCTURE ASSEMBLY
C***********************************************************************
C
   60 DO 80 I=1,24
      DO 75 J=13,18
      TX1=T(I,J)
      T(I,J)=T(I,J+6)
   75 T(I,J+6)=TX1
   80 CONTINUE
      DO 90 I=1,24
      DO 85 J=13,18
      TX1=T(J,I)
      T(J,I)=T(J+6,I)
   85 T(J+6,I)=TX1
```

```
   90 CONTINUE
C
      A = ATEMP
  100 RETURN
      END
```

```
      SUBROUTINE FORMK (INDCR,BIGK,BB,NQ,MB,NL,NZ)
C
C***********************************************************************
C     THIS SUBROUTINE FORMS ONE BLOCK OF THE STRUCTURE STIFFNESS AT
C     A TIME AND STORES IT ON TAPE 2. IT THEN MODIFIES THE STIFFNESS
C     MATRIX BLOCK DUE TO BOUNDARY CONDITIONS AND STORES THE MODIFIED
C     STIFFNESS ON TAPE 3. IF THE STRUCTURE CONTAINS INTERIOR DIAPHRAGM
C     NODES, THESE ARE CONDENSED OUT AND THE INFORMATION NEEDED TO FIND
C     THE ELIMINATED DISPLACEMENTS, SAVED ON TAPE 7.
C***********************************************************************
C
C     COMMON,DIMENSION, AND EQUIVALENCE STATEMENTS
C
      DIMENSION BIGK(NQ,MB),INDCR(NL),NB(2),NN(4),BB(NQ,NZ)
      COMMON/SETUP/NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH,
     1              INDAV,NLC,XS(41),A(40),NPE,NDT,NDE,NDS,NSD(10),
     2              NFT,NFE,NFS,NSF(10),NTRT,NTRE,NTRS,NSTR(20),NLRT,
     3              NLRE,NLRS,NBLR(40),IFLAG,NA,MBAND,ISPD,NX,LOCD,
     4              LOCL,LOCF,LOCT
      COMMON/PLATE/H(90),V(90),TH(90),E(90),FNU(90),B(90),
     1              NPI(30),NPJ(30),KPL(30),NEL(30),IBLK(60),IPET(60),
     2              NSEGX(40),NSEGY(40)
      COMMON/DIAPH/DIAH(40),DIAW(40),DIATH(40),DIAE(40),DIAN(40),
     1              NDTY(20),NPID(20),NPJD(20),NPKD(20),NPLD(20),
     2              NDSE(20),NDSD(20),NDST(20),NSEGV(10),NSEGH(10)
      COMMON/FRAME/EFX(40),EFY(40),EFZ(40),EFR(40),FH(40),FV(40),
     1              FEA(40),FEIY(40),FEIZ(40),FGJX(40),
     2              NFTY(10),NFI(10),NFJ(10),NFSE(30),NFSF(30),NFST(30)
      COMMON/TRIBS/NPT(60),ETX(60),ETY(60),ETR(60),
     1              TREA(60),TREIY(60),TREIZ(60),TRGJX(60),
     2              NTRTY(30),NTRP(30),NTRSE(30),NTRSS(30),NTRST(30)
      COMMON/LRIBS/ELY(50),ELZ(50),ELR(50),
     1              TLEA(50),TLEIY(50),TLEIZ(50),TLGJX(50),
     2              NLRTY(30),NLRJ(30),NLRSE(30),NLRSB(30),NLRST(30)
C
C***********************************************************************
C     INITIALIZE STRUCTURE STIFFNESS FOR SECTION  I
C***********************************************************************
C
      REWIND 1
      REWIND 2
      REWIND 3
      NEQ=6*NPTS
      IF(NQ.GT.NEQ) REWIND 7
      N1=NEQ+1
      N2=NEQ+NEQ
      DO 500 I=1,NX
      I1=I-1
      DO 10 J=1,NQ
      DO 10 K=1,MB
   10 BIGK(J,K)=0.0
C
C***********************************************************************
C     STORE STIFFNESS OF DIAPHRAGM AT SECTION  I
C***********************************************************************
C
```

```
      IF(NDIAPH.LE.0) GO TO 100
      DO 25 J=1,NDIAPH
      IF(I.EQ.NSD(J)) GO TO 30
   25 CONTINUE
      GO TO 100
   30 NNL=0
      DO 45 J=1,NDE
      KP=NDTY(J)
      CALL SPECIAL (NDS,NDSD,NDSE,NDST,I,J,KP)
      NLOC=LOCD+KP
      NN(1)=NPID(J)
      NN(2)=NPJD(J)
      NN(3)=NPKD(J)
      NN(4)=NPLD(J)
      CALL STORE(NNL,NLOC,300,24,4,4,0,NN,BIGK,NQ,MB)
   45 NNL=NLOC
C
C     ELIMINATE INTERIOR NODES BY STATIC CONDENSATION
C
      IF(NEQ.EQ.NQ) GO TO 100
      DO 60 N=1,NZ
      L=NQ-N
      M=L+1
      PIVOT=BIGK(M,1)
      IF(PIVOT.EQ.0.) GO TO 60
      M1=M+1
      DO 55 J=1,L
      LL=M1-J
      PP=BIGK(J,LL)
      IF(PP.EQ.0.) GO TO 55
      C=PP/PIVOT
      JL=J-1
      DO 50 K=J,L
      KK=K-JL
      LJ=M1-K
   50 BIGK(J,KK)=BIGK(J,KK)-C*BIGK(K,LJ)
      BIGK(J,LL)=C
   55 CONTINUE
   60 CONTINUE
C
C     SAVE ON TAPE 7 INFORMATION NEEDED TO DETERMINE ELIMINATED DOF-S
C
      DO 70 J=2,NQ
      JI=NQ-J+2
      DO 70 K=1,NZ
      KK=JI-K
      IF(KK.LT.1) GO TO 70
      KJ=NZ-K+1
      BB(J,KJ)=BIGK(J,KK)
      BIGK(J,KK)=0.0
   70 CONTINUE
      WRITE (7) ((BB(J,K), K=1,NZ), J=1,NQ)
      DO 75 J=1,NQ
      DO 75 K=1,NZ
   75 BB(J,K)=0.0
C
```

```
C***********************************************************************
C     STORE PLATE ELEMENT STIFFNESSES
C***********************************************************************
C
  100 A1=0.0
      A2=0.0
      IF(I.NE.1) A1=XS(I)-XS(I-1)
      IF(I.NE.NX) A2=XS(I+1)-XS(I)
      DO 110 J=1,NA
      IF(A1.EQ.A(J)) NB(1)=J
      IF(A2.EQ.A(J)) NB(2)=J
  110 CONTINUE
      NNL=0
      DO 160 J=1,NUMELY
      KP=KPL(J)
      NN(1)=NPI(J)
      NN(2)=NPJ(J)
      NN(3)=NN(1)+NPTS
      NN(4)=NN(2)+NPTS
C
C     STORE CONTRIBUTIONS OF BLOCK  I
C     (UPPER LEFT TRIANGLE AND UPPER RIGHT SQUARE)
C
      IF(I.EQ.NX) GO TO 130
      CALL SPECIAL (NPE,IBLK,NEL,IPET,I,J,KP)
      NLOC=NB(2)*NFEL-NFEL+KP
      CALL STORE(NNL,NLOC,300,24,2,4,0,NN,BIGK,NQ,MB)
      NNL=NLOC
C
C     STORE CONTRIBUTIONS OF BLOCK  I-1
C     (LOWER RIGHT TRIANGLE)
C
  130 IF(I.EQ.1) GO TO 160
      KP=KPL(J)
      CALL SPECIAL (NPE,IBLK,NEL,IPET,I1,J,KP)
      NLOC=NB(1)*NFEL-NFEL+KP
      CALL STORE(NNL,NLOC,300,24,2,2,2,NN,BIGK,NQ,MB)
      NNL=NLOC
  160 CONTINUE
C
C***********************************************************************
C     ADD LONGITUDINAL RIBS
C***********************************************************************
C
      IF(NLRIB.LE.0) GO TO 200
      IY=0
      DO 165 J=1,NLRIB
      IF(NBLR(J).NE.I1) GO TO 163
      NB(1)=J
      IY=IY+1
  163 IF(NBLR(J).NE.I) GO TO 165
      NB(2)=J
      IY=IY+2
  165 CONTINUE
      IF(IY.LE.0) GO TO 200
      NNL=0
```

```
      DO 195 J=1,NLRE
      KP=NLRTY(J)
      NN(1)=NLRJ(J)
      NN(2)=NN(1)+NPTS
      IF(IY.LT.2) GO TO 180
      CALL SPECIAL (NLRS,NLRSB,NLRSE,NLRST,I,J,KP)
      NLOC=LOCL+NB(2)*NLRT-NLRT+KP
      CALL STORE(NNL,NLOC,78,12,1,2,0,NN,BIGK,NQ,MB)
      NNL=NLOC
  180 IF(IY.EQ.2) GO TO 195
      KP=NLRTY(J)
      CALL SPECIAL (NLRS,NLRSB,NLRSE,NLRST,I1,J,KP)
      NLOC=LOCL+NB(1)*NLRT-NLRT+KP
      CALL STORE(NNL,NLOC,78,12,1,1,1,NN,BIGK,NQ,MB)
      NNL=NLOC
  195 CONTINUE
C
C***********************************************************************
C     ADD TRANSVERSE RIBS
C***********************************************************************
C
  200 IF(NTRIB.LE.0) GO TO 230
      DO 205 J=1,NTRIB
      IF(NSTR(J).EQ.I) GO TO 210
  205 CONTINUE
      GO TO 230
  210 NNL=0
      DO 225 J=1,NTRE
      KP=NTRTY(J)
      CALL SPECIAL (NTRS,NTRSS,NTRSE,NTRST,I,J,KP)
      KL=NTRP(J)
      NN(1)=NPI(KL)
      NN(2)=NPJ(KL)
      NLOC=LOCT+KP
      CALL STORE(NNL,NLOC,78,12,2,2,0,NN,BIGK,NQ,MB)
  225 NNL=NLOC
C
C***********************************************************************
C     ADD TRANSVERSE FRAMES
C***********************************************************************
C
  230 IF(NFRAME.LE.0) GO TO 260
      DO 235 J=1,NFRAME
      IF(NSF(J).EQ.I) GO TO 240
  235 CONTINUE
      GO TO 260
  240 NNL=0
      DO 255 J=1,NFE
      KP=NFTY(J)
      CALL SPECIAL (NFS,NFSF,NFSE,NFST,I,J,KP)
      NN(1)=NFI(J)
      NN(2)=NFJ(J)
      NLOC=LOCF+KP
      CALL STORE (NNL,NLOC,78,12,2,2,0,NN,BIGK,NQ,MB)
  255 NNL=NLOC
C
```

```
C***********************************************************************
C     MODIFY STIFFNESS DUE TO BOUNDARY CONDITICNS
C***********************************************************************
C
C     SAVE ORIGINAL STIFFNESS ON TAPE 2
C
  260 WRITE (2) ((BIGK(J,K), K=1,MBAND), J=1,NEQ)
C
C     READ BOUNDARY CONDITION INDICATOR ARRAY FROM TAPE 1
C
      IF(I.GT.1) GO TO 265
      READ (1) (INDCR(J), J=1,NEQ)
      READ (1) (INDCR(J), J=1,NEQ)
      GO TO 272
  265 DO 270 J=1,NEQ
      JL=J+NEQ
  270 INDCR(J)=INDCR(JL)
      IF(I.EQ.NX) GO TO 275
  272 READ (1) (INDCR(J), J=N1,N2)
      READ (1) (INDCR(J), J=N1,N2)
C
C     MODIFY STIFFNESS DUE TO BOUNDARY CONDITIONS
C
  275 LJ=N2
      IF(I.EQ.NX) LJ=NEQ
      DO 290 J=1,LJ
      IF(INDCR(J).EQ.0) GO TO 290
      KI=J-MBAND+1
      IF(KI.LT.1) KI=1
      KJ=J
      IF(KJ.GT.NEQ) KJ=NEQ
      DO 280 K=KI,KJ
      JI=J-K+1
  280 BIGK(K,JI)=0.0
      IF(J.GT.NEQ) GO TO 290
      DO 285 K=2,MBAND
  285 BIGK(J,K)=0.0
  290 CONTINUE
C
C     SAVE MODIFIED STIFFNESS ON TAPE 3
C
      WRITE (3) ((BIGK(J,K), K=1,MBAND), J=1,NEQ)
  500 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE STORE(NNL,NLOC,LR,M,LZ,KZ,IL,NN,BIGK,NQ,MB)
C
C     THIS SUBROUTINE READS ONE- OR TWO-DIMENSIONAL ELEMENT
C     STIFFNESSES FROM DISK AND STORES THEM INTO THE STRUCTURE ASSEMBLY
C
      DIMENSION BIGK(NQ,MB),NN(4),ST(300)
      COMMON/STIFFT/T(24,24)
      EQUIVALENCE (T,ST)
C
      IF(NNL.EQ.NLOC) GO TO 20
      CALL RDDISK(NLOC,ST,LR)
      KL=LR+1
      DO 10 K=1,M
      KK=M+1-K
      DO 10 L=KK,M
      LL=M+KK-L
      KL=KL-1
      T(KK,LL)=ST(KL)
   10 T(LL,KK)=T(KK,LL)
   20 DO 40 L=1,LZ
      LL=6*NN(L)-6
      LV=6*(L+IL)-6
      DO 40 K=1,KZ
      KK=6*NN(K)-6
      IF(KK.LT.LL) GO TO 40
      KH=6*(K+IL)-6
      DO 30 II=1,6
      LLI=LL+II
      LVI=LV+II
      DO 30 JJ=1,6
      KKJ=KK+JJ
      IF(KKJ.LT.LLI) GO TO 30
      KKJ=KKJ-LLI+1
      KHJ=KH+JJ
      BIGK(LLI,KKJ)=BIGK(LLI,KKJ) + T(LVI,KHJ)
   30 CONTINUE
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SPECIAL (NSE,NSX,NSY,NST,I,J,KP)
C
C     THIS SUBROUTINE CHECKS IF A GIVEN ELEMENT J IN BLOCK (OR SECTION)
C     NO. I  IS A SPECIAL ELEMENT. IF YES, THEN ITS ELEMENT TYPE
C     NUMBER KP IS CORRECTED ACCORDINGLY
C
      DIMENSION NSX(60),NSY(60),NST(60)
      IF(NSE.LE.0) GO TO 20
      DO 10 K=1,NSE
      IF(NSX(K).NE.I.OR.NSY(K).NE.J) GO TO 10
      KP=NST(K)
      GO TO 20
   10 CONTINUE
   20 RETURN
      END
```

```
      SUBROUTINE BANSOL (B,A,NH,NQ,MB,LC,NX,ISPD)
C
C**********************************************************************
C     THIS SUBROUTINE DECOMPOSES STIFFNESS MATRIX (IN BLOCK FORM)
C     AND SOLVES SYSTEM OF EQUATIONS FOR DIFFERENT LOAD VECTORS
C
C                             -  INPUT  -
C
C     A      - STIFFNESS MATRIX, STORED ON TAPE 3
C     B      - LOAD VECTOR, STORED ON TAPE 4, OR, IF MODIFIED DUE TO
C              SPECIFIED NON-ZERO DISPLACEMENTS, ON TAPE 5
C     NH     - NUMBER OF ROWS IN DIMENSION STATEMENT OF A
C     NQ     - NUMBER OF EQUATIONS IN ONE BLOCK
C     MB     - HALF-BANDWIDTH PLUS  1
C     LC     - LOAD CASE INDICATOR, EQUAL TO
C               1  FOR FIRST LOAD CASE
C               2  FOR ANY SUBSEQUENT LOAD CASE
C     NX     - NUMBER OF BLOCKS
C     ISPD   - PRESCRIBED DISPLACEMENT INDICATOR, EQUAL TO
C               0  IF ONLY ZERO DISPLACEMENTS SPECIFIED
C               1  IF AT LEAST ONE NON-ZERO DISPLACEMENT SPECIFIED
C
C                             -  OUTPUT  -
C
C     B      - SOLUTION VECTOR, STORED ON TAPE 5
C     A      - REDUCED STIFFNESS MATRIX, AVAIABLE ON TAPE 6 FOR
C              REDUCTION OF SUBSEQUENT LOAD VECTORS
C**********************************************************************
C
      DIMENSION B(1), A(NH,1)
C
C        INITIALIZATION
C
      NEQ=NX*NQ
      NN=NQ
      MM=MB
      NL=NN+1
      NUMBLK=NX
      IB=5
      IF(ISPD.EQ.0) IB=4
      REWIND IB
      REWIND 3
      IF(LC.GT.1) GO TO 405
      REWIND 6
      NB = 0
      GO TO 150
C
C**********************************************************************
C     REDUCE EQUATIONS BY BLOCKS
C**********************************************************************
C
C
C     1. SHIFT BLOCK OF EQUATIONS
C
  100 NB = NB + 1
      DO 125 N=1,NN
```

```
      NM = NN + N
      DO 125 M=1,MM
      A(N,M) = A(NM,M)
  125 A(NM,M) = 0.0
C
C     2. READ BLOCK OF EQUATIONS FROM TAPE 3
C
      IF (NUMBLK.EQ.NB) GO TO 200
  150 READ (3) ((A(N,M), M=1,MM), N=NL,NH)
      IF (NB.EQ.0) GO TO 100
C
C     3. REDUCE BLOCK OF EQUATIONS
C
  200 DO 300 N=1,NN
      IF (A(N,1).EQ.0.0) GO TO 300
      N1=N-1
      DO 275 L=2,MM
      IF (A(N,L).EQ.0.0) GO TO 275
  230 C=A(N,L) / A(N,1)
      I=N1+L
      J=0
      DO 250 K=L,MM
      J=J+1
  250 A(I,J)=A(I,J) - C * A(N,K)
      A(N,L) = C
  275 CONTINUE
  300 CONTINUE
C
C     4. WRITE BLOCK OF REDUCED EQUATIONS ON TAPE 6
C
      WRITE (6) ((A(N,M),M=1,MM),N=1,NN)
      IF (NUMBLK.NE.NB) GO TO 100
C
C*********************************************************************
C     REDUCE LOAD VECTOR IN BLOCK FORM AND WRITE REDUCED VECTOR ON TAPE 3
C*********************************************************************
C
  405 REWIND 6
      REWIND 3
      NB = 0
      GO TO 450
  420 NB=NB+1
      DO 430 N=1,NN
      NM = NN + N
      B(N) = B(NM)
  430 B(NM) = 0.0
      IF (NUMBLK.EQ.NB) GO TO 460
  450 READ (IB) (B(N), N=NL,NH)
      IF (NB.EQ.0) GO TO 420
  460 READ (6) ((A(N,M),M=1,MM),N=1,NN)
      DO 480 N=1,NN
      IF (A(N,1).EQ.0.0) GO TO 480
      N1=N-1
      DO 470 L=2,MM
      IF (A(N,L).EQ.0.0) GO TO 470
      I=N1+L
```

```
      B(I) = B(I) - A(N,L)*B(N)
  470 CONTINUE
      B(N) = B(N)/A(N,1)
  480 CONTINUE
      IF (NUMBLK.EQ.NB) GO TO 490
      WRITE (3) (B(N),N=1,NN)
      GO TO 420
C
C***********************************************************************
C     BACK-SUBSTITUTION
C***********************************************************************
C
  490 BACKSPACE 6
  500 BACKSPACE 6
      BACKSPACE 3
      DO 520 M=1,NN
      N=NL-M
      N1=N-1
      DO 510 K=2,MM
      L=N1+K
  510 B(N) = B(N) - A(N,K) * B(L)
  520 CONTINUE
      DO 525 M=1,NN
      N=NL-M
      NM=N+NN
      A(NM,NB)=B(N)
  525 B(NM)=B(N)
      NB=NB-1
      IF (NB.EQ.0) GO TO 540
  530 READ (3)(B(N),N=1,NN)
      READ (6) ((A(N,M),M=1,MM),N=1,NN)
      BACKSPACE 3
      BACKSPACE 6
      GO TO 500
C
C***********************************************************************
C     STORE SOLUTION VECTOR ON TAPE 5
C***********************************************************************
C
  540 REWIND 5
      DO 600 NB=1,NUMBLK
      WRITE (5) (A(N,NB), N=NL,NH)
  600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE LOADS (L,BIGK,FORCE,DISPL,INDCR,NELSL,DL,YL,ZL,NBLSL,
     1                NSLSL,SDL,SYL,SZL,NJL,NSA,NSO,NID,FF,NT,NQ,MB,NH)
C
C***********************************************************************
C     THIS SUBROUTINE READS ALL LOAD INPUT FOR A GIVEN LOAD CASE,
C     FORMS THE LOAD VECTOR  FORCE  AND STORES IT ON TAPE 4. IF NON-ZERO
C     BOUNDARY CONDITIONS ARE SPECIFIED, THE VECTOR IS MODIFIED
C     ACCORDINGLY AND THEN STORED ON TAPE 5.
C***********************************************************************
C
C     DIMENSION, COMMON, AND EQUIVALENCE STATEMENTS
C
      DIMENSION BIGK(NQ,MB),FORCE(NT),DISPL(NH),INDCR(NH),NELSL(NQ),
     1          DL(NQ),YL(NQ),ZL(NQ),NBLSL(NQ),NSLSL(NQ),SDL(NQ),
     2          SYL(NQ),SZL(NQ),NJL(NQ),NSA(NQ),NSO(NQ),NID(NQ),FF(NQ),
     3          NN(4)
      COMMON/SETUP/NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH,
     1             INDAV,NLC,XS(41),A(40),NPE,NDT,NDE,NDS,NSD(10),
     2             NFT,NFE,NFS,NSF(10),NTRT,NTRE,NTRS,NSTR(20),NLRT,
     3             NLRE,NLRS,NBLR(40),IFLAG,NA,MBAND,ISPD,NX,LOCD,
     4             LOCL,LOCF,LOCT
      COMMON/PLATE/H(90),V(90),TH(90),E(90),FNU(90),B(90),
     1             NPI(30),NPJ(30),KPL(30),NEL(30),IBLK(60),IPET(60),
     2             NSEGX(40),NSEGY(40)
C
C     INITIALIZE LOAD VECTOR
C
      DO 5 I=1,NT
    5 FORCE(I)=0.0
C
C***********************************************************************
C     READ AND PRINT SURFACE LOAD DATA
C***********************************************************************
C
      READ 1003, NESL,NSSL
      PRINT 2000,L
      PRINT 2001, NESL,NSSL
C
      IF(NESL.EQ.0) GO TO 10
      READ 1001, (NELSL(I),DL(I),YL(I),ZL(I), I=1,NESL)
      PRINT 2002
      PRINT 2003
      PRINT 2004, (NELSL(I),DL(I),YL(I),ZL(I), I=1,NESL)
C
   10 IF(NSSL.EQ.0) GO TO 20
      READ 1002, (NBLSL(I),NSLSL(I),SDL(I),SYL(I),SZL(I), I=1,NSSL)
      PRINT 2005
      PRINT 2006
      PRINT 2007, (NBLSL(I),NSLSL(I),SDL(I),SYL(I),SZL(I), I=1,NSSL)
C
C***********************************************************************
C     CALCULATE EQUIVALENT NODAL FORCES DUE TO SURFACE LOADS
C***********************************************************************
C
C     ORDINARY ELEMENTS
C
```

```
   20 IF(NESL.EQ.0) GO TO 75
      NTEMP=0
      DO 70 I=1,NUMELX
      AA=(XS(I+1)-XS(I))/4.
      DO 65 J=1,NESL
      IJ=NELSL(J)
      IF(NSSL.EQ.0) GO TO 55
      DO 50 K=1,NSSL
      IF(NBLSL(K).EQ.I.AND.NSLSL(K).EQ.IJ) GO TO 65
   50 CONTINUE
   55 KI=KPL(IJ)
      ZF=(DL(J)*B(KI)+ZL(J)*ABS(H(KI)))*AA
      YF=YL(J)*ABS(V(KI))*AA
      NN(1)=NTEMP+NPI(IJ)
      NN(2)=NTEMP+NPJ(IJ)
      NN(3)=NN(1)+NPTS
      NN(4)=NN(2)+NPTS
      DO 60 K=1,4
      NPY=6*NN(K)-4
      NPZ=NPY+1
      FORCE(NPY)=FORCE(NPY)+YF
   60 FORCE(NPZ)=FORCE(NPZ)+ZF
   65 CONTINUE
   70 NTEMP=NTEMP+NPTS
C
C     SPECIAL ELEMENTS
C
   75 IF(NSSL.LE.0) GO TO 90
      DO 85 I=1,NSSL
      IX=NBLSL(I)
      IJ=NSLSL(I)
      KI=KPL(IJ)
      AA=(XS(IX+1)-XS(IX))/4.
      ZF=(SDL(I)*B(KI)+SZL(I)*ABS(H(KI)))*AA
      YF=SYL(I)*ABS(V(KI))*AA
      NTEMP=IX*NPTS-NPTS
      NN(1)=NTEMP+NPI(IJ)
      NN(2)=NTEMP+NPJ(IJ)
      NN(3)=NN(1)+NPTS
      NN(4)=NN(2)+NPTS
      DO 80 K=1,4
      NPY=6*NN(K)-4
      NPZ=NPY+1
      FORCE(NPY)=FORCE(NPY)+YF
   80 FORCE(NPZ)=FORCE(NPZ)+ZF
   85 CONTINUE
C
C************************************************************************
C     READ AND PRINT CONCENTRATED AND DISTRIBUTED JOINT LOADS
C************************************************************************
C
   90 READ 1001, NCL
      IF(NCL.EQ.0) GO TO 110
      READ 1003, (NJL(I),NSA(I),NSO(I),NID(I),FF(I), I=1,NCL)
      PRINT 2008
      PRINT 2009
```

```
      PRINT 2010, (NJL(I),NSA(I),NSO(I),NID(I),FF(I), I=1,NCL)
      PRINT 2011
C
C***********************************************************************
C     ADD EQUIVALENT NODAL FORCES INTO FORCE ARRAY
C***********************************************************************
C
      DO 105 I=1,NCL
      JA=NSA(I)
      JE=NSO(I)
      IF(JA.LT.JE) GO TO 95
      IJ=JA*NPTS-NPTS+NJL(I)
      K1=IJ*6-6+NID(I)
      FORCE(K1)=FORCE(K1)+FF(I)
      GO TO 105
   95 JE=JE-1
      DO 100 J=JA,JE
      IJ=J*NPTS+NJL(I)
      K2=IJ*6-6+NID(I)
      K1=K2-6*NPTS
      ZF=(XS(J+1)-XS(J))*FF(I)/2.
      FORCE(K1)=FORCE(K1)+ZF
  100 FORCE(K2)=FORCE(K2)+ZF
  105 CONTINUE
C
C***********************************************************************
C     MODIFY LOAD VECTOR FOR SPECIFIED NON-ZERO DISPLACEMENTS
C***********************************************************************
C
C     SAVE ORIGINAL LOAD VECTOR ON TAPE 4
C
  110 REWIND 4
      NP=1
      DO 112 I=1,NX
      NK=NP+NQ-1
      WRITE (4) (FORCE(J), J=NP,NK)
  112 NP=NP+NQ
C
C     READ ORIGINAL STRUCTURE STIFFNESS AND DISPL AND FORCE ARRAYS
C     FROM TAPE 1 AND 2
C
      IF(ISPD.EQ.0) GO TO 200
      REWIND 1
      REWIND 2
      N1=NQ+1
      N2=NQ+NQ
      JJ=0
      DO 170 I=1,NX
      READ (2) ((BIGK(J,K), K=1,MB), J=1,NQ)
      IF(I.GT.1) GO TO 115
      READ (1) (DISPL(J), J=1,NQ)
      READ (1) (INDCR(J), J=1,NQ)
      GO TO 125
  115 DO 120 J=1,NQ
      IJ=NQ+J
      DISPL(J)=DISPL(IJ)
```

```
  120 INDCR(J)=INDCR(IJ)
      IF(I.EQ.NX) GO TO 130
  125 READ (1) (DISPL(J), J=N1,N2)
      READ (1) (INDCR(J), J=N1,N2)
C
C     MODIFY LOAD VECTOR
C
  130 NK=N2
      IF(I.EQ.NX) NK=NQ
      DO 150 J=1,NK
      IF(INDCR(J).EQ.0.OR.DISPL(J).EQ.0.) GO TO 150
      IJ=J-MB+1
      IF(IJ.LT.1) IJ=1
      IK=J
      IF(IK.GT.NQ) IK=NQ
      DO 135 K=IJ,IK
      JK=J-K+1
      JI=JJ+K
  135 FORCE(JI)=FORCE(JI)-BIGK(K,JK)*DISPL(J)
      IF(J.GT.NQ) GO TO 150
      JK=JJ+J-1
      DO 140 K=2,MB
      JI=JK+K
  140 FORCE(JI)=FORCE(JI)-BIGK(J,K)*DISPL(J)
  150 CONTINUE
  170 JJ=JJ+NQ
C
C     STORE MODIFIED LOAD VECTOR ON TAPE 5
C
      REWIND 5
      NP=1
      DO 180 I=1,NX
      NK=NP+NQ-1
      WRITE (5) (FORCE(J), J=NP,NK)
  180 NP=NP+NQ
C
C***********************************************************************
C     FORMAT STATEMENTS
C***********************************************************************
C
 1001 FORMAT(7X,I3,3F10.3)
 1002 FORMAT(2I5,3F10.3)
 1003 FORMAT(4I4,4X,F10.3)
C
 2000 FORMAT(1H1,44X,30H LOAD INPUT FCR LOAD CASE NO.   ,I3)
 2001 FORMAT(////,55H NUMBER OF ELEMENTS IN BLOCK W. REGULAR SURFACE LOA
     1DS =,I5/,55H NUMBER OF ELEMENTS WITH SPECIAL SURFACE LOADS
     2=,I5)
 2002 FORMAT(//////38X,45H ELEMENTS IN BLOCK WITH REGULAR SURFACE LOADS)
 2003 FORMAT(//29X,57H ELEMENT NUMBER    DEAD LOAD      Y - LOAD        Z
     1- LOAD      /)
 2004 FORMAT(33X,I5,4X,3F15.3)
 2005 FORMAT(///////42X,36H ELEMENTS WITH SPECIAL SURFACE LOADS)
 2006 FORMAT(//22X,72H  BLOCK NUMBER   ELEMENT NUMBER   DEAD LOAD       Y
     1 - LOAD         Z - LOAD   /)
 2007 FORMAT(16X,2I15,4X,3F15.3)
```

```
 2008 FORMAT(////////39X,41H DISTRIBUTED AND CONCENTRATED JOINT LOADS )
 2009 FORMAT(//23X,80H JOINT NO.   START SECTICN    END SECTION   COMP.I
     1NDICATOR          LOAD INTENSITY   /)
 2010 FORMAT(17X,4I14,F26.5)
 2011 FORMAT(////19X,23H COMPONENT INDICATOR - ,
     1 34H - 1 - APPLIED LOAD IN X-DIRECTION/,42X,
     2 34H - 2 - APPLIED LOAD IN Y-DIRECTION/,42X,
     3 34H - 3 - APPLIED LOAD IN Z-DIRECTION/,42X,
     4 34H - 4 - APPLIED MOMENT ABOUT X-AXIS/,42X,
     5 34H - 5 - APPLIED MOMENT ABOUT Y-AXIS/,42X,
     6 34H - 6 - APPLIED MOMENT ABOUT Z-AXIS)
C
  200 RETURN
      END
```

```
      SUBROUTINE OUTPUT(BIGK,DISPL,INDCR,FORCE,PRDIS,BB,NEQ,MB,NH,NZ,NQ)
C
C***********************************************************************
C     THIS SUBROUTINE DETERMINES AND OUTPUTS THE FINAL DISPLACEMENT
C     VECTOR, THE REACTIONS AT POINTS WITH SPECIFIED DISPLACEMENTS,
C     AND RESIDUAL LOAD CHECKS, FOR EACH SECTION. INTERNAL FORCES
C     OF ALL ONE- AND TWO-DIMENSIONAL ELEMENTS ARE CALCULATED AND
C     PRINTED OUT.
C***********************************************************************
C
C     DIMENSION, COMMON, AND EQUIVALENCE STATEMENTS
C
      DIMENSION BIGK(NEQ,MB),DISPL(NH),INDCR(NH),FORCE(NH),PRDIS(NEQ),
     1          BB(NZ,NQ),DD(6),NN(4)
      COMMON/SETUP/NFEL,NPTS,NUMELX,NUMELY,NTRIB,NLRIB,NFRAME,NDIAPH,
     1             INDAV,NLC,XS(41),A(40),NPE,NDT,NDE,NDS,NSD(10),
     2             NFT,NFE,NFS,NSF(10),NTRT,NTRE,NTRS,NSTR(20),NLRT,
     3             NLRE,NLRS,NBLR(40),IFLAG,NA,MBAND,ISPD,NX,LOCD,
     4             LOCL,LOCF,LOCT
      COMMON/PLATE/H(90),V(90),TH(90),E(90),FNU(90),B(90),
     1             NPI(30),NPJ(30),KPL(30),NEL(30),IBLK(60),IPET(60),
     2             NSEGX(40),NSEGY(40)
      COMMON/DIAPH/DIAH(40),DIAW(40),DIATH(40),DIAE(40),DIAN(40),
     1             NDTY(20),NPID(20),NPJD(20),NPKD(20),NPLD(20),
     2             NDSE(20),NDSD(20),NDST(20),NSEGV(10),NSEGH(10)
      COMMON/FRAME/EFX(40),EFY(40),EFZ(40),EFR(40),FH(40),FV(40),
     1             FEA(40),FEIY(40),FEIZ(40),FGJX(40),
     2             NFTY(10),NFI(10),NFJ(10),NFSE(30),NFSF(30),NFST(30)
      COMMON/TRIBS/NPT(60),ETX(60),ETY(60),ETR(60),
     1             TREA(60),TREIY(60),TREIZ(60),TRGJX(60),
     2             NTRTY(30),NTRP(30),NTRSE(30),NTRSS(30),NTRST(30)
      COMMON/LRIBS/ELY(50),ELZ(50),ELR(50),
     1             TLEA(50),TLEIY(50),TLEIZ(50),TLGJX(50),
     2             NLRTY(30),NLRJ(30),NLRSE(30),NLRSB(30),NLRST(30)
      COMMON/DISPLT/C(24)
      COMMON/STRESS/STRESS(5,30)
      LOGICAL ID(30),ICD
C
C***********************************************************************
C     ADD SPECIFIED DISPLACEMENTS INTO SOLUTION VECTOR
C***********************************************************************
C
C     INITIALIZATION
C
      REWIND 1
      REWIND 2
      REWIND 4
      REWIND 5
      IF(NQ.GT.NEQ) REWIND 7
      N1=NEQ+1
      N2=NEQ+NEQ
      READ (1) (PRDIS(J), J=1,NEQ)
      READ (1) (INDCR(J), J=1,NEQ)
      READ (5) (DISPL(J), J=1,NEQ)
      READ (4) (FORCE(J), J=1,NEQ)
      DO 15 J=1,NEQ
```

```
      IF(INDCR(J).EQ.1) DISPL(J)=PRDIS(J)
   15 CONTINUE
C
      DO 500 I=1,NX
      I1=I+1
      IF(I.EQ.1) GO TO 25
      DO 20 J=1,NEQ
      NJ=NEQ+J
      FORCE(J)=FORCE(NJ)
      INDCR(J)=INDCR(NJ)
   20 DISPL(J)=DISPL(NJ)
      IF(I.EQ.NX) GO TO 30
   25 AA=XS(I1)-XS(I)
      READ (1) (PRDIS(J), J=1,NEQ)
      READ (1) (INDCR(J), J=N1,N2)
      READ (5) (DISPL(J), J=N1,N2)
      READ (4) (FORCE(J), J=N1,N2)
   30 DO 35 J=1,NEQ
      NJ=NEQ+J
      IF(INDCR(NJ).EQ.1) DISPL(NJ)=PRDIS(J)
   35 CONTINUE
C
C***********************************************************************
C     FIND RESIDUAL LOAD CHECKS AND REACTIONS
C***********************************************************************
C
      READ (2) ((BIGK(J,K), K=1,MB), J=1,NEQ)
      NJ=N2
      IF(I.EQ.NX) NJ=NEQ
      DO 55 J=1,NJ
      IJ=J-MB+1
      IF(IJ.LT.1) IJ=1
      IK=J
      IF(IK.GT.NEQ) IK=NEQ
      DO 40 K=IJ,IK
      JK=J-K+1
   40 FORCE(J)=FORCE(J)-BIGK(K,JK)*DISPL(K)
      IF(J.GT.NEQ) GO TO 55
      IK=MB
      IL=N2-J+1
      IF(IK.GT.IL) IK=IL
      DO 45 K=2,IK
      JK=J+K-1
   45 FORCE(J)=FORCE(J)-BIGK(J,K)*DISPL(JK)
      FORCE(J)=-FORCE(J)
   55 CONTINUE
C
C***********************************************************************
C     PRINT RESIDUAL LOAD CHECKS AND REACTIONS
C***********************************************************************
C
C     SET UP ID-ARRAY TO SKIP NODAL JOINTS UNDEFINED AT SECTIONS
C     WITHOUT FRAME ELEMENTS
C
      DO 60 J=1,NPTS
   60 ID(J)=.FALSE.
```

```
      IF(NFRAME.LE.0) GO TO 80
      DO 65 J=1,NFRAME
      IF(NSF(J).EQ.I) GO TO 80
   65 CONTINUE
      DO 75 J=1,NPTS
      DO 70 K=1,NUMELY
      IF(NPI(K).EQ.J.OR.NPJ(K).EQ.J) GO TO 75
   70 CONTINUE
      ID(J)=.TRUE.
   75 CONTINUE
C
C     PRINT RESIDUAL LOAD CHECKS
C
   80 PRINT 2000, I, XS(I)
      PRINT 2001
      PRINT 2002
      DO 90 J=1,NPTS
      IF(ID(J)) GO TO 90
      JJ=J*6-6
      DO 85 K=1,6
      DD(K)=0.0
      JK=JJ+K
   85 IF(INDCR(JK).EQ.0) DD(K)=FORCE(JK)
      PRINT 2003, J,(DD(K), K=1,6)
   90 CONTINUE
C
C     PRINT REACTIONS
C
      PRINT 2004
      PRINT 2002
      DO 100 J=1,NPTS
      IF(ID(J)) GO TO 100
      JJ=J*6-6
      DO 95 K=1,6
      DD(K)=0.0
      JK=JJ+K
   95 IF(INDCR(JK).EQ.1) DD(K)=FORCE(JK)
      PRINT 2003, J,(DD(K), K=1,6)
  100 CONTINUE
C
C***********************************************************************
C     FIND DISPLACEMENTS OF INTERIOR DIAPHRAGM NODES
C***********************************************************************
C
      NT=NEQ
      ICD=.TRUE.
      IF(NQ.EQ.NEQ) GO TO 150
      DO 103 J=1,NDIAPH
      IF(I.EQ.NSD(J)) GO TO 104
  103 CONTINUE
      GO TO 150
  104 NT=NQ
      READ (7) ((BB(K,J), K=1,NZ), J=1,NQ)
      IF(I.EQ.NX) GO TO 106
      DO 105 J=1,NEQ
      NJ=NEQ+J
```

```
  105 PRDIS(J)=DISPL(NJ)
      ICD=.FALSE.
  106 DO 120 J=N1,NQ
      DISPL(J)=0.0
      JJ=J-1
      JK=J-NEQ
      DO 110 K=1,JJ
  110 DISPL(J)=DISPL(J)-BB(JK,K)*DISPL(K)
  120 CONTINUE
C
C***********************************************************************
C     PRINT DISPLACEMENTS
C***********************************************************************
C
  150 PRINT 2005
      PRINT 2006
      NM=NT/6
      DO 165 J=1,NM
      IF(J.GT.NPTS) GO TO 155
      IF(ID(J)) GO TO 165
  155 JJ=J*6-6
      DO 160 K=1,6
      KJ=JJ+K
  160 DD(K)=DISPL(KJ)
      PRINT 2003, J,(DD(K), K=1,6)
  165 CONTINUE
C
C***********************************************************************
C     CALCULATE AND PRINT INTERNAL FORCES OF DIAPHRAGMS
C***********************************************************************
C
      IF(NDIAPH.LE.0) GO TO 230
      DO 170 J=1,NDIAPH
      IF(NSD(J).NE.I.OR.NSEGV(J).EQ.0.OR.NSEGH(J).EQ.0) GO TO 170
      KK=J
      GO TO 175
  170 CONTINUE
      GO TO 230
  175 XX=NSEGV(KK)
      SEGX=1./XX
      YY=NSEGH(KK)
      SEGY=1./YY
      PRINT 2007, I
      NL=NSEGV(KK)+1
      NK=NSEGH(KK)+1
      DO 210 J=1,NDE
      KP=NDTY(J)
      CALL SPECIAL (NDS,NDSD,NDSE,NDST,I,J,KP)
      NN(1)=NPID(J)
      NN(2)=NPJD(J)
      NN(3)=NPLD(J)
      NN(4)=NPKD(J)
      CALL ELDIS (4,NN,C,DISPL)
      CALL INTFOS (DIAW(KP),0.,DIATH(KP),DIAN(KP),DIAE(KP),DIAH(KP),
     1             NSEGV(KK),NSEGH(KK),1)
C
```

```
      PRINT 2008, J,(NN(K), K=1,4)
      PRINT 2009
      YRAT=0.0
      DO 200 K=1,NK
      XRAT=0.0
      DO 195 L=1,NL
      IL=L*6
      IK=IL-5
      STRNX=STRESS(K,IK)/DIATH(KP)
      STRNY=STRESS(K,IK+1)/DIATH(KP)
      STRNXY=STRESS(K,IK+2)/DIATH(KP)
      PRINT 2010,XRAT,YRAT,(STRESS(K,M),M=IK,IL),STRNX,STRNY,STRNXY
  195 XRAT=XRAT+SEGX
  200 YRAT=YRAT+SEGY
  210 PRINT 2011
C
C***********************************************************************
C     CALCULATE AND PRINT INTERNAL FORCES OF PLATE ELEMENTS
C***********************************************************************
C
  230 IF(I.EQ.NX) GO TO 300
      IF(NSEGX(I).EQ.0.OR.NSEGY(I).EQ.0) GO TO 300
      IF(ICD) GO TO 240
      DO 235 J=1,NEQ
      NJ=NEQ+J
  235 DISPL(NJ)=PRDIS(J)
  240 NL=NSEGX(I)+1
      NK=NSEGY(I)+1
      PRINT 2012, I
      XX=NSEGX(I)
      SEGX=1./XX
      YY=NSEGY(I)
      SEGY=1./YY
      DO 260 J=1,NUMELY
      KP=KPL(J)
      CALL SPECIAL (NPE,IBLK,NEL,IPET,I,J,KP)
      IF(TH(KP).EQ.0..OR.E(KP).EQ.0.) GO TO 260
      NN(1)=NPI(J)
      NN(2)=NPJ(J)
      NN(3)=NN(2)+NPTS
      NN(4)=NN(1)+NPTS
      CALL ELDIS (4,NN,C,DISPL)
      CALL INTFOS (H(KP),AA,TH(KP),FNU(KP),E(KP),V(KP),NSEGX(I),
     1                NSEGY(I),0)
C
      PRINT 2013, J,NN(1),NN(2)
      PRINT 2009
      YRAT=0.0
      DO 250 K=1,NK
      XRAT=0.0
      DO 245 L=1,NL
      IL=6*L
      IK=IL-5
      STRNX=STRESS(K,IK)/TH(KP)
      STRNY=STRESS(K,IK+1)/TH(KP)
      STRNXY=STRESS(K,IK+2)/TH(KP)
```

```
      PRINT 2010, XRAT,YRAT,(STRESS(K,M),M=IK,IL),STRNX,STRNY,STRNXY
  245 XRAT=XRAT+SEGX
  250 YRAT=YRAT+SEGY
  260 CONTINUE
C
C***********************************************************************
C     CALCULATE AND PRINT FORCES OF BEAM ELEMENTS
C***********************************************************************
C
C     LONGITUDINAL RIBS
C
      IF(NLRIB.LE.0) GO TO 300
      DO 265 J=1,NLRIB
      IF(NBLR(J).EQ.I) GO TO 270
  265 CONTINUE
      GO TO 300
  270 PRINT 2014, I
      PRINT 2015
      DO 290 J=1,NLRE
      KP=NLRTY(J)
      CALL SPECIAL (NLRS,NLRSB,NLRSE,NLRST,I,J,KP)
      NN(1)=NLRJ(J)
      NN(2)=NN(1)+NPTS
      CALL ELDIS (2,NN,C,DISPL)
      CALL ELSTIF (0.,0.,AA,0.,ELY(KP),ELZ(KP),ELR(KP),
     1             TLEA(KP),TLEIY(KP),TLEIZ(KP),TLGJX(KP),0,2)
      PRINT 2016, J,I,(C(K), K=13,18)
      PRINT 2016, J,I1,(C(K), K=19,24)
  290 CONTINUE
C
C     TRANSVERSE RIBS
C
  300 IF(NTRIB.LE.0) GO TO 350
      DO 305 J=1,NTRIB
      IF(NSTR(J).EQ.I) GO TO 310
  305 CONTINUE
      GO TO 350
  310 PRINT 2017, I
      PRINT 2018
      DO 330 J=1,NTRE
      KP=NTRTY(J)
      CALL SPECIAL (NTRS,NTRSS,NTRSE,NTRST,I,J,KP)
      KL=NTRP(J)
      NN(1)=NPI(KL)
      NN(2)=NPJ(KL)
      IP=NPT(KP)
      CALL ELDIS (2,NN,C,DISPL)
      CALL ELSTIF (H(IP),V(IP),0.,ETX(KP),ETY(KP),0.,ETR(KP),
     1             TREA(KP),TREIY(KP),TREIZ(KP),TRGJX(KP),2,2)
      PRINT 2016, J,NN(1),(C(K), K=13,18)
      PRINT 2016, J,NN(2),(C(K), K=19,24)
  330 CONTINUE
C
C     TRANSVERSE FRAMES
C
  350 IF(NFRAME.LE.0) GO TO 500
```

```
      DO 355 J=1,NFRAME
      IF(NSF(J).EQ.I) GO TO 360
  355 CONTINUE
      GO TO 500
  360 PRINT 2019, I
      PRINT 2018
      DO 380 J=1,NFE
      KP=NFTY(J)
      CALL SPECIAL (NFS,NFSF,NFSE,NFST,I,J,KP)
      NN(1)=NFI(J)
      NN(2)=NFJ(J)
      CALL ELDIS (2,NN,C,DISPL)
      CALL ELSTIF (FH(KP),FV(KP),0.,EFX(KP),EFY(KP),EFZ(KP),EFR(KP),
     1             FEA(KP),FEIY(KP),FEIZ(KP),FGJX(KP),1,2)
      PRINT 2016, J,NN(1),(C(K), K=13,18)
      PRINT 2016, J,NN(2),(C(K), K=19,24)
  380 CONTINUE
C
  500 CONTINUE
C
C***********************************************************************
C     FORMAT STATEMENTS
C***********************************************************************
C
 2000 FORMAT(1H1,45X,30H FINAL RESULTS FOR SECTION NO., I5,
     1 10H    ( X =,F10.3,2H ))
 2001 FORMAT(///50X,21H RESIDUAL LOAD CHECKS/)
 2002 FORMAT(/6X,108H NODAL POINT      X-FORCE         Y-FORCE         Z
     1-FORCE         X-MOMENT        Y-MOMENT        Z-MOMENT  /)
 2003 FORMAT(I13,5X,6E16.6)
 2004 FORMAT(///55X,10H REACTIONS/)
 2005 FORMAT(///47X,26H NODAL POINT DISPLACEMENTS/)
 2006 FORMAT(/6X,108H NODAL POINT X-DISPLACEMENT  Y-DISPLACEMENT  Z-DISP
     1LACEMENT    X-ROTATION      Y-ROTATION      Z-ROTATION   /)
 2007 FORMAT(1H1,38X,44H INTERNAL FORCES OF DIAPHRAGM AT SECTION NO.,I5)
 2008 FORMAT(///21X,22H DIAPHRAGM ELEMENT NO.,I5,30H      MADE UP OF NO
     1DAL POINTS,4I5)
 2009 FORMAT(/120H XRAT YRAT     NX-FORCE    NY-FORCE   NXY-FORCE   X-M
     1OMENT    Y-MOMENT   XY-MOMENT   NX-STRESS   NY-STRESS  NXY-STRESS
     2/)
 2010 FORMAT(2F5.2,2X,1P9E12.4)
 2011 FORMAT(/////)
 2012 FORMAT(1H1,36X,47H INTERNAL FORCES OF PLATE ELEMENTS IN BLOCK NO.,
     1 I5)
 2013 FORMAT(///37X,12H ELEMENT NO.,I5,23H   BETWEEN NODAL POINT, I5,
     1 6H   AND,I5)
 2014 FORMAT(/////37X,45H END FORCES OF LONGITUDINAL RIBS IN BLOCK NO.
     1 I5)
 2015 FORMAT(/118H  ELE.NO.   AT SECTION    AXIAL FORCE       Y-SHEAR
     1      Z-SHEAR         TORQUE         Y-MOMENT        Z-MOMENT   /)
 2016 FORMAT(I6,I12,5X,6E16.6)
 2017 FORMAT(/////37X,45H END FORCES OF TRANSVERSE RIBS AT SECTION NO.
     1 I5)
 2018 FORMAT(/118H  ELE.NO.   NODAL POINT    AXIAL FORCE       Y-SHEAR
     1       Z-SHEAR         TORQUE         Y-MOMENT        Z-MOMENT  /)
 2019 FORMAT(/////32X,55H END FORCES CF TRANSVERSE FRAME ELEMENTS AT SEC
```

```
     1TION NO.,I5)
C
      RETURN
      END
```

```
      SUBROUTINE ELDIS (M,NN,C,DISPL)
      DIMENSION NN(4),C(24),DISPL(1)
C
C     THIS SUBROUTINE EXTRACTS THE NODAL DISPLACEMENTS OF AN ELEMENT
C     FROM THE FINAL DISPLACEMENT VECTOR
C
      DO 20 K=1,M
      IK=6*NN(K)-6
      IL=6*K-6
      DO 10 L=1,6
      KN=IK+L
      LN=IL+L
   10 C(LN)=DISPL(KN)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTFOS (H,A,TH,FNU,E,V,NSEGX,NSEGY,IEO)
C
C*********************************************************************
C     THIS SUBROUTINE EVALUATES THE INTERNAL FORCES OF A RECTANGULAR
C     ELEMENT ACCORDING TO THE MATRIX EQUATION
C                       SIGMA   =   D * B * (A-INVERSE) * DISPL
C     WHERE THE MATRICES D, B (IN THIS SUBROUTINE CALLED D), AND
C     A-INVERSE ARE TAKEN FROM ABU GHAZALEH-S THESES, BUT THE DIS-
C     PLACEMENTS HAVE TO BE CONVERTED TO THE CONSISTENT SIGN CONVENTION
C
C
C                                - INPUT -
C
C     H      - HORIZONTAL ELEMENT PROJECTION (ALONG GLOBAL Y-AXIS)
C     A      - LONGITUDINAL ELEMENT PROJECTION (ALONG GLOBAL X-AXIS)
C     V      - VERTICAL ELEMENT PROJECTION (ALONG GLOBAL Z-AXIS)
C     TH     - ELEMENT THICKNESS
C     E      - ELASTIC MODULUS
C     FNU    - POISSON-S RATIO
C     NSEGX  - NUMBER OF ELEMENT SUBDIVISIONS ALONG LOCAL X-AXIS
C              FOR INTERNAL FORCE OUTPUT
C     NSEGY  - NUMBER OF ELEMENT SUBDIVISIONS ALONG LOCAL Y-AXIS
C              FOR INTERNAL FORCE OUTPUT
C     IEO    - INDEX OF ELEMENT ORIENTATION
C              0 - ELEMENT X-AXIS IS IDENTICAL WITH GLOBAL X-AXIS
C                  (ORDINARY PLATE ELEMENTS)
C              1 - ELEMENT Y-AXIS IS IDENTICAL WITH GLOBAL Y-AXIS
C                  (DIAPHRAGM ELEMENTS)
C     C      - NODAL DISPLACEMENT VECTOR
C
C
C                                - OUTPUT  -
C
C     STRESS - INTERNAL FORCE MATRIX
C*********************************************************************
C
      DIMENSION D(9,12)
      COMMON/DISPLT/C(24)
      COMMON/STRESS/STRESS(5,30)
C
      XX = NSEGX
      SEGX = 1./XX
      YY = NSEGY
      SEGY = 1./YY
      NNX = NSEGX + 1
      NNY = NSEGY + 1
      NY6 = NNY*6
      DO 8 I=1,NNX
      DO 8 J=1,NY6
    8 STRESS(I,J) = 0.0
      IF(E.EQ.0..OR.TH.EQ.0.) RETURN
      IF(IEO.EQ.0) GO TO 1
      AX = H
      AY = SQRT(A*A + V*V)
      A1 = 1./AY
      A2 = 1./AX
```

```
      CC=A*A1
      SS=V*A1
      GO TO 2
    1 AX = SQRT(H*H + V*V)
      AY = A
      A1 = 1./AY
      A2 = 1./AX
      CC=H*A2
      SS=V*A2
    2 COMM1 = E*TH/(1.-FNU*FNU)
      COMM2 = E*TH**3/(12.*(1.-FNU*FNU))
C
C***********************************************************************
C        1) TRANSFORMATION TO ELEMENT COORDINATES (IN-PLANE AND PLATE
C           BENDING ACTIONS SEPARATED)
C***********************************************************************
C
C     DIAPHRAGM ELEMENTS
C
      IF(IEO.EQ.0) GO TO 5
      DO 4 I=1,4
      II=6*I-6
      IJ=3*I-3
      D(1,IJ+1)=C(II+4)*CC+C(II+6)*SS
      D(1,IJ+2)=-C(II+5)
      D(1,IJ+3)=C(II+3)*CC-C(II+1)*SS
      S=C(II+1)
      C(IJ+1)=C(II+2)
      C(IJ+2)=S*CC+C(II+3)*SS
      C(IJ+3)=C(II+4)*SS-C(II+6)*CC
    4 CONTINUE
      GO TO 9
C
C     PLATE ELEMENTS
C
    5 DO 7 I=1,4
      II=6*I-6
      IJ=3*I-3
      D(1,IJ+1)=C(II+4)
      D(1,IJ+2)=-C(II+5)*CC-C(II+6)*SS
      D(1,IJ+3)=C(II+3)*CC-C(II+2)*SS
      S=C(II+1)
      C(IJ+1)=C(II+2)*CC+C(II+3)*SS
      C(IJ+2)=S
      C(IJ+3)=C(II+5)*SS-C(II+6)*CC
    7 CONTINUE
C
    9 DO 10 I=1,12
   10 C(I+12)=D(1,I)
C
C***********************************************************************
C        2) MULTIPLICATION  A-INVERSE * C    ( = ALPHA)
C***********************************************************************
C
      C(3)  = C(3)  + (-C(1)*A1 + C(2)*A2 - C(5)*A2 + C(10)*A1)*0.5
      C(6)  = C(6)  + ( C(2)*A2 - C(4)*A1 - C(5)*A2 + C(7)*A1 )*0.5
```

```
      C(9)  = C(9)   + (-C(4)*A1 + C(7)*A1 - C(8)*A2 + C(11)*A2)*0.5
      C(12) = C(12)  + (-C(1)*A1 - C(8)*A2 + C(10)*A1+ C(11)*A2)*0.5
      C(13) = C(13)  + (C(15) - C(18))*A2
      C(14) = C(14)  + (C(15) - C(24))*A1
      C(16) = C(16)  + (C(15) - C(18))*A2
      C(17) = C(17)  + (C(18) - C(21))*A1
      C(19) = C(19)  - (C(21) - C(24))*A2
      C(20) = C(20)  + (C(18) - C(21))*A1
      C(22) = C(22)  - (C(21) - C(24))*A2
      C(23) = C(23)  + (C(15) - C(24))*A1
C
C***********************************************************************
C       3) DISPLACEMENTS, SLOPES, AND CURVATURES THROUGHOUT THE ELEMENT
C***********************************************************************
C
      NCX = 1
      XRAT = 0.0
      DO 40 I = 1,NNX
      XR2 = XRAT*XRAT
      XR3 = XR2*XRAT
      NCY = 1
      YRAT = 0.0
      DO 35 J = 1,NNY
      YR2 = YRAT*YRAT
      YR3 = YR2*YRAT
      DEFL1X = 1. - XRAT
      DEFL1Y = 1. - YRAT
      DEFL2X = XRAT
      DEFL2Y = YRAT
      DEFL3X = AX*(XR3 - 2.*XR2 + XRAT)
      DEFL3Y =  A*(YR3 - 2.*YR2 + YRAT)
      DEFL4X = AX*(XR2 - XR3)
      DEFL4Y =  A*(YR2 - YR3)
      DEFL5X = 2.*XR3 - 3.*XR2 + 1.0
      DEFL5Y = 2.*YR3 - 3.*YR2 + 1.0
      DEFL6X = 3.*XR2 - 2.*XR3
      DEFL6Y = 3.*YR2 - 2.*YR3
C
      SLOP1X = -A2
      SLOP1Y = -A1
      SLOP2X =  A2
      SLOP2Y =  A1
      SLOP3X = 3.*XR2 - 4.*XRAT + 1.0
      SLOP3Y = 3.*YR2 - 4.*YRAT + 1.0
      SLOP4X = 2.*XRAT - 3.*XR2
      SLOP4Y = 2.*YRAT - 3.*YR2
      SLOP5X = (XR2 - XRAT)*6.*A2
      SLOP5Y = (YR2 - YRAT)*6.*A1
      SLOP6X = -SLOP5X
      SLOP6Y = -SLOP5Y
C
      ACTN1X = 0.0
      ACTN1Y = 0.0
      ACTN2X = 0.0
      ACTN2Y = 0.0
      ACTN3X = (6.*XRAT - 4.0)*A2
```

```
      ACTN3Y = (6.*YRAT - 4.0)*A1
      ACTN4X = (2.0 - 6.*XRAT)*A2
      ACTN4Y = (2.0 - 6.*YRAT)*A1
      ACTN5X = (12.*XRAT - 6.)*A2*A2
      ACTN5Y = (12.*YRAT - 6.)*A1*A1
      ACTN6X = (6. - 12.*XRAT)*A2*A2
      ACTN6Y = (6. - 12.*YRAT)*A1*A1
C
C*****************************************************************************
C        4) FORM  B - MATRIX
C*****************************************************************************
C
      D(1,1) = SLOP1X*DEFL1Y
      D(2,1) = 0.0
      D(3,1) = DEFL1X*SLOP1Y
      D(4,1) = 0.0
      D(1,2) = 0.0
      D(2,2) = DEFL1X*SLOP1Y
      D(3,2) = 0.0
      D(4,2) = SLOP1X*DEFL1Y
      D(1,3) = -SLOP5X*DEFL3Y
      D(2,3) = DEFL3X*SLOP5Y
      D(3,3) = -DEFL5X*SLOP3Y
      D(4,3) = SLOP3X*DEFL5Y
      D(1,4) = SLOP2X*DEFL1Y
      D(2,4) = 0.0
      D(3,4) = DEFL2X*SLOP1Y
      D(4,4) = 0.0
      D(1,5) = 0.0
      D(2,5) = DEFL2X*SLOP1Y
      D(3,5) = 0.0
      D(4,5) = SLOP2X*DEFL1Y
      D(1,6) = -SLOP6X*DEFL3Y
      D(2,6) = -DEFL4X*SLOP5Y
      D(3,6) = -DEFL6X*SLOP3Y
      D(4,6) = -SLOP4X*DEFL5Y
      D(1,7) = SLOP2X*DEFL2Y
      D(2,7) = 0.0
      D(3,7) = DEFL2X*SLOP2Y
      D(4,7) = 0.0
      D(1,8) = 0.0
      D(2,8) = DEFL2X*SLOP2Y
      D(3,8) = 0.0
      D(4,8) = SLOP2X*DEFL2Y
      D(1,9) = SLOP6X*DEFL4Y
      D(2,9) = -DEFL4X*SLOP6Y
      D(3,9) = DEFL6X*SLOP4Y
      D(4,9) = -SLOP4X*DEFL6Y
      D(1,10) = SLOP1X*DEFL2Y
      D(2,10) = 0.0
      D(3,10) = DEFL1X*SLOP2Y
      D(4,10) = 0.0
      D(1,11) = 0.0
      D(2,11) = DEFL1X*SLOP2Y
      D(3,11) = 0.0
      D(4,11) = SLOP1X*DEFL2Y
```

```
      D(1,12) = SLOP5X*DEFL4Y
      D(2,12) = DEFL3X*SLOP6Y
      D(3,12) = DEFL5X*SLOP4Y
      D(4,12) = SLOP3X*DEFL6Y
      D(5,1) = ACTN3X*DEFL5Y
      D(6,1) = DEFL3X*ACTN5Y
      D(7,1) = SLOP3X*SLOP5Y
      D(5,2) = ACTN5X*DEFL3Y
      D(6,2) = DEFL5X*ACTN3Y
      D(7,2) = SLOP5X*SLOP3Y
      D(5,3) = ACTN1X*DEFL1Y
      D(6,3) = DEFL1X*ACTN1Y
      D(7,3) = SLOP1X*SLOP1Y
      D(5,4) = -ACTN4X*DEFL5Y
      D(6,4) = -DEFL4X*ACTN5Y
      D(7,4) = -SLOP4X*SLOP5Y
      D(5,5) = ACTN6X*DEFL3Y
      D(6,5) = DEFL6X*ACTN3Y
      D(7,5) = SLOP6X*SLOP3Y
      D(5,6) = ACTN2X*DEFL1Y
      D(6,6) = DEFL2X*ACTN1Y
      D(7,6) = SLOP2X*SLOP1Y
      D(5,7) = -ACTN4X*DEFL6Y
      D(6,7) = -DEFL4X*ACTN6Y
      D(7,7) = -SLOP4X*SLOP6Y
      D(5,8) = -ACTN6X*DEFL4Y
      D(6,8) = -DEFL6X*ACTN4Y
      D(7,8) = -SLOP6X*SLOP4Y
      D(5,9) = ACTN2X*DEFL2Y
      D(6,9) = DEFL2X*ACTN2Y
      D(7,9) = SLOP2X*SLOP2Y
      D(5,10) = ACTN3X*DEFL6Y
      D(6,10) = DEFL3X*ACTN6Y
      D(7,10) = SLOP3X*SLOP6Y
      D(5,11) = -ACTN5X*DEFL4Y
      D(6,11) = -DEFL5X*ACTN4Y
      D(7,11) = -SLOP5X*SLOP4Y
      D(5,12) = ACTN1X*DEFL2Y
      D(6,12) = DEFL1X*ACTN2Y
      D(7,12) = SLOP1X*SLOP2Y
C
C***********************************************************************
C        5) MULTIPLICATION  B * ALPHA   ( = EPSILON)
C***********************************************************************
C
      DO 20 K = 1,4
      D(8,K) = 0.0
      DO 20 L = 1,12
   20 D(8,K) = D(8,K) + D(K,L)*C(L)
C
      DO 25 K = 1,3
      D(9,K) = 0.0
      DO 25 L = 1,12
   25 D(9,K) = D(9,K) + D(K+4,L)*C(L+12)
C
C***********************************************************************
```

```
C       6) MULTIPLICATION  D * EPSILON   ( = SIGMA)
C***********************************************************************
C
      NOR = NCX
      NOC = NCY*6 - 6
      STRESS(NOR,NOC+1) = COMM1*(D(8,2) + FNU*D(8,1))
      STRESS(NOR,NOC+2) = COMM1*(D(8,1) + FNU*D(8,2))
      STRESS(NOR,NOC+3) = COMM1*(1.-FNU)/2.*(D(8,3) + D(8,4))
      STRESS(NOR,NOC+4) =-COMM2*(D(9,2) + FNU*D(9,1))
      STRESS(NOR,NOC+5) =-COMM2*(D(9,1) + FNU*D(9,2))
      STRESS(NOR,NOC+6) = COMM2*(1.-FNU)*D(9,3)
C
      NCY = NCY + 1
   35 YRAT = YRAT + SEGY
      NCX = NCX + 1
   40 XRAT = XRAT + SEGX
C
      RETURN
      END
```

Note

In addition to the FORTRAN subroutines already listed the following subroutines, written in COMPASS language, are needed for the execution of the program.

RFL, LWA
OPDISK, RDDISK, WRDISK

Listings of these are not given here because they are machine dependent. They are explained on pages 14 and 15 of this report. Similar subroutines are generally available in the library for the computer system to be used and must be added to the above FORTRAN listing.

Appendix B

Input Data for Example 5C

```
FXAMPLE    5 C   -  FRAME-SUPPORTED BOX GIRDER BRIDGE, TRUCK LOADING      1/23/70
     120.0    8   12   18   10    2    0    3    3
      .0      10.      18.      25.      32.      39.      46.      53.    56.5     60.
    63.5      67.      74.      81.      88.      95.     102.     110.    120.
              1         3.0        0.0     .541667    432000.        .15
              2         11.        0.0     .541667    432000.        .15
              3         5.0        0.0     .541667    432000.        .15
              4         6.0        0.0     .541667    432000.        .15
              5         1.0        3.0     .666667    432000.        .15
              6         0.0        3.0     .666667    432000.        .15
              7         -1.        3.0     .666667    432000.        .15
              8         10.        0.0     .458333    432000.        .15
   1    1    2    1
   2    2    4    2
   3    4    6    3
   4    6    8    4
   5    8    9    1
   6    2    3    5
   7    4    5    6
   8    8    7    7
   9    3    5    8
  10    5    7    8

   1    2    0
  1 19
    1      8         0.0       1.229        0.0   1728000.     576000.     576000.     422925.
   1    1    9
   2    1   10
   4    3    3
  1 10  19
   1   0.0     1.0 2.229    0.0     0.0      12.   1728000.     576000.     576000.     422925.
   2   0.0     0.0   0.0    0.0     0.0      12.        0.0        0.0         0.0         0.0
   3   0.0     0.     .229  0.0     0.0      14.   3064000.   2124000.    2124000.    1844000.
   4   0.0     -1. 2.229    0.0     0.0      12.   1728000.     576000.     576000.     422925.
   1    1    3   10
   2    2    5   12
   3    4    7   11
   1    1    2    2
   2    2    2    3
   3    3    2    2
   2    2    2
  1 10  19
              1         3.0       10.5         2.0    432000.        .15
              2         3.0       10.5         3.0    432000.        .15
   1    1    2    4    3    5
   2    1    4    8    5    7
   1    1    2    2
   2    2    2    2
   1    1    1
   2    1    1
   3    1    1
   4    1    1
   5    1    1
   6    1    1
   7    1    1
   8    1    1
   9    1    1
```

```
10    1    1
11    1    1
12    1    1
13    1    1
14    1    1
15    1    1
16    1    1
17    1    1
18    1    1
 1    1    1
 2    1    1
 3    1    1

       18
10    1   19    1           0.0
10    1   19    2           0.0
10    1   19    3           0.0
10    1   19    4           0.0
10    1   19    5           0.0
10    1   19    6           0.0
11    1   19    1           0.0
11    1   19    2           0.0
11    1   19    3           0.0
11    1   19    4           0.0
11    1   19    5           0.0
11    1   19    6           0.0
12    1   19    1           0.0
12    1   19    2           0.0
12    1   19    3           0.0
12    1   19    4           0.0
12    1   19    5           0.0
12    1   19    6           0.0
        1

       12
 6    4    4    3           14.
 6    6    6    3           14.
 6    8    8    3           4.0
 6   12   12    3           14.
 6   14   14    3           14.
 6   16   16    3           4.0
 8    4    4    3           14.
 8    6    6    3           14.
 8    8    8    3           4.0
 8   12   12    3           14.
 8   14   14    3           14.
 8   16   16    3           4.0
```