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Matrix computer analysis of curvilinear grid systems

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MATRIX COMPUTER ANALYSIS
OF CURVILINEAR GRID SYSTEMS

BY

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A

DISSERTATION

submitted to the faculty of

THE UNIVERSITY OF MISSOURI AT ROLLA

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Approved by

Joseph [illegible] (advisor) John Best

B E Gillett   Wm A Andrews

ABSTRACT

A general equilibrium-stiffness method of matrix structural analysis was adapted and applied to the solution of the member end forces and moments of each of the members in a curvilinear structural grid system. A structural system of this nature is commonly used as the supporting framework for a "steel-framed dome", in addition to being a basic structural component in many aerospace applications.

An integral part of the development of the analysis was the development of a computer program to perform the many complex operations required to obtain the solution. The engineer, by supplying the appropriate structural data and load data to the computer program, is able to obtain the forces and moments at the ends of each of the members in the structural system corresponding to the six possible degrees of freedom of each one of the joints, or nodal points as they are referred to.

David Leon Fenton

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The writer also wishes to express his gratitude to Barry Gregory for his valuable assistance in the development of the computer program.

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P'	Member end-loads in system coordinates.
δ'	Member end-displacements in system coordinates
K'	Appropriate member stiffness matrix in system coordinates
F	Flexibility matrix
p_x, p_y, p_z	Member end-forces and moments in member coordinates.
m_x, m_y, m_z	
H	Equilibrium matrix.
$*$	Rigid body end-displacements.
K	Appropriate member stiffness matrix in member coordinates.
T	Transformation matrix.
K''	System stiffness matrix
S	One half of the cord length of the member.
R	Radius of curvature of the member.
e	Perpendicular distance from radius focus to the end of the member.
ϕ	One half of the total angle subtended by the member.
Θ	Member end rotation
θ	General reference angle
N	Normal force on any cross-section of a member.
A	Cross-sectional area of a member.

M_x, M_y, M_z	General moments at any point along a member with respect to member coordinate axes.
M_T, M_{YN}	Moments with respect to the major axis of the cross-section.
I_N	Equivalent polar moment of inertia.
I_{yN}	Moment of inertia about major "y" axis.
I_z	Moment of inertia about major "z" axis.
E	Modulus of elasticity
G	Shear modulus.
λ	Direction cosine.
α	Rotation of major axis of a member about member x-axis.
β	Angle between system x-axis and the projection of the member x-axis on the system xz-plane
γ	Vertical angle between the member x-axis and its projection on the system xa-plane.

Chapter 1

INTRODUCTION

The appearance of the dome structure in today's modern space age society is as accepted and as appropriate as it was hundreds of years ago. Today's modern materials and advancements made in construction methods have made the dome structure one of the most economical space-structure systems in use today.

There is an ever growing trend to enclose larger and larger areas and in so doing man is endeavoring to control his environment in order to eliminate the influence of weather on his daily activities. By enclosing large areas such as shopping centers the loss of business due to unfavorable weather can be reduced. The same is true of athletic stadiums, civic centers and auditoriums, green houses, opera houses and a multitude of other applications. The present demands, in addition to demands of the future where domes spanning a mile or more may be desired, present today's engineer with a tremendous challenge. The analysis of these structural systems will require talented and creative engineers with more than average ability, and, in addition, there will be a continuing need for the development of more efficient and sophisticated methods of analysis.

Modern matrix analysis of large structural systems together with the use of the high speed computer is becoming as common to the structural engineer's world today as the slope-deflection and moment-distribution methods have been in the past. The analysis of space frames, as well as flat grids, consisting of straight members has been well documented.[1,2,3] On the other hand it is felt that there is a definite need for a clean straight forward approach to the analysis of space-structure systems composed of curved members.

Much of the work that has been done with curved members deals with two dimensional structure such as arch and multi-arch frames.[5] In the area of members curved in space the following approaches have been taken, a matrix procedure using a trial and error approach was suggested by, Baron,[7] in the paper by Eisemann, Woo, and Namyet[1], it is suggested that curved members or members with variable cross-sections could be approximated by the introduction of additional rigid joints along the length of the member resolving the member into a series of straight segments. This approach, however, would greatly increase the number of equations required to solve and would be highly inefficient for large systems. Another approach to the solution of "curvilinear grid frames" has been suggested[4], which involves the use of trigonometric series to approximate moments and deflections.

In a paper on "Mettalic Dome-Structure Systems," by Shu-t'ien Li[9], it is suggested that any surface of revolution supported on a horizontal thrust ring may, if symmetrically loaded by distributed loads, be regarded as supporting itself directly by tension or compression. This paper then suggests that by adapting the established theory of thin-shell spherical domes, the analysis of the lattice dome can be made quite simply. The compressive stresses toward the pole and around lines of latitude when multiplied by the rib spacing will give the rib stress. The shell approach, however, does not include the bending and torsion taking place in the lattice structure, which is necessary in order to describe more accurately the behavior of the structure.

In a recent paper by J. Michalos[10], a general approach to the analysis of "space networks' is described. The method of analysis described, employs the use of both the displacement and force methods of matrix analysis, however, the method of formulation still uses an iterative approach. The resisting forces and moments in each branch of the network are first computed by the force method, while the rotations and displacements of the ends of a branch are prevented. Correction moments and forces resulting from rotations and displacements of the nodes are then computed from the displacement method and finally the correction moments and forces are added to the resisting moments and forces previously determined.

The number of operations and steps required by this analysis would still encourage the development of a more straightforward and simplified approach.

In view of the preceding discussion, a need for a more direct method of analysis for the curvilinear space structure still exists. The fact that a given matrix method of formulation has been developed does not eliminate the possibility of the existence of a more efficient and more direct method of matrix formulation.

The majority of the structures built are not designed with unusual assortments of member shapes and cross-sectional patterns, for the obvious reasons of economy. In most cases the members are either all straight or all curved and in some cases there may be a combination of straight and curved members. In structures where curved members are used, they are usually of the same type, (i.e. all segments of circles or parabolas, etc.).

It is for these reasons that this author favors deriving the equations for the member flexibility coefficients directly from energy considerations, in terms of the geometric and elastic constants of a typical member and then substitute the appropriate geometric and elastic constants of each individual member into these equations to obtain the member flexibility matrices. The member stiffness matrices are then obtained simply by inverting the member flexibility matrices.

It was with this philosophy that the following method of analysis was developed. The method used to formulate the analysis was a general equilibrium-stiffness formulation in which the load-displacement equations for the individual members are used to generate directly the system stiffness matrix for the entire structure, from which the nodal displacements are obtained. These displacements are then substituted into the member load-displacement equations to obtain the final member-end loads.

Finally, a computer program was developed to effectively carry out the necessary computations, and an experimental model was build to correlate the results.

Chapter 2

GENERAL FORMULATION

2.1 Method of Formulation

The equilibrium (or displacement) method has been chosen as the most suitable approach to the formulation of the curvilinear space grid. The load-displacement equations are first derived for a single segmental circular element, (or in general any other element for that matter) in terms of the most convenient element coordinate system, which in most cases is different from the coordinate system chosen to represent the entire structure. Similar equations for all the elements of the structure are then combined to form a set of load-displacement equations for the structure, the details, of which, will be described later.

The elements of a structure may be oriented in any manner relative to the structural system. It is, therefore, necessary to express the member equations in terms of the system coordinates before conditions of compatibility and equilibrium can be applied. The following equations (2-1), for example, are illustrative of the equations which contain a complete description of the load-displacement characteristics of a single element in system coordinates.

$$\begin{aligned} P'_1 &= K'_{11}\,\delta'_1 + K'_{12}\,\delta'_2 \\ P'_2 &= K'_{21}\,\delta'_1 + K'_{22}\,\delta'_2 \end{aligned} \tag{2-1}$$

Where P' and δ' represent end loads and displacements respectively, K' represents the appropriate stiffness matrix and the primes indicate that these quantities are expressed in system coordinates.

One important advantage of this method is that equations (2-1) can be derived for a single element without regard to how this element will be oriented in the structure. The formulation of the problem can be separated into two separate parts, (1) developing the equations (2-1) for a single element using the elastic properties and geometry of the element, (2) applying the conditions of compatibility and equilibrium which are concerned with the topology of the structure. Each of these parts are entirely independent of one another which is a tremendous advantage in the formulation of complex structural systems. It is assumed in the formulation which follows that the theory of small deflections holds true.

2.2 Flexibility and Stiffness Matrices for a Single Element

It has been found in the case of a curved member, that it is much easier to derive the flexibility matrix and invert it to obtain the stiffness matrix than to derive the stiffness matrix directly as would be the case for a straight member. The inversion can be done quite efficiently and rapidly on the computer since the maximum size of an element flexibility matrix would be 6 X 6.

It will be necessary to consider a member as having direction. As shown in Figure 2.1 the direction of a member is from its 1-end to its 2-end.

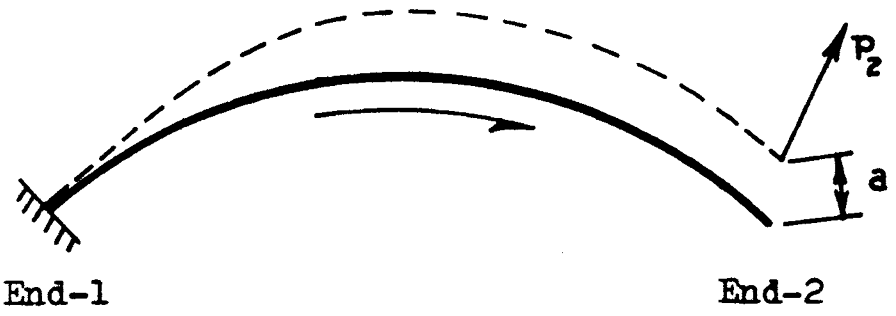


Figure 2.1 Fundamental member load-displacement.

The flexibility matrix will be derived by fixing the 1-end of the member and computing the general deformation vector "a" resulting from the general applied load vector "p_2". Each of these vectors will contain six elements, the deformation vector having three translations and three rotations and the load vector having three forces and three moments. The relationship between the deformation and the load vector can be expressed in terms of the flexibility matrix, F, as follows,

$$a = Fp_2 \qquad (2-2)$$

Since the 1-end of the member is completely fixed against any deformation, the deformations at the 2-end can be expressed uniquely in terms of p_2 thereby establishing the validity for the existence of the inverse of F. p_2 can then be written in terms of "a" and F^{-1} which equals K, the stiffness matrix, as

$$p_2 = F^{-1}a = Ka, \qquad (2\text{-}3)$$

where both K and F are symmetric matrices.

If p_2 can be expressed uniquely as in (2-3) it is a simple matter to obtain p_1 from equilibrium considerations. Figure 2.2 shows a segmental circular member with forces and moments at each end directed in a positive sense, followed by the equilibrium equations for the member.

End Loads

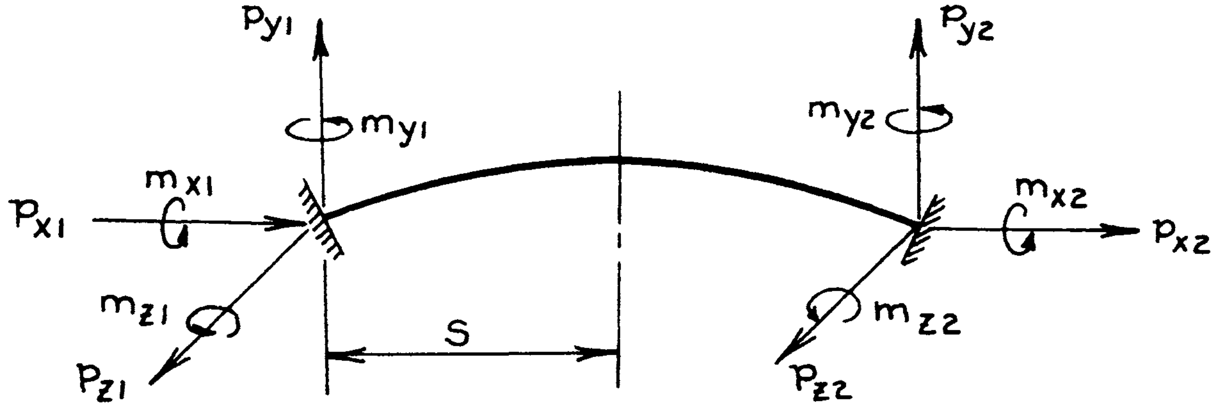


Figure 2.2 Member end load coordinates

$$\begin{aligned} p_{x1} + p_{x2} &= 0 \qquad & m_{x1} + m_{x2} &= 0 \\ p_{y1} + p_{y2} &= 0 \qquad & m_{y1} + m_{y2} - 2Sp_{z2} &= 0 \\ p_{z1} + p_{z2} &= 0 \qquad & m_{z1} + m_{z2} + 2Sp_{y2} &= 0 \end{aligned} \qquad (2\text{-}4)$$

The equilibrium equations can be written in matrix form as follows,

$$\begin{bmatrix} p_{x1} \\ p_{y1} \\ p_{z1} \\ m_{x1} \\ m_{y1} \\ m_{z1} \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -2S & 0 & 1 & 0 \\ 0 & 2S & 0 & 0 & 0 & 1 \end{bmatrix} X \begin{bmatrix} p_{x2} \\ p_{y2} \\ p_{z2} \\ m_{x2} \\ m_{y2} \\ m_{z2} \end{bmatrix} = 0 \qquad (2\text{-}5)$$

or,

$$p_1 + Hp_2 = 0. \qquad (2\text{-}5a)$$

In equation (2-5a) the matrix H is introduced and will be referred to as the "equilibrium matrix". H is a function which depends entirely on the geometry of the member, therefore, if the force vector at one end of the member is known, the force vector at the other end can be computed from simple matrix multiplication of H or H^{-1} by the appropriate force vector.

i.e. $p_1 = -Hp_2$

(2-5b)

or, $p_2 = -H^{-1}pl.$

The inverse of H can be obtained directly by matrix inversion, or it can be obtained more easily from physical considerations. This is accomplished by interchanging the 1-end and the 2-end, which only reverses the signs of the coordinates. This affects the H matrix simply by reversing the signs of the off-diagonal elements.

End Displacements

The equilibrium matrix, H, can also be used to relate the displacements at one end of the member to the displacements at the other end.

Let, δ^*_1, δ^*_2 equal rigid body end-displacements of a particular member. Since rigid body displacements by definition do not affect the equilibrium of the member, the total work resulting from the rigid body displacement is equal to zero. This can be expressed as follows,

$$p^t_1 \ \delta^*_1 + p^t_2 \ \delta^*_2 = 0, \qquad (2\text{-}6)$$

where p^t_1 and p^t_2 are the transpose of the force matrix.

Eliminating p^t_1 from equation (2-6) by using (2-5b) results in the following,

if, $p_1 = -Hp_2$

then, $p^t_1 = -p^t_2 H^t.$

Substituting into (2-6) then yields,

$$-p^t_2 H^t \delta^*_1 + p^t_2 \delta^*_2 = 0.$$

Finally,

$$\delta^*_2 = H^t \delta^*_1. \qquad (2\text{-}7)$$

If the rigid body displacements are now superimposed on the displacements in Figure 2.1 of $\delta_1 = 0$ and $\delta_2 = a$ the results are,

$$\begin{aligned} \delta_1 &= \delta^*_1 \\ \delta_2 &= \delta^*_2 + a \end{aligned} \qquad (2\text{-}8)$$

If the rigid body displacements are now eliminated from equations (2-7) and (2-8) the following results are obtained,

$$\delta^*_2 = H^t \delta_1$$

and,

$$\delta_2 = H^t \delta_1 + a \qquad (2\text{-}9)$$

or,

$$a = \delta_2 - H^t \delta_1, \qquad (2\text{-}9a)$$

where equation (2-9a) expresses a measure of the amount of elastic strain associated with any arbitrary end displacements δ_1 and δ_2. Finally, if equation (2-9a) is substituted into equation (2-3) the equation for p_2

becomes,

$$p_2 = -KH^t \delta_1 + K\delta_2.$$

Using equation (2-5b), ($p_1 = -Hp_2$), p_1 can now be defined as,

$$p_1 = +HKH^t \delta_1 - HK \delta_2.$$

This results in a set of equations in member coordinates,

$$\begin{aligned} p_1 &= HKH^t \delta_1 - HK \delta_2 \\ , \quad p_2 &= -KH^t \delta_1 + K \delta_2, \end{aligned} \qquad (2\text{-}10)$$

which are similar to equations (2-1) in system coordinates. These equations can be written in matrix form as follows,

$$\begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \begin{bmatrix} K_{11} & -K_{12} \\ -K_{21} & K_{22} \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} \qquad (2\text{-}11)$$

or, $p = K\delta$

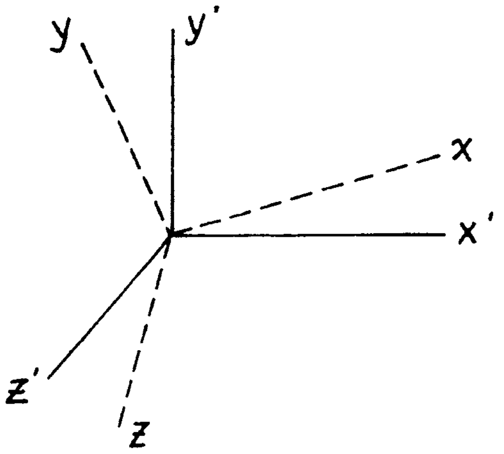
where, $K_{11} = HKH^t$, $K_{12} = HK$, $K_{21} = KH^t$ and

$K_{22} = K$, remembering that K = the inverse of F.

It can also be shown that if K is symmetric that $K_{12} = K^t_{21}$. The symmetry of K can be verified by considering Maxwell's Law.

Because individual members of a structural framework can be connected in any orientation relative to the system coordinates, member forces and displacements must be expressed in terms of system coordinates before the conditions of compatibility and equilibrium can be applied in assembling the complete stiffness matrix of the structure.

It therefore becomes necessary to derive a transformation matrix to transform both p and δ in member coordinates to p' and δ' in system coordinates. This can be accomplished with a general three dimensional, rotation of axis transformation matrix of the type,



$$T = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} & 0 & 0 & 0 \\ \lambda_{21} & \lambda_{22} & \lambda_{23} & 0 & 0 & 0 \\ \lambda_{31} & \lambda_{32} & \lambda_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & \lambda_{11} & \lambda_{12} & \lambda_{15} \\ 0 & 0 & 0 & \lambda_{21} & \lambda_{22} & \lambda_{23} \\ 0 & 0 & 0 & \lambda_{21} & \lambda_{32} & \lambda_{33} \end{bmatrix} \qquad (2\text{-}12)$$

where, λ_{ij} represents the cosines of the angles between the appropriate member and system axis. Since T is an orthogonal matrix it follows that $T^t = T^{-1}$. After T has been defined, p' and δ' can be written as,

$$p' = Tp$$

and,
$$\delta' = T\delta. \tag{2-13}$$

Using (2-13), the equations (2-11) can be re-written as,

$$p_1' = TK_{11}T^t\ \delta'_1 - TK_{12}T^t\ \delta_2'$$

and,
$$p_2' = -TK_{21}T^t\ \delta_1' + TK_{22}T^t\ \delta_2' \tag{2-14}$$

defining $TK_{ij}T^t = K_{ij}'$ results in an expression of the form of Eq. (2-1)

$$p_1' = K_{11}'\ \delta_1' + K_{12}'\ \delta'_2$$

$$p_2' = K_{21}'\ \delta_1' + K_{22}'\ \delta_2'.$$

The general form of the four system stiffness matrices can now be written from equations (2-11) and (2-14) as follows,

$$K_{11}' = THKH^tT^t$$

$$K_{12}' = -THKT^t$$

$$K_{21}' = -TKH^tT^t \tag{2-15}$$

$$K_{22}' = TKT^t.$$

It can be shown that K'^{t}_{12} and K'_{21} are equal thereby making K' symmetric. If K' is symmetric,

$$K'_{21} = K'^{t}_{12}$$

and,
$$K'^{t}_{12} = -TKH^{t}T,$$

(K is symmetric, $K = K^{t}$) and the symmetry is therefore verified.

2.3 Assembly of System Stiffness Matrix and Solution of Member Forces

The assembly of the system stiffness matrix from the member stiffness matrices makes no further reference to the elastic behavior of the material, but depends only on the way the members are connected together along with considerations of equilibrium and compatibility. Figure 2.3 illustrates a simple curvilinear grid which will be used to illustrate how the system stiffness matrix is assembled.

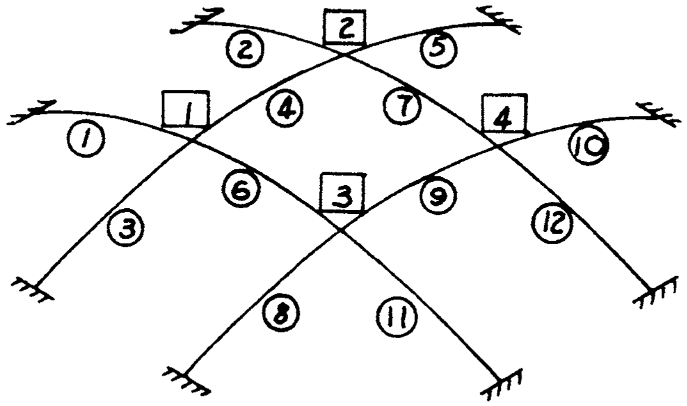


Figure 2.3 Simple curvilinear grid.

The principles involved are exactly the same for any space frame. Consider any member "I" connecting nodes J1 and J2, the member equations being,

$$p_{1I} = (K'_{11})_I \, \delta'_{1I} + (K'_{12})_I \, \delta'_{21}$$

$$p_{2I} = (K'_{21})_I \, \delta'_{1I} + (K'_{22})_I \, \delta'_{2I} \qquad (2\text{-}16)$$

Considering compatibility,

$$\delta'_{1I} = \delta'_{J1}$$

$$\delta'_{2I} = \delta'_{J2}$$

Equations (-16) can be re-written in terms of the displacements of nodes J1 and J2 as,

$$p_{1I} = (K'_{11})_I \, \delta'_{J1} + (K'_{12})_I \, \delta'_{J2}$$

and, $p_{2I} = (K'_{21})_I \, \delta'_{J1} + (K'_{22})_I \, \delta'_{J2}$,

which expresses the forces and moments at each end of member "I" in terms of nodal displacements. From equilibrium considerations applied nodal loads can be equated in terms of member end loads at a given node as,

$p_{J1} = p_{1I}$ + the contributions of any other member at node "J1",

and, $p_{J2} = p_{2I}$ + the contributions of any other member at node "J2".

The load-displacement equations can be written for nodes J1 and J2 as,

$$p_{J1} = (K'_{11})_I\,\delta'_{J1} + (K'_{12})_I\,\delta'_{J2}$$

$$+ \text{ contributions of other members,}$$

and

$$p_{J2} = (K'_{21})_I\,\delta'_{J1} + (K'_{22})_I\,\delta'_{J2}$$

$$+ \text{ contributions of other members.}$$

From the preceding equations the assembly scheme for system stiffness matrix can be deduced.

Consider for example the structure in Figure 2.3. Each node is capable of six degrees of freedom which produces a displacement vector δ' having three translations and three rotations, a load vector p, having three forces and three moments, and a 6 X 6 nodal stiffness matrix, K'. The size of the system stiffness matrix necessary to describe the four node structure in Figure 2.3 equals six times the number of nodes square or 24 X 24.

As an example, the load-displacement equation will be written for node 1;

$$p_1 = \left[(K'_{22})_1 + (K'_{22})_3 + (K'_{11})_4 + (K'_{11})_6\right]\delta'_1$$

$$+ \left[(K'_{12})_4\right]\delta'_2 + \left[(K'_{12})_6\right]\delta'_3.$$

Similarly the equations for the other nodes are

$$p_2 = \left[(K'_{21})_4\right]\delta'_1 + \left[(K'_{22})_2 + (K'_{22})_4 + (K'_{22})_5\right.$$

$$\left. + (K'_{11})_7\right]\delta'_2 + \left[(K'_{12})_7\right]\delta'_4,$$

$$p_3 = \left[(K'_{21})_6\right]\delta'_1 + \left[(K'_{22})_6 + (K'_{22})_8 + (K'_{11})_9 + (K'_{22})_{11}\right]\delta'_3 + \left[(K'_{12})_9\right]\delta'_4,$$

$$p_4 = \left[(K'_{21})_7\right]\delta'_2 + \left[(K'_{21})_9\right]\delta'_3 + \left[(K'_{22})_7 + (K'_{22})_9 + (K'_{22})_{10} + (K'_{22})_{12}\right]\delta'_4.$$

The preceding equations written in matrix form would appear as,

$$\begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{bmatrix} = \begin{bmatrix} K''_{11} & K''_{12} & K''_{13} & 0 \\ K''_{21} & K''_{22} & 0 & K''_{24} \\ K''_{31} & 0 & K''_{33} & K''_{34} \\ 0 & K''_{42} & K''_{34} & K''_{44} \end{bmatrix} \begin{bmatrix} \delta'_1 \\ \delta'_2 \\ \delta'_3 \\ \delta'_4 \end{bmatrix}$$

or as,

$$P = K''\delta',$$

where K" is the system stiffness matrix. The contribution that a single member makes to system stiffness matrix can now be seen more easily from the preceding equations. Consider member $\boxed{6}$. The direction of member $\boxed{6}$, as well as all other members, is considered to be from the smaller node number to the larger node number. Member $\boxed{6}$, therefore, has its 1-end at node ① and its 2-end at node ③ . The contribution of member $\boxed{6}$ then to the system stiffness matrix will be as follows;

(1) $(K'_{11})_6$ will be added to K''_{11}, the direct stiffness of node ①,

(2) $(K'_{22})_6$ will be added to K''_{33}, the direct stiffness of node ③,

(3) $(K'_{12})_6 = (K'_{21})^t_6$ will be added to the appropriate off diagonal stiffnesses K''_{13} and K''_{31},

which demonstrates the symmetry of the K" matrix. The systematic nature of the method of assembly of system stiffness matrix lends itself well to computer programming.

2.4 Pinned-End Rigid Foundation Attachment

The discussion thus far has been concerned only with the fixed-end rigid foundation attachments with no reference to the pinned-end or other types of foundation attachments. The following discussion explains the modifications in formulation, necessary for the treatment of the non-fixed rigid foundation attachment. The more common case of the pinned-end rigid foundation attachment will be explained in detail.

The pinned-end case could be handled in a manner similar to what is done in slope deflection solutions, where modified end equations are developed by presolving the general slope equations of a member so as to eliminate the unknown displacements of the pinned-end. This reduces the number of unknowns which one has to solve for and simplifies the solution. In the case of matrix methods, however, such as the equilibrium method where the high speed computer is being used to solve the problem it is desirable to preserve the general nature of the solution as much as possible so that the programming of the method of solution can be accomplished in a straightforward manner. The load-displacement equations (2-1) expressing the end-reactions of a member in terms of the end-displacements of that member are general in nature and are still equally valid even though some of the end displacements and end reactions may be zero, as is also the case in the general slope deflection equations. With this in mind the following treatment of the pinned-end foundation attachment can be seen more readily.

In the equilibrium method the "system stiffness matrix" is generated as though the pinned-end foundation attachment was like any other node in the structural system. Then the rows corresponding to zero joint displacements are altered. This is done simply by placing 1's on the leading diagonal of the system stiffness matrix and setting all other coefficients in the rows equal to zero. The 1's on the diagonal are necessary in order to prevent the equation solving routine from being upset by zeros on the diagonal. Symmetry of the system stiffness matrix can be maintained by placing zeros in the appropriate columns.

Similar adjustments in the system stiffness matrix can be made to handle other types of foundation attachments.

2.5 Intermediate Span Loads

The treatment of loads applied at points other than node points can be handled in a straightforward manner by the use of the principle of superposition. It is, therefore, necessary to assume linear behavior of the structure since the principle of superposition is only valid for structures which behave linearly.

The analysis would procede in the following manner, the loaded span in question would first be considered fixed at each end and the forces and moments necessary to prevent any translation or rotation of the ends of the member would then be computed as in Figure 2.4a. Next, the sense of these forces and moments are reversed and applied to the ends of the loaded member, thus replacing the intermediate span loads with a system of "equivalent fixed-end forces and moments" as in Figure 2.4b. These fixed-end forces and moments are then combined with any other forces or moments applied directly to the nodes at the ends of the member, resulting in the final nodal load vector. It is necessary not to forget that before the nodal load vector can be incorporated in the solution of the structural system it must be transformed to system coordinates.

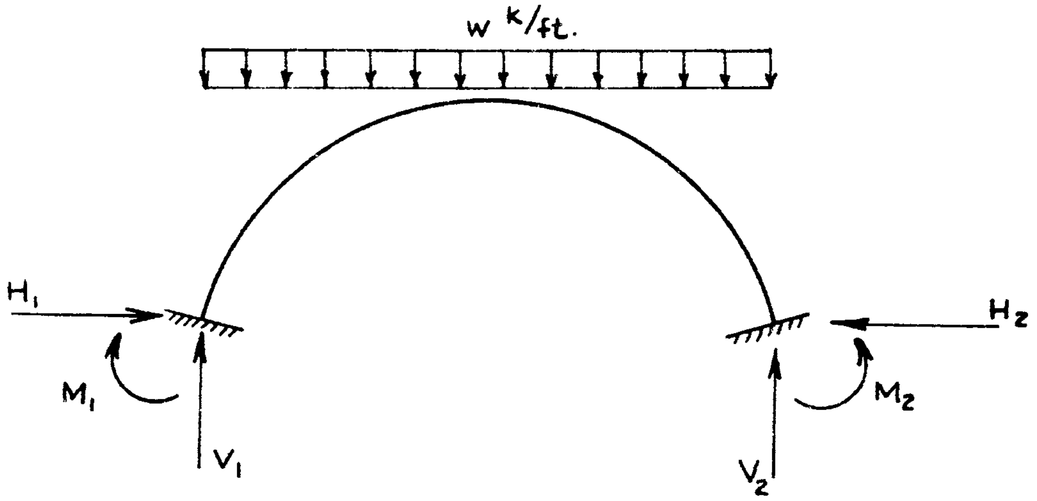
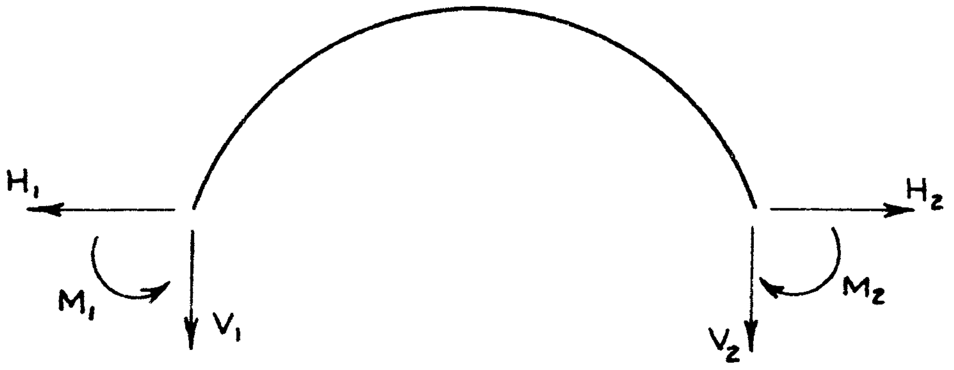


Figure 2.4a Fixed-end forces and moments on the loaded member.



2.4b Equivalent nodal loads

An additional assumption which can be made to simplify the solution of the fixed end forces and moments is that the intermediate span loads lie in the plane of the member, however, the nodal loads may be applied in any orientation.

Chapter 3

SEGMENTAL CIRCULAR MEMBER

3.1 Geometric Properties of a Segmental Circular Member

Although the stiffness method will be used to analyze the curvilinear system, the member flexibilities will be derived first and then the member stiffness matrix will be obtained by inverting the member flexibility matrix. The geometry is as follows,

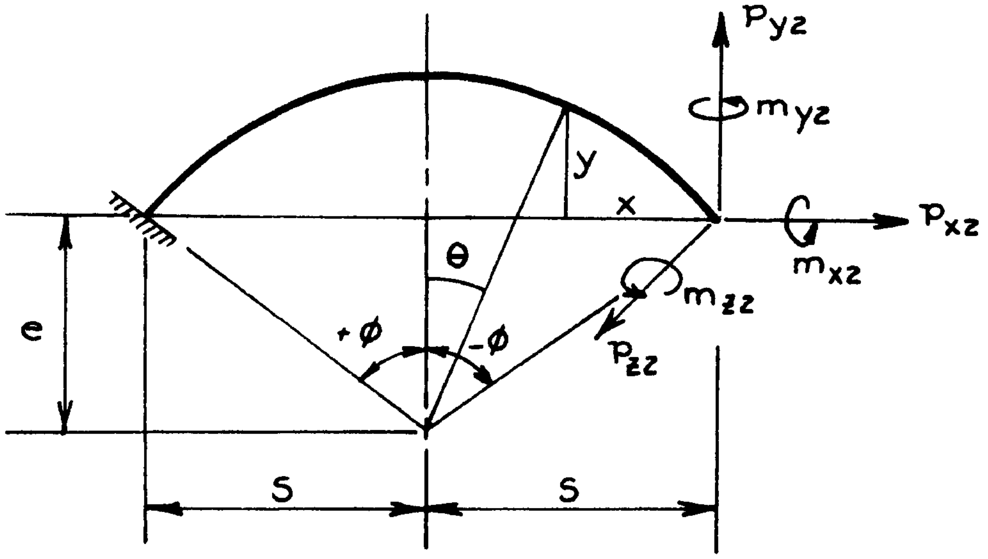


Figure 3.1 Geomerty of the segmental circular member

S = one-half member span

R = radius of member

e = vertical distance from focus to end of member

ϕ = one-half of the total angle subtended by the member

The variables x and y expressed in terms of geometric constants are,

$$x = S - R \sin\theta \qquad S = R \sin \phi$$

$$y = R \cos\theta - e \qquad e = R \cos \phi$$

$$ds = R d\theta$$

3.2 Load-Displacement Equations Derivation

The load displacement equations will be derived using Castigliano's Second Theorem,

$$\frac{\partial U}{\partial p_i} = u_i \qquad (3\text{-}1)$$

which says that the first derivative of the energy expression, U , with respect to p_i equals the corresponding displacement u_i. Energy due to bending, torsion and axial deformation will be considered in the following derivation, neglecting the effects of shear since members will generally be light and flexible.

The general expressions for moments at any point along the member about an x, y and z axis are,

about the "x" axis, $M_x = -p_z y + m_x$

about the "y" axis, $M_y = -p_z x + m_y$

about the "z" axis, $M_x = p_x y + p_y x + m_z$

In order to be able to write the general energy expression for the member, the forces and moments must be expressed with respect to the major axes of the cross-section at any point along the member. (Figure 3.2)

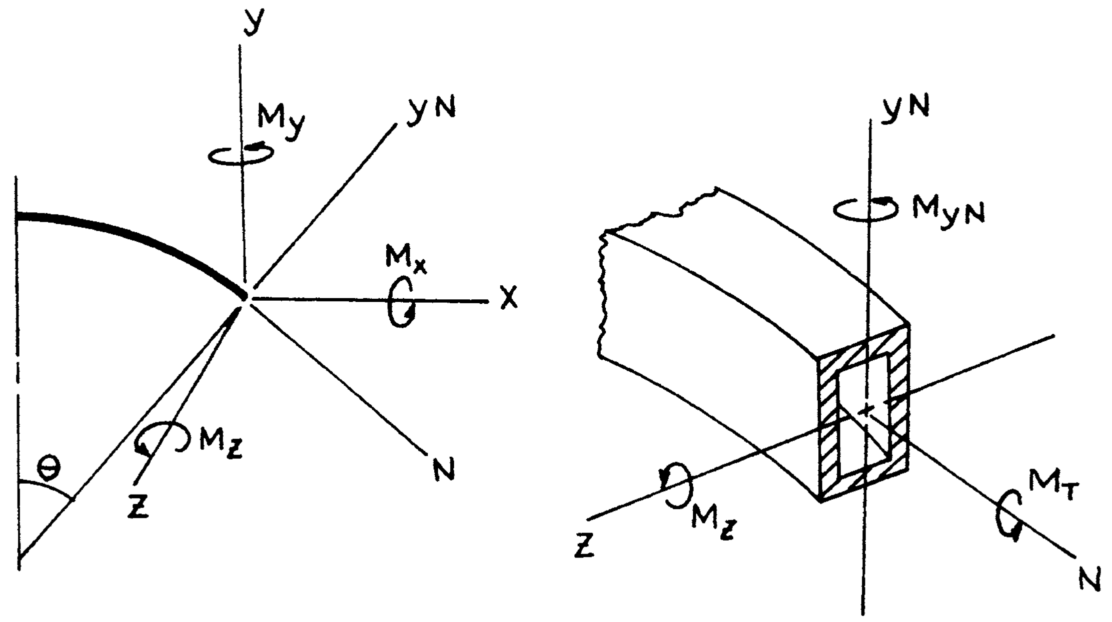


Figure 3.2 Forces and moments on major axes.

The moments and forces with respect to the axis in Figure 3.2, are,

a) Axial Force,

$$N = p_x \cos\theta - p_y \sin\theta$$

b) Torsion,

$$M_T = M_x \cos\theta - M_y \sin\theta$$

c) Moment about "z" axis,

$$M_z = p_x y + p_y x + m_z$$

d) Moment about "y_N" axis,

$$M_{yN} = M_x \sin\theta + M_y \cos\theta .$$

The previous equations can now be written in terms of the end forces and moments, and the geometric constants as;

a) $N = p_x \cos\theta - p_y \sin\theta$

b) $M_T = p_z (S \sin\theta + e \cos\theta - R) + m_x \cos\theta - m_y \sin\theta$

c) $M_z = p_x (R \cos\theta - e) + p_y (S - R \sin\theta) + m_z$

d) $M_{yN} = p_z (e \sin\theta - S \cos\theta) + m_x \sin\theta + m_y \cos\theta .$

3.3 General Energy Expression

The general energy expression can now be written as,

$$U = \int \frac{N^2 ds}{2AE} + \int \frac{M_T^2 ds}{2GI_N} + \int \frac{M_z^2 ds}{2EI_z} + \int \frac{M_{yN}^2 ds}{2EI_{yN}}$$

The deflections corresponding to the six degrees of freedom are,

$$\delta_x = \frac{\partial U}{\partial p_x}, \qquad \delta_y = \frac{\partial U}{\partial p_y}, \qquad \delta_z = \frac{\partial U}{\partial p_z} ,$$

$$\theta_x = \frac{\partial U}{\partial m_x}, \qquad \theta_y = \frac{\partial U}{\partial m_y}, \qquad \theta_z = \frac{\partial U}{\partial m_z}.$$

The following Table 3.1 which tabulates the partial derivatives of N, M_T, M_z and M_{yN} with respect to the various coordinate forces and moments can be very helpful in setting up the various integrals.

TABLE 3.1

	∂N	∂M_T	∂M_z	∂M_{yN}
∂p_x	$\cos\theta$	0	$(R\cos\theta - e)$	0
∂p_y	$-\sin\theta$	0	$(S - R\sin\theta)$	0
∂p_z	0	$(S\sin\theta + e\cos\theta - R)$	0	$(e\sin\theta - S\cos\theta)$
∂m_x	0	$\cos\theta$	0	$\sin\theta$
∂m_y	0	$-\sin\theta$	0	$\cos\theta$
∂m_z	0	0	1	0

3.4 Deflection Calculations

The deflections will now be calculated assuming that members have constant cross sectional areas and that I_N is the equivalent polar moment of inertia for the section.

1) The deflection in the x-direction is,

$$\delta_x = \int \frac{N\,\partial N}{\partial p_x}\frac{ds}{AE} \quad + \quad \int M_z \frac{\partial M_z}{\partial p_x}\frac{ds}{EI_z} \ ,$$

$$\delta_x = \frac{R}{AE}\int (p_x \cos^2\theta \ - p_y \sin\theta \cos\theta)\, d\theta$$

$$+ \frac{R}{EI_z}\int \Big[p_x (R\cos\theta \ - e) + p_y \ (S - R\sin\theta\ )$$

$$+ m_z \Big] \Big[R\cos\theta \ - e \Big]\, d\theta$$

after integrating and simplifying, the results are

$$\delta_x = \frac{p_x R}{AE}\,(\phi + \tfrac{1}{2}\sin 2\phi) + \frac{p_x R^3}{EI_z}\,(\phi - \tfrac{3}{2}\sin 2\phi$$

$$+ 2\phi\cos^2\phi) + \frac{p_y R^3}{EI_z}\,(2\sin^2\phi - \phi\sin 2\phi)$$

$$\frac{m_z R^2}{EI_z}\,(2\sin\phi - 2\phi\cos\phi).$$

2) The deflection in the y-direction is,

$$\delta_y = \int \frac{N\,\partial N}{\partial p_y}\frac{ds}{AE} + \int M_z \frac{\partial M_z}{\partial p_y}\frac{ds}{EI_z}$$

$$\delta_y = \frac{R}{AE}\int (p_x \cos\theta - p_y \sin\theta)(-\sin\theta)\, d\theta$$

$$+ \frac{R}{EI_z}\int\left[p_x (R\cos\theta - e) + p_y (S - R\sin\theta) + m_z\right]$$

$$\left[S - R\sin\theta\right] d\theta ,$$

after integrating and simplifying, the results are,

$$\delta_y = \frac{p_y R}{AE}(\emptyset - \tfrac{1}{2}\sin 2\emptyset) + \frac{p_x R^3}{EI_z}(2\sin^2\emptyset - \emptyset \sin 2\emptyset)$$

$$+ \frac{p_y R^3}{EI_z}(2\emptyset \sin^2\emptyset + \emptyset - \tfrac{1}{2}\sin 2\emptyset) + \frac{m_z R^2}{EI_z}(2\emptyset \sin\emptyset).$$

3) The deflection in the z-direction is,

$$\delta_z = \int \frac{M_T \partial M_T}{\partial p_z}\frac{ds}{GI_N} + \int M_{yN}\frac{\partial M_{yN}}{\partial p_z}\frac{ds}{EI_{yN}},$$

$$\delta_z = \frac{R}{GI_N}\int\left[p_z (S\sin\theta + e\cos\theta - R) + m_x \cos\theta\right.$$

$$\left.- m_y \sin\theta\right]\left[S\sin\theta + e\cos\theta - R\right] d\theta$$

$$+ \frac{R}{EI_{yN}}\int\left[p_z(e\sin\theta - S\cos\theta) + m_x \sin\theta\right.$$

$$\left.+ m_y \cos\theta\right]\left[e\sin\theta - S\cos\theta\right] d\theta$$

after integrating and simplifying, the results are,

$$\delta_z = \frac{p_z R^3}{GI_N}(3\phi + \frac{1}{4}\sin 4\phi - 2\sin 2\phi) + \frac{m_x R^2}{GI_N}(\phi \cos\phi$$

$$- 2\sin\phi + \frac{1}{2}\cos\phi \sin 2\phi) - \frac{m_y R^2}{GI_N}(\phi \sin\phi$$

$$- \frac{1}{2}\sin\phi \sin 2\phi) + \frac{p_z R^3}{EI_{yN}}(\phi - \frac{1}{4}\sin 4\phi)$$

$$+ \frac{m_x R^2}{EI_{yN}}(\phi \cos\phi - \frac{1}{2}\cos\phi \sin 2\phi) - \frac{m_y R^2}{EI_{yN}}(\phi \sin\phi$$

$$+ \frac{1}{2}\sin\phi \sin 2\phi).$$

4) The rotation about the x-axis is,

$$\theta_x = \int M_T \frac{\partial M_T}{\partial m_x}\frac{ds}{GI_N} + \int M_{yN}\frac{\partial M_{yN}}{\partial m_x}\frac{ds}{EI_{yN}},$$

$$\theta_x = \frac{R}{GI_N}\int\Big[p_x(s \sin\theta + e\cos\theta - R) + m_x \cos\theta$$

$$- m_y \sin\theta\Big]\Big[\cos\theta\Big]\, d\theta + \frac{R}{EI_{yN}}\int\Big[p_z(e \sin\theta$$

$$- S\cos\theta) + m_x \sin\theta + m_y \cos\theta\Big]\Big[\sin\theta\Big]\, d\theta ,$$

after integrating and simplifying, the results are,

$$\theta_x = \frac{p_z R^2}{GI_N}(\phi \cos\phi - 2 \sin\phi + \frac{1}{2} \cos\phi \sin 2\phi)$$

$$+ \frac{m_x R}{GI_N}(\phi + \frac{1}{2} \sin 2\phi) + \frac{p_z R^2}{EI_{yN}}(\phi \cos\phi - \frac{1}{2} \cos\phi \sin 2\phi)$$

$$+ \frac{m_x R}{EI_{yN}}(\phi - \frac{1}{2} \sin 2\phi).$$

5) The rotation about the y-axis is,

$$\theta_y = \int M_T \frac{\partial M_T}{\partial m_y} \frac{ds}{GI_N} + \int M_{yN} \frac{\partial M_{yN}}{\partial m_y} \frac{ds}{EI_{yN}} ,$$

$$\theta_y = \frac{R}{GI_N} \int \Big[p_z(S \sin\theta + e \cos\theta - R + m_x \cos\theta$$

$$- m_y \sin\theta \Big] \Big[-\sin\theta \Big] d\theta + \frac{R}{EI_{yN}} \int \Big[p_z(e \sin\theta$$

$$- s \cos\theta) + m_x \sin\theta + m_y \cos\theta \Big] \Big[\cos\theta \Big] d\theta ,$$

after integrating and simplifying, the results are,

$$\theta_y = \frac{-p_z R^2}{GI_N}(\phi \sin\phi - \frac{1}{2} \sin\phi \sin 2\phi) + \frac{m_y R}{GI_N}(\phi - \frac{1}{2} \sin 2\phi)$$

$$- \frac{p_z R^2}{EI_{yN}}(\phi \sin\phi + \frac{1}{2} \sin\phi \sin 2\phi + \frac{m_y R}{EI_{yN}}(\phi + \frac{1}{2} \sin 2\phi).$$

6) The rotation about the z-axis is,

$$\theta_z = \int M_z \frac{\partial M_z}{\partial m_z} \frac{ds}{EI_z}$$

$$\theta_z = \frac{R}{EI_z} \int \Big[p_x (R \cos\theta - e) + p_y (S - R \sin\theta) + M_z \Big] \Big[1 \Big] d\theta ,$$

after integrating and simplifying, the results are,

$$\theta_z = \frac{p_x R^2}{EI_z} (2 \sin\phi - 2\phi \cos\phi) + \frac{p_y R^2}{EI_z} (2\phi \sin\phi) - \frac{m_z R}{EI_z} (2\phi).$$

3.5 Flexibility Matrix

Now that the deflections and rotations of end 2 of the member have been found in terms of the six degrees of freedom, the flexibilities f_{ij} can be found, according to definition, by setting the jth force equal to unity and computing the ith displacement (i = 1, 2, ... 6)when the other forces and moments are set equal to zero. Flexibility f_{ij} can also be found by,

$$f_{ij} = \frac{\partial^2 U}{\partial p_i \partial p_j} , \qquad (3\text{-}2)$$

which is equivalent to the definition previously stated. Now for simplicity let;

$$\begin{array}{llll} p_x = p_1 & m_x = p_4 & \delta_x = \delta_1 & \theta_x = \theta_4 \\ p_y = p_2 & m_y = p_5 & \delta_y = \delta_2 & \theta_y = \theta_5 \\ p_z = p_3 & m_z = p_6 & \delta_z = \delta_3 & \theta_z = \theta_6. \end{array}$$

The elements of the resulting flexibility matrix will then be;

$$f_{11} = \frac{R}{AE}\left(\phi + \frac{1}{2}\sin\phi\right) + \frac{R^3}{EI_z}\left(\phi - \frac{3}{2}\sin 2\phi + 2\phi\cos^2\phi\right)$$

$$f_{22} = \frac{R}{AE}\left(\phi - \frac{1}{2}\sin\phi\right) + \frac{R^3}{EI_z}\left(\phi - \frac{1}{2}\sin 2\phi + 2\phi\sin^2\phi\right)$$

$$f_{33} = \frac{R^3}{GI_N}\left(3\phi - 2\sin 2\phi + \frac{1}{4}\sin 4\phi\right) + \frac{R^3}{EI_{yN}}\left(\phi - \frac{1}{4}\sin 4\phi\right)$$

$$f_{44} = \frac{R}{GI_N}\left(\phi + \frac{1}{2}\sin 2\phi\right) + \frac{R}{EI_{yN}}\left(\phi - \frac{1}{2}\sin 2\phi\right)$$

$$f_{55} = \frac{R}{GI_N}\left(\phi - \frac{1}{2}\sin 2\phi\right) + \frac{R}{EI_{yN}}\left(\phi + \frac{1}{2}\sin 2\phi\right)$$

$$f_{66} = \frac{R}{EI_z}(2\phi),$$

which are the diagonal elements of the flexibility matrix.

The off diagonal elements of the flexibility matrix are;

$$f_{12} = f_{21} = \frac{R^3}{EI_z}(2 \sin^2\phi - \phi \sin 2\phi$$

$$f_{13} = f_{31} = f_{14} = f_{41} = f_{51} = f_{15} = 0$$

$$f_{61} = f_{16} = \frac{R^2}{EI_z}(2 \sin\phi - 2\phi \cos\phi)$$

$$f_{32} = f_{23} = f_{42} = f_{24} = f_{52} = f_{25} = 0$$

$$f_{26} = f_{62} = \frac{R^2}{EI_z}(2\phi \sin\phi)$$

$$f_{36} = f_{63} = f_{45} = f_{54} = f_{46} = f_{64} = f_{56} = f_{65} = 0$$

$$f_{34} = f_{43} = \frac{R^2}{GI_N}(\phi \cos\phi - 2 \sin\phi + \frac{1}{2} \cos\phi \sin 2\phi)$$

$$+ \frac{R^2}{EI_{yN}}(\phi \cos\phi - \frac{1}{2} \cos\phi \sin 2\phi)$$

$$f_{35} = f_{53} = - \frac{R^2}{GI_N}(\phi \sin\phi - \frac{1}{2} \sin\phi \sin 2\phi)$$

$$- \frac{R^2}{EI_{yN}}(\phi \sin\phi + \frac{1}{2} \sin\phi \sin 2\phi).$$

As can be seen a considerable number of the off diagonal elements of the flexibility matrix are equal to zero, which makes finding the inverse of the six by six much easier than if the matrix was completely full.

Finally, the assembled member flexibility matrix written in matrix form would be,

$$\begin{bmatrix} f_{11} & f_{12} & 0 & 0 & 0 & f_{16} \\ f_{21} & f_{22} & 0 & 0 & 0 & f_{26} \\ 0 & 0 & f_{33} & f_{34} & f_{35} & 0 \\ 0 & 0 & f_{43} & f_{44} & 0 & 0 \\ 0 & 0 & f_{53} & 0 & f_{55} & 0 \\ f_{61} & f_{62} & 0 & 0 & 0 & f_{66} \end{bmatrix},$$

and it is evident also that the flexibility matrix is symmetrical. The K matrix in equation (2-3) can now be computed by inverting F. This K corresponds to K_{22} in Equation (2-11). If the equilibrium matrix is known, K_{11}, K_{12}, K_{21} can be computed. These K's, however, are still in member coordinates and before they are transformed into system coordinates, the transformation matrix T must be derived.

3.6 Three Dimensional Axis Rotation Transformation Matrix

In order to keep the formulation of system stiffness matrix general in nature, the transformation matrix, T, will be derived for a member whose axis is skewed to all three system axes, as indicated in Figure 3.2.

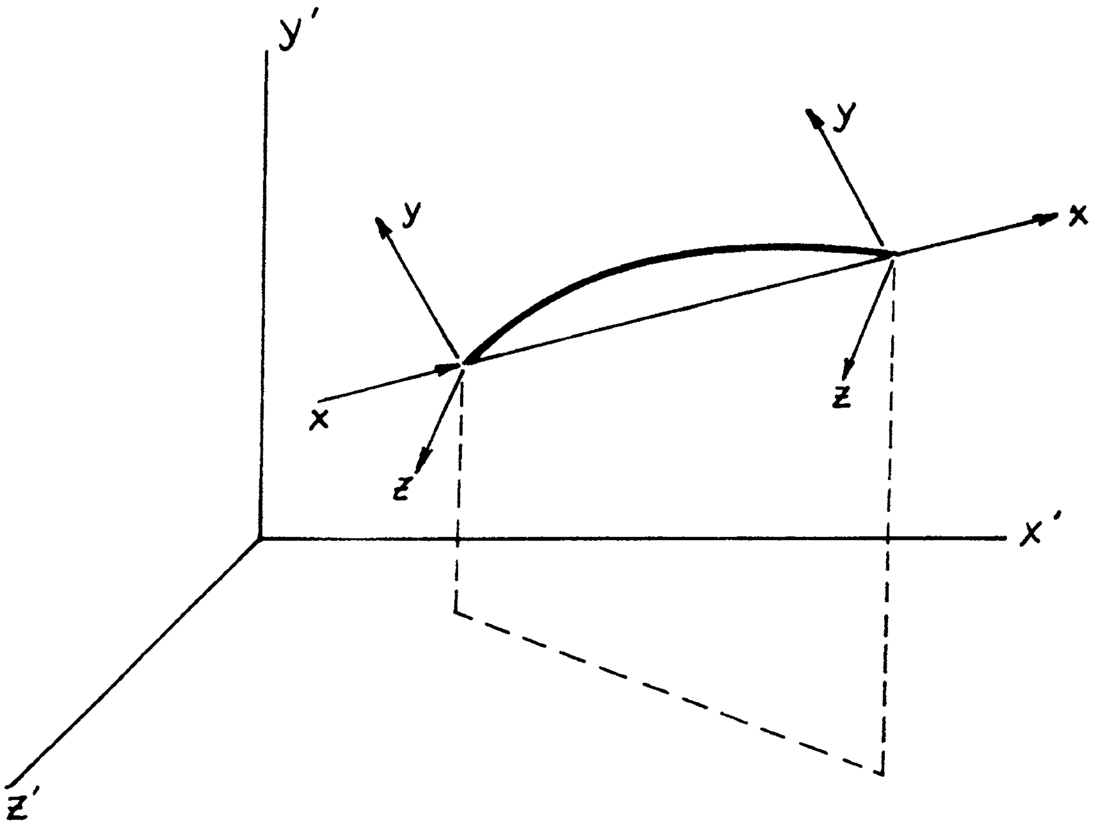


Figure 3.3 Typical member orientation

From equations (2.13) for example,

$$p' = Tp$$

and,

$$\delta' = T\delta$$

or in matrix form,

$$\begin{bmatrix} p'_x \\ p'_y \\ p'_z \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} \end{bmatrix} \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$

where λ_{11}, λ_{12}, ...etc. are direction cosines. It can be shown that T is an orthogonal matrix thereby making $T^{-1} = T^t$ so that

$$p = T^t p'$$

$$(3\text{-}1)$$

and,

$$\delta = T^t \delta'.$$

The derivation of the transformation matrix T can now procede in a systematic manner by considering T^t as the product of three individual rotation transformation matrices T_α, T_β and T_γ corresponding to the three rotations which must be performed required to transform from member to system coordinates as shown in Figure 3.3. In each row of T^t is located the direction cosines of the corresponding member axis.

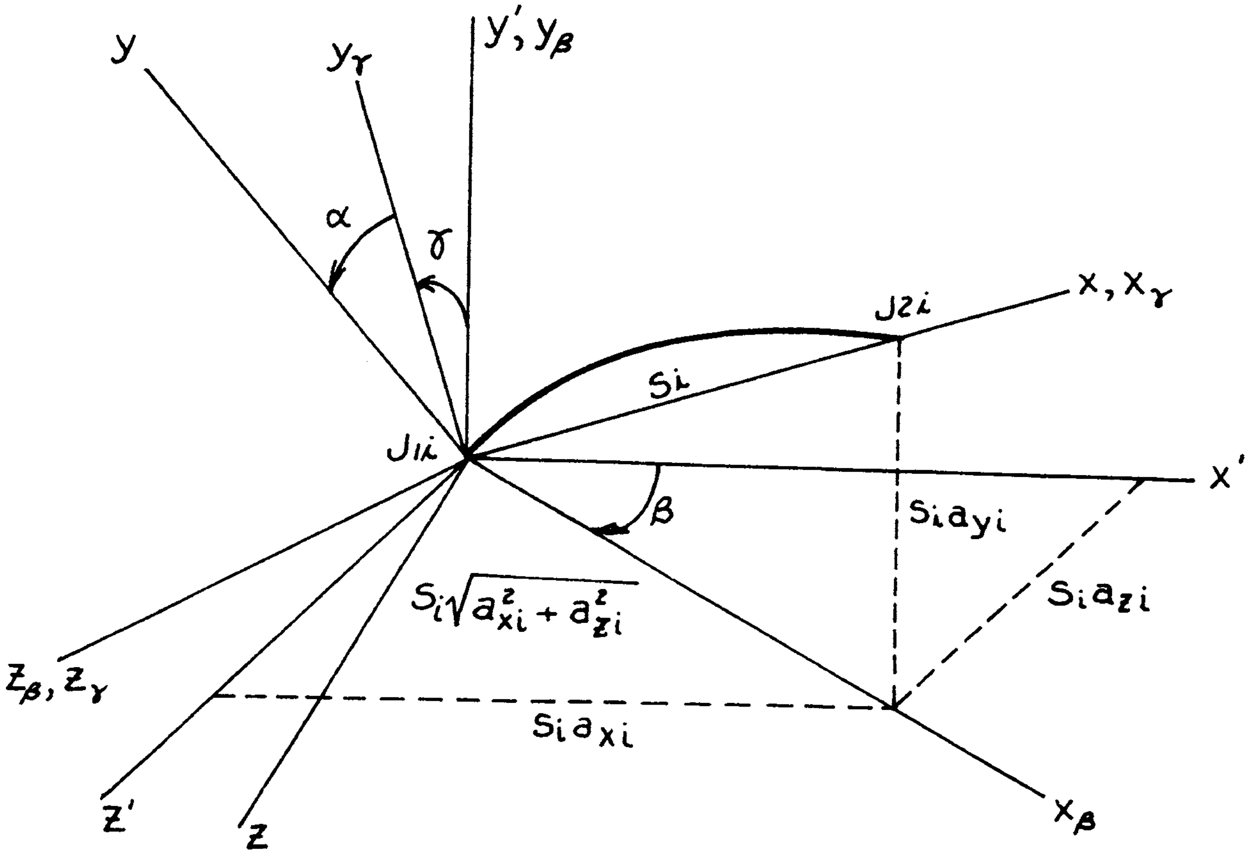


Figure 3.4 The three required rotations

Let a_x, a_y and a_z equal the direction cosines of x. Then,

$$a_x = \frac{x_{J2} - x_{J1}}{S} \; ; \qquad a_y = \frac{y_{J2} - y_{J1}}{S} \; ; \qquad a_z = \frac{z_{J2} - z_{J1}}{S}$$

where,

$$S = \sqrt{(x_{J2} - x_{J1})^2 + (y_{J2} - y_{J1})^2 + (z_{J2} - z_{J1})^2}$$

Row 1 of T^t equals a_x, a_y and a_z which are the direction cosines of the x axis and can be found directly from the end coordinates of the member. The last two rows can be found by considering β, γ and α rotations. Consider first the β rotation and T_β where,

$$T_\beta = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \qquad (3\text{-}2)$$

The elements $\cos\beta$ and $\sin\beta$ can be expressed in terms of a_x, a_y and a_z as follows,

$$\cos\beta = \frac{a_x}{\sqrt{a_x^2 + a_z^2}} \qquad \sin\beta = \frac{a_z}{\sqrt{a_x^2 + a_z^2}}$$

The system forces have now been transformed to the axis where,

$$p_\beta = T_\beta \, p'$$

Next the β-axis will be rotated to the γ-axis or i.e., the β-forces will be transformed to γ oriented forces.

$$T_\gamma = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad (3\text{-}3)$$

where,

$$\cos\gamma = \sqrt{a_x^2 + a_z^2}, \qquad \sin\gamma = a_y,$$

so that the system forces have now been transformed to the γ-axis as,

$$p_\gamma = T_\gamma P_\beta$$

or,

$$p_\gamma = T_\gamma T_\beta P'$$

Finally, the α-transformation, where α is the rotation of the y-axis of the member with respect to Y_γ-axis about the member x-axis and is part of the input data.

$$T_\alpha = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix} \qquad (3\text{-}4)$$

The member forces can now be expresses as,

$$p = T_\alpha P_\gamma$$

or, using Equations (3-2), (3-3) and (3-4),

$$p = T_\alpha T_\gamma T_\beta P'$$

where,

$$T^t = T_\alpha T_\gamma T_\beta$$

and,

$$p = T^t p'$$

or,

$$p' = Tp \; .$$

In a similar manner the member stiffness matrix can be transformed to system stiffness matrix by,

$$K' = TKT^t.$$

Now if the appropriate terms for $\cos\beta$, $\sin\beta$, $\cos\gamma$, $\sin\gamma$ are substituted into the appropriate matrices and the indicated multiplications of T_α T_γ T_β are carried out the final form of T^t will be as follows,

$$T^t = \begin{bmatrix} \lambda_{11} & \lambda_{21} & \lambda_{31} \\ \lambda_{12} & \lambda_{22} & \lambda_{32} \\ \lambda_{13} & \lambda_{23} & \lambda_{33} \end{bmatrix}$$

where,

$$\lambda_{11} = a_x$$

$$\lambda_{12} = \frac{-a_x a_y \cos\alpha - a_z \sin\alpha}{\sqrt{a_x^2 + a_z^2}}$$

$$\lambda_{13} = \frac{a_x a_y \sin\alpha - a_z \cos\alpha}{\sqrt{a_x^2 + a_z^2}}$$

$$\lambda_{21} = a_y$$

$$\lambda_{22} = \sqrt{a_x^2 + a_z^2}\,\cos\alpha$$

$$\lambda_{23} = -\sqrt{a_x^2 + a_z^2}\,\sin\alpha$$

$$\lambda_{31} = a_z$$

$$\lambda_{32} = \frac{-a_y a_z \cos\alpha + a_x \sin\alpha}{\sqrt{a_x^2 + a_z^2}}$$

$$\lambda_{33} = \frac{a_y a_z \sin\alpha + a_x \cos\alpha}{\sqrt{a_x^2 + a_z^2}} .$$

Chapter 4

APPLICATION OF ANALYSIS

In this chapter the information obtained from Chapters 2 and 3 will be applied to the analysis of "curvilinear space grids". The details of the computer program, which performs the necessary calculations, are discussed in the following chapter. The objective of the material in this chapter is to demonstrate the validity of the solution and to develop confidence in the analysis.

4.1 Procedure

Three different mathematical models were chosen to demonstrate the analysis. These models are circular framed dones having height to span ratios, (h/L), of one-sixth, one-fourth and one-half respectively, with each one having a span of 72.0 inches.

Each of the structures were analyzed under the influence of symmetric and unsymmetric loads. In one case, all foundation attachments were fixed, while in the other case half of the foundation attachments were fixed and half were pinned. The details of the mathematical models can be seen clearly in the diagrams which follow in (4.2).

Finally, an experimental model was build and tested in order to provide the necessary correlation between the analytical solution of the mathematical model and experimental results from the physical model.

4.2 Mathematical Models

Each of the mathematical models are composed of twenty-four segmental circular members, whose topological arrangement describes a "lattice dome". All of the members lie on the arc of a great circle. The model dome has nine interior nodal points and twelve foundation attachments.

a.) Mathematical Model 1 - The computations involved in obtaining the geometric data will be shown in detail for this model as an example of the required hand calculations, and subsequently deleted from the remaining models as they are handled in the same manner.

1.) Basic Geometry:

$$\frac{h}{L} = \frac{1}{6}, \qquad L = 72.0'', \qquad h = 12.0''$$

$$R = \frac{h}{2}\left[1 + \frac{1}{4\left(\frac{h}{L}\right)^2}\right]$$

$$R = 60.0''$$

2.) Plan View - Figures 4.1 and 4.2 illustrate the node and member numbering scheme used in the analysis of the model with fixed foundation attachments and combined fixed and pinned foundation attachments.

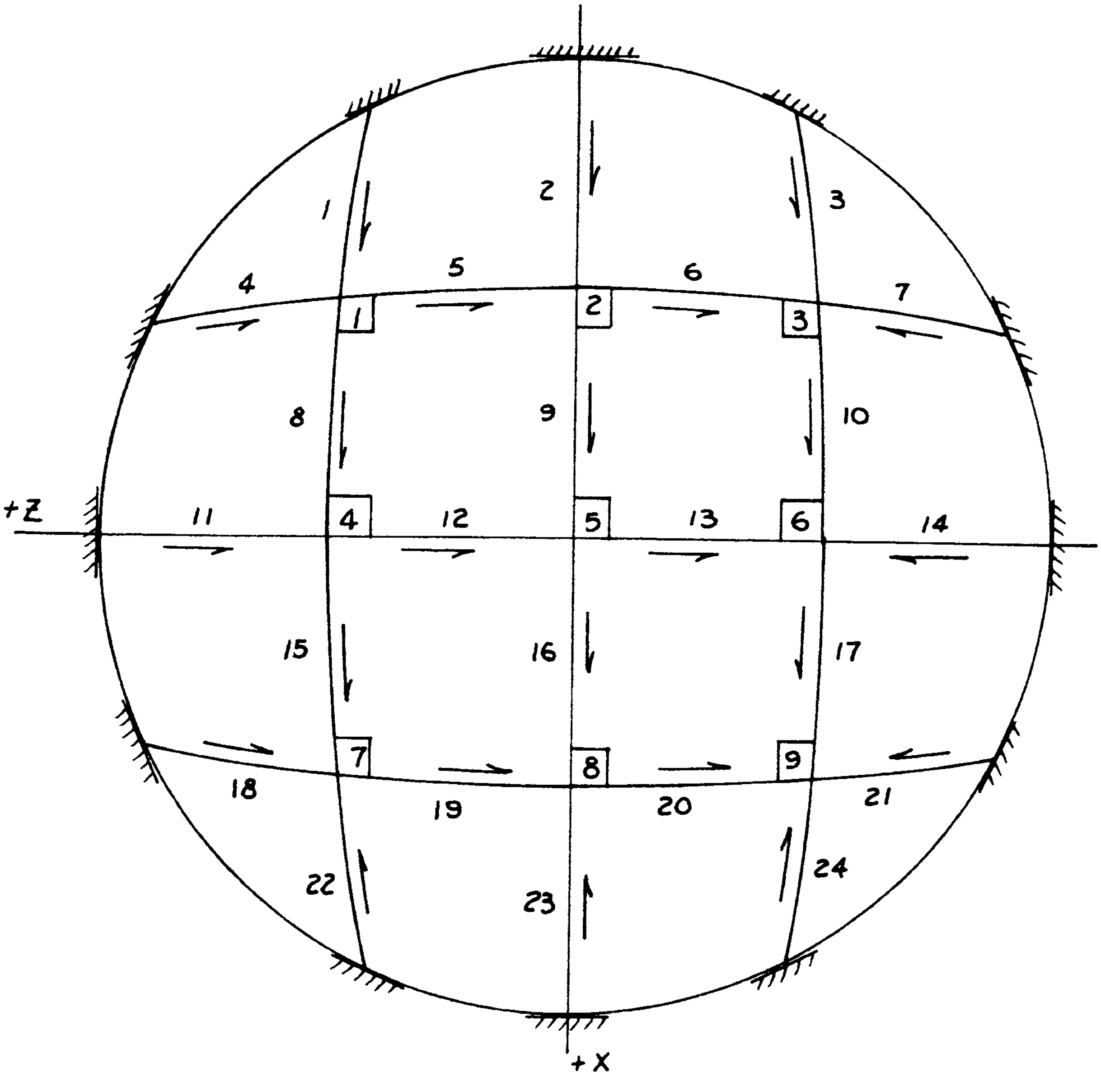


Figure 4.1 Mathematical Model-1 $\left(\frac{h}{L} = \frac{1}{6}\right)$, all foundation attachments fixed.

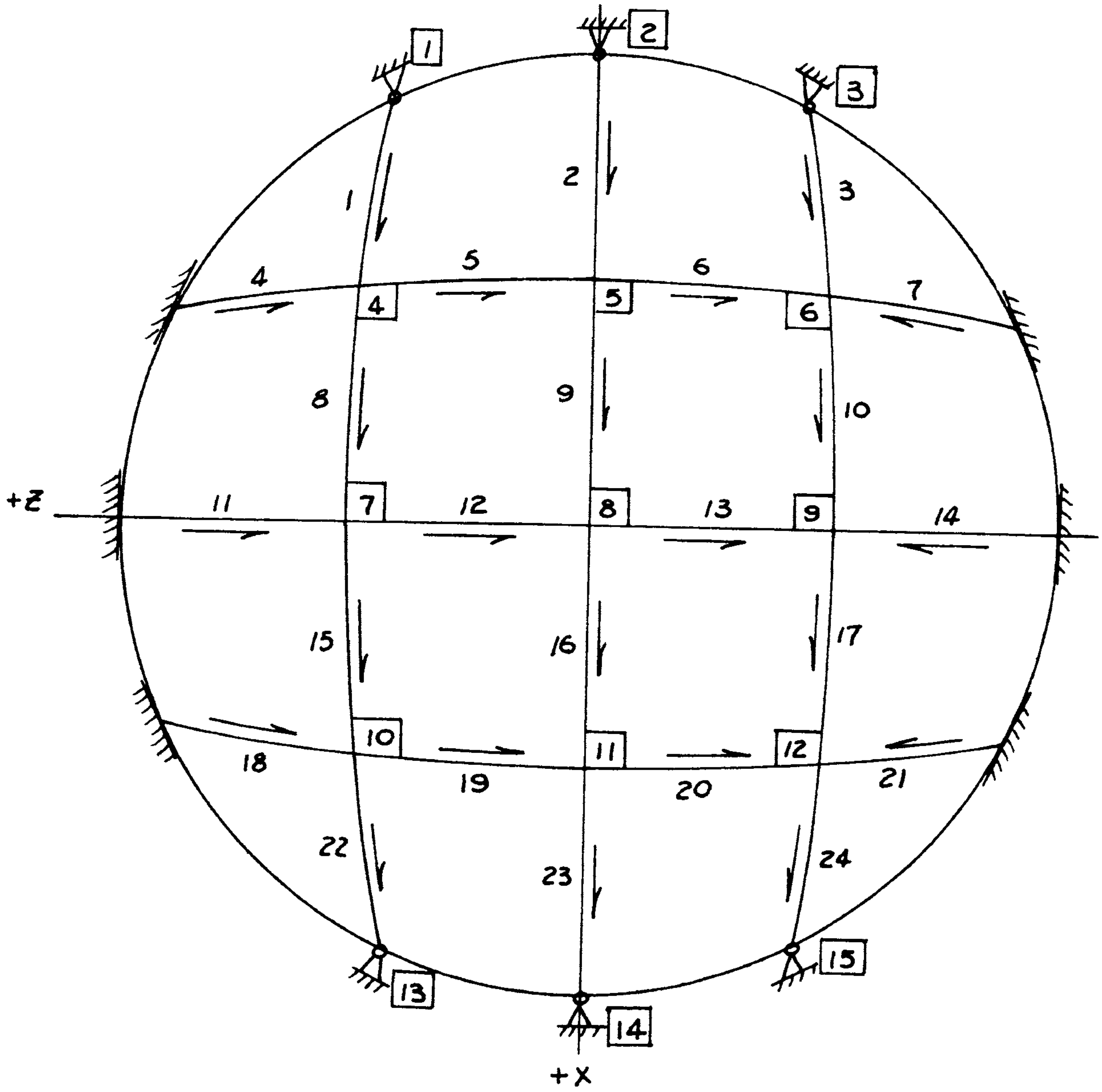


Figure 4.2 Mathematical Model-1 $\left(\frac{h}{L} = \frac{1}{6}\right)$, with both pinned and fixed foundation attachments.

3.) Model profile:

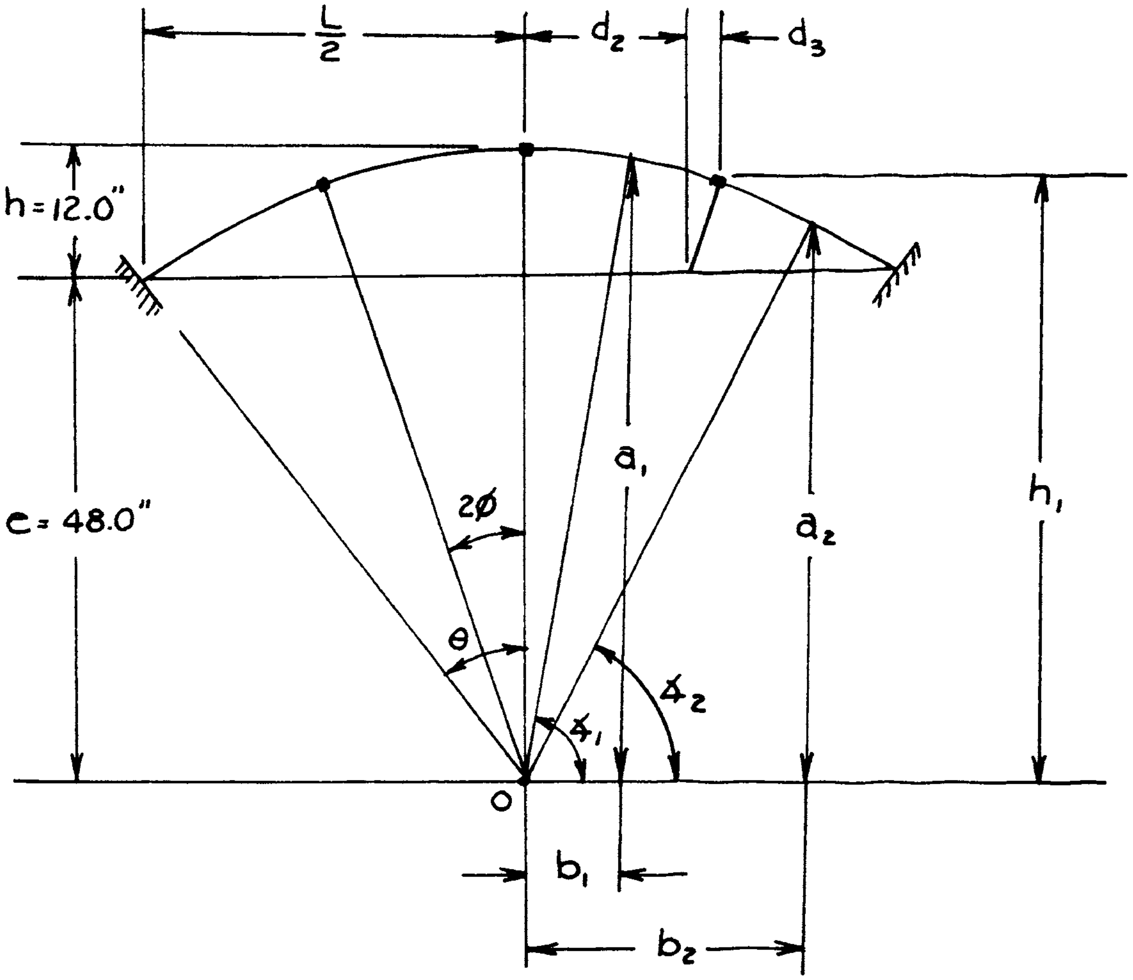


Figure 4.3 Basic coordinate dimensions

$$\theta = \sin^{-1} \frac{L/2}{R} = 36.87°$$

$$h_1 = R \sin (90° - 2\phi) = 56.92 \text{ in.}$$

$$d_1 = d_2 + d_3$$

$$d_1 = R \cos (90° - 2\phi) = 18.97 \text{ in.}$$

$$d_3 = (h_1 - e) \frac{d_1}{h_1} = 2.97 \text{ in.}$$

$$d_2 = d_1 - d_3 = 16.0 \text{ in.} \quad \text{(See Fig. 4.1)}$$

4.) General coordinates of nodes 1, 3, 7, 9

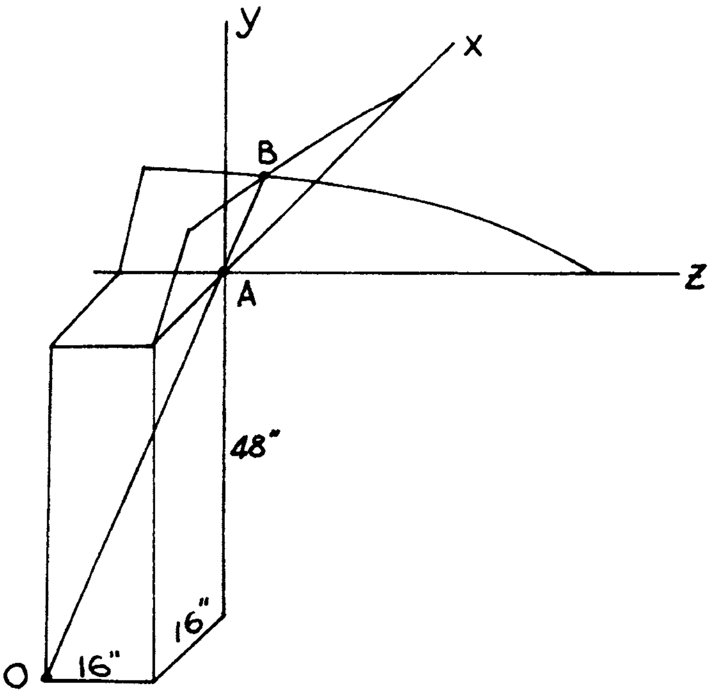


Figure 4.4 Geometry of 1, 3, 7, 9 node points.

OAB = 60.0 in.

$$OA = \sqrt{2(16)^2 + (48)^2} = 53.066 \text{ in.}$$

AB = 60.000 - 53.066 = 6.934 in.

$$\Delta x = \Delta z = 6.934 \frac{16}{53.066} = 2.09 \text{ in.}$$

$$y = 6.934 \frac{48}{53.066} = 6.27 \text{ in.}$$

The resulting coordinates of B without regard to sign are,

$x = z = 16.0 + \Delta x = 18.09$ in.

$y = 6.27$ in.

5.) General coordinates of nodes 2, 4, 6, and 8 are,

$x = z = d_1 = 18.97$ in. (See Fig. 4.3)

$y = h_1 - e = 8.92$ in.

6.) Member - Ø - Calculations

$$\phi_1 = \frac{\Theta}{4} = \frac{36.87}{4} = 9.2175°$$

$$\phi_1 = 0.160877 \text{ rad.}$$

<u>ϕ_2 - Members 5, 6, 8, 10, 15, 17, 19, 20</u>

$$\phi_2 = \sin^{-1} \frac{S_2}{60.0},$$

where, S_2 = one half the chord length of the member.

Then,

$$2S_2 = \sqrt{(.88)^2 + (2.65)^2 + (18.091)^2} = 18.305 \text{ in.}$$

$$\phi_2 = \sin^{-1} \frac{18.305/2}{60} = 8.774°$$

$$\phi_2 = 0.153135 \text{ rad.}$$

<u>ϕ_3 - Members 1, 3, 4, 7, 18, 21, 22, 24</u>

$$\phi_3 = \sin^{-1} \frac{S_3}{60.0},$$

where, S_3 equals one half the chord length of the member.

Then,

$$2S_3 = \sqrt{(14.16)^2 + (6.27)^2 + (2.09)^2} = 15.625 \text{ in.}$$

$$\phi_3 = \sin^{-1} \frac{15.625/2}{60.0} = 7.48°$$

$$\phi_3 = 0.13055 \text{ rad.}$$

7.) Member $-\alpha-$ computations

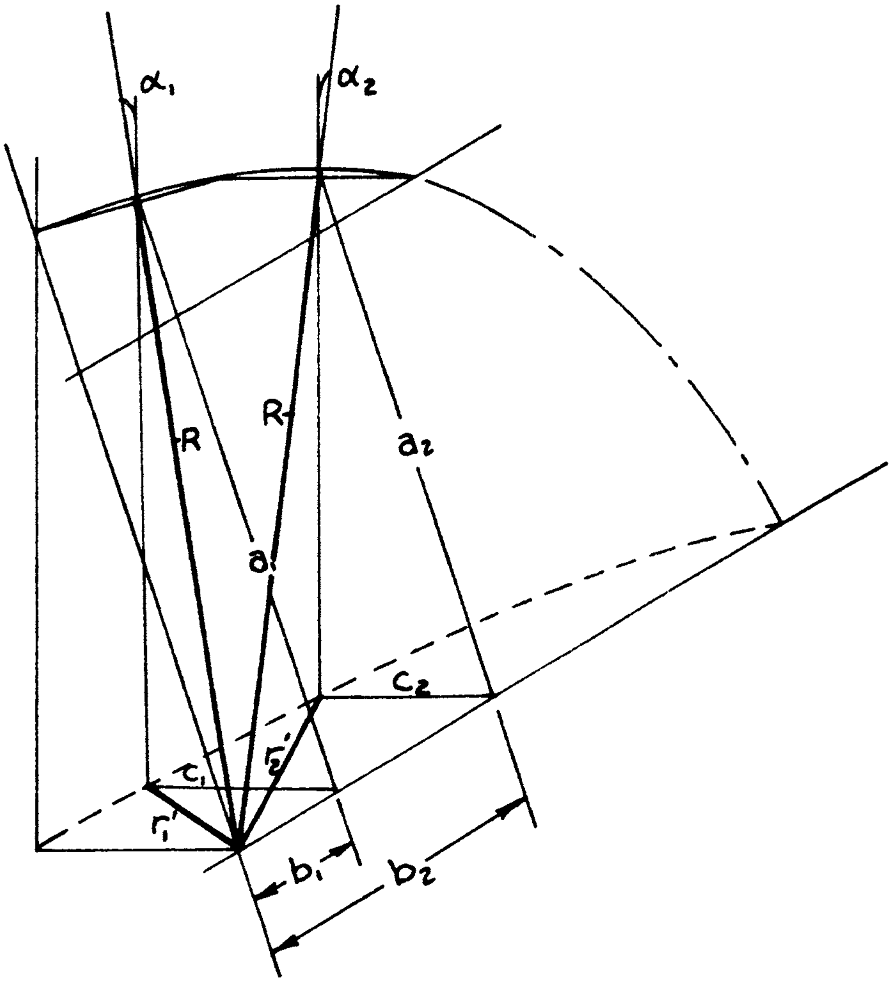


Figure 4.5 Required geometry for α.

Computations continued,

$\underline{\measuredangle_1 = 81.23^\circ:}$ (See Fig. 4.3)

$a_1 = 60 \sin (81.23^\circ) = 59.30$ in.

$b_1 = 60 \cos (81.23^\circ) = 9.15$

$c_1 = 59.3 \sin (18.43^\circ) = 18.75$

$r_1' = \sqrt{(9.15)^2 + (18.75)^2} = 20.864$

$\alpha_1 = \sin^{-1} \dfrac{20.864}{60.0} = 20.35^\circ$

$\underline{\underline{\alpha_1 = .35517 \text{ rad.}}}$

$\underline{\measuredangle_2 = 54.97^\circ:}$

$a_2 = 60 \sin (54.97) = 49.13$ in.

$b_2 = 60 \cos (54.97) = 34.44$ in.

$c_2 = 49.13 \sin (18.43) = 15.53$ in.

$r_2' = \sqrt{(34.44)^2 + (15.53)^2} = 37.727$ in.

$\alpha_2 = \sin^{-1} \dfrac{37.727}{60.0} = 38.96^\circ$

$\underline{\underline{\alpha_2 = .67998 \text{ rad.}}}$

4.3 Example Computer Analysis

The computer solution of Mathematical Model-1, with fixed foundation attachments and symmetrically loaded is presented here to illustrate the computer output.

The input data, such as coordinates, member properties, nodal data and nodal loads is printed first. The input data is followed by the computed data such as the "Link" array, a sample flexibility, stiffness and transformation matrix, the nodal displacements and the member-end forces and moments in both system and member coordinates.

The computer solutions for the other mathematical models are presented in Appendix A.

```
NUMBER OF NODES  9
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                              MEMBER COORDINANTS
 MEMBER-I       X(I,1)           X(I,2)           Y(I,1)           Y(I,2)           Z(I,1)           Z(I,2)

     1       -32.250000       -18.089996        0.0              6.270000        16.000000        18.089996
     2       -36.000000       -18.969986        0.0              8.919999         0.0              0.0
     3       -32.250000       -18.089996        0.0              6.270000       -16.000000       -18.089996
     4       -16.000000       -18.089996        0.0              6.270000        32.250000        18.089996
     5       -18.089996       -18.969986        6.270000         8.919999        18.089996         0.0
     6       -18.969986       -18.089996        8.919999         6.270000         0.0            -18.089996
     7       -16.000000       -18.089996        0.0              6.270000       -32.250000       -18.089996
     8       -18.089996         0.0              6.270000         8.919999        18.089996        18.969986
     9       -18.969986         0.0              8.919999        12.000000         0.0              0.0
    10       -18.089996         0.0              6.270000         8.919999       -18.089996       -18.969986
    11         0.0              0.0              0.0              8.919999        36.000000        18.969986
    12         0.0              0.0              8.919999        12.000000        18.969986         0.0
    13         0.0              0.0             12.000000         8.919999         0.0            -18.969986
    14         0.0              0.0              0.0              8.919999       -36.000000       -18.969986
    15         0.0             18.089996         8.919999         6.270000        18.969986        18.089996
    16         0.0             18.969986        12.000000         8.919999         0.0              0.0
    17         0.0             18.089996         8.919999         6.270000       -18.969986       -18.089996
    18        16.000000        18.089996         0.0              6.270000        32.250000        18.089996
    19        18.089996        18.969986         6.270000         8.919999        18.089996         0.0
    20        18.969986        18.089996         8.919999         6.270000         0.0            -18.089996
    21        16.000000        18.089996         0.0              6.270000       -32.250000       -18.089996
    22        32.250000        18.089996         0.0              6.270000        16.000000        18.089996
    23        36.000000        18.969986         0.0              8.919999         0.0              0.0
    24        32.250000        18.089996         0.0              6.270000       -16.000000       -18.089996


                                                  MEMBER PROPERTIES
 MEMBER-I        IX               IY               IZ              AREA             RADIUS            PHI              ALPHA

     1        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550         0.679980
     2        0.000550         0.000325         0.000326         0.062500        60.000000         0.160877         0.0
     3        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550        -0.679980
     4        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550        -0.679980
     5        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135        -0.355170
     6        0.000550         0.000325         0.000326         0.062500        60.000000         0.153135        -0.355170
     7        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550         0.679980
     8        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135         0.355170
     9        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    10        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135        -0.355170
    11        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    12        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    13        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    14        0.000550         0.000325         0.000326         0.062500        60.000000         0.160877         0.0
    15        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135         0.355170
    16        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    17        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135        -0.355170
    18        0.000550         0.000325         0.000326         0.062500        60.000000         0.130550         0.679980
    19        0.000550         0.000326         0.000326         0.062500        60.000000         0.153135         0.355170
    20        0.000550         0.000326         0.000325         0.062500        60.000000         0.153135         0.355170
    21        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550        -0.679980
    22        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550        -0.679980
    23        0.000550         0.000326         0.000326         0.062500        60.000000         0.160877         0.0
    24        0.000550         0.000326         0.000326         0.062500        60.000000         0.130550         0.679980


 MEMBER    NODE(I,1)   NODE(I,2)

     1         0           1
     2         0           2
     3         0           3
     4         0           1
     5         1           2
     6         2           3
     7         0           3
     8         1           4
     9         2           5
    10         3           6
    11         0           4
    12         4           5
    13         5           6
    14         0           6
    15         4           7
    16         5           8
    17         6           9
    18         0           7
    19         7           8
    20         8           9
    21         0           9
    22         0           7
    23         0           8
    24         0           9


 NODE     NUMBER               LINK
                     1      2      3      4      5      6
 ---------------------------------------------------------------------

    1        4      -1     -4      5      8
    2        4      -2     -5      6      9
    3        4      -3     -6     -7     10
    4        4      -8    -11     12     15
    5        4      -9    -12     13     16
    6        4     -10    -13    -14     17
    7        4     -15    -18     19    -22
    8        4     -16    -19     20    -23
    9        4     -17    -20    -21    -24
```

```
                                              APPLIED NODAL LOADS
 NODE         PX              PY              PZ              MX              MY              MZ

   1          0.0         -10.000000          0.0             0.0             0.0             0.0
   2          0.0         -10.000000          0.0             0.0             0.0             0.0
   3          0.0         -10.000000          0.0             0.0             0.0             0.0
   4          0.0         -10.000000          0.0             0.0             0.0             0.0
   5          0.0         -10.000000          0.0             0.0             0.0             0.0
   6          0.0         -10.000000          0.0             0.0             0.0             0.0
   7          0.0         -10.000000          0.0             0.0             0.0             0.0
   8          0.0         -10.000000          0.0             0.0             0.0             0.0
   9          0.0         -10.000000          0.0             0.0             0.0             0.0


      MEMBER    1

                                              FLEXIBILITY MATRIX

        0.00023279          0.00425726          0.0                 0.0                 0.0                 0.00054506
        0.00425726          0.13037485          0.0                 0.0                 0.0                 0.01251159
        0.0                 0.0                 0.13124073         -0.00106771         -0.01254572          0.0
        0.0                 0.0                -0.00106771          0.00236927          0.0                 0.0
        0.0                 0.0                -0.01254572          0.0                 0.00160621          0.0
        0.00054506          0.01251159          0.0                 0.0                 0.0                 0.00160184

                                              STIFFNESS MATRIX

    21175.05468750          0.06886506          0.0                 0.0                 0.0             -7205.85546875
        0.06904332         30.62805176          0.0                 0.0                 0.0              -239.25207520
        0.0                 0.0                30.51765442         13.75273800        238.36636353          0.0
        0.0                 0.0                13.75273609        428.26928711        107.41940308          0.0
        0.0                 0.0               238.36636353        107.41941833       2484.40771484          0.0
    -7205.85546875       -239.25204468          0.0                 0.0                 0.0              4944.98828125

                                              TRANSFORMATION MATRIX

        0.90615481         -0.40046787          0.13604748          0.0                 0.0                 0.0
        0.40124214          0.71224648         -0.57594246          0.0                 0.0                 0.0
        0.13374716          0.57648093          0.80609012          0.0                 0.0                 0.0
        0.0                 0.0                 0.0                 0.90615481         -0.40046787          0.13604748
        0.0                 0.0                 0.0                 0.40124214          0.71224648         -0.57594246
        0.0                 0.0                 0.0                 0.13374716          0.57648093          0.80609012



 DETERMINANT OF SYSTEM STIFFNESS MATRIX =      0.0


                                          NODAL DISPLACEMENTS

 NODE        DELTA-X         DELTA-Y         DELTA-Z         THETA-X         THETA-Y         THETA-Z

   1         0.001350       -0.004734       -0.001350       -0.000140        0.000000       -0.000140
   2        -0.000405       -0.004765        0.000000       -0.000000       -0.000000       -0.000845
   3         0.001350       -0.004733        0.001350        0.000140       -0.000000       -0.000140
   4        -0.000000       -0.004766        0.000405       -0.000845        0.000000       -0.000000
   5        -0.000000       -0.015624        0.000000       -0.000001       -0.000000       -0.000001
   6        -0.000000       -0.004765       -0.000405        0.000845       -0.000000       -0.000000
   7        -0.001350       -0.004733       -0.001350       -0.000140        0.000000        0.000140
   8         0.000405       -0.004765        0.000000       -0.000000        0.000000        0.000845
   9        -0.001351       -0.004734        0.001351        0.000140        0.000000        0.000140
```

```
                                    MEMBER END FORCES AND MOMENTS
                           PPX          PPY          PPZ          MPX          MPY          MPZ
MEMB.  END      PX         PY           PZ           MX           MY           MZ

        1'              15.517446     7.001240     2.324160    -0.784251     3.107269    -3.710376
  1     1   17.181229    0.112203    -0.047720     0.039862     0.388247    -4.887200
        2'             -15.517446    -7.001240    -2.324160     0.724175    -3.585968     5.553484
        2  -17.181229   -0.112203     0.047720    -0.039864     0.357376     6.640440

        1'              16.367950     8.497645    -0.000002     0.000013     0.000026    -9.736763
  2     1   18.442215   -0.066948    -0.000002     0.000024     0.000017    -9.736763
        2'             -16.367950    -8.497645     0.000002    -0.000034     0.000013     8.449424
        2  -18.442215    0.066948     0.000002    -0.000024     0.000027     8.449424

        1'              15.517225     7.001164    -2.324138     0.784242    -3.107175    -3.710217
  3     1   17.181000    0.112226     0.047725    -0.039853    -0.388268    -4.887016
        2'             -15.517225    -7.001164     2.324138    -0.724180     3.585979     5.553543
        2  -17.181000   -0.112226    -0.047725     0.039856    -0.357401     6.640495

        1'              -2.324136     7.001158   -15.517267    -3.710324    -3.107235    -0.784243
  4     1   17.181046    0.112203     0.047716    -0.039862    -0.388250    -4.887137
        2'               2.324136    -7.001158    15.517267     5.553438     3.585930     0.724165
        2  -17.181046   -0.112203    -0.047716     0.039864    -0.357380     6.640380

        1'              -0.620195     2.001202   -13.813441    -6.420940    -2.696871     0.143279
  5     1   13.971319   -0.038348     0.040918    -0.223351    -0.292174    -6.956066
        2'               0.620195    -2.001201    13.813439     6.017086     1.760520    -0.260799
        2  -13.971316    0.038348    -0.040918     0.223351    -0.456797     6.254135

        1'               0.620194    -2.001200   -13.813398    -6.017179    -1.760560    -0.260802
  6     1   13.971276    0.038343    -0.040918     0.223355     0.456791    -6.254237
        2'              -0.620194     2.001200    13.813398     6.420956     2.696895     0.143291
        2  -13.971276   -0.038343     0.040918    -0.223355     0.292192     6.956089

        1'              -2.324149     7.001185    15.517304     3.710232     3.107190    -0.784243
  7     1   17.181091    0.112216    -0.047716     0.039858     0.388272    -4.887037
        2'               2.324149    -7.001185   -15.517304    -5.553582    -3.586001     0.724181
        2  -17.181091   -0.112216     0.047716    -0.039858     0.357406     6.640539

        1'              13.813387     2.001194     0.620192     0.143279     2.696865    -6.420915
  8     1   13.971274   -0.038347    -0.040918     0.223351     0.292177    -6.956040
        2'             -13.813387    -2.001193    -0.620192    -0.260800    -1.760509     6.017069
        2  -13.971263    0.038347     0.040918    -0.223350     0.456802     6.254115

        1'              15.127604     2.500037    -0.000007     0.000141     0.000038    -7.927845
  9     1   15.332743    0.043326    -0.000007     0.000145     0.000015    -7.927845
        2'             -15.127597    -2.500037     0.000007    -0.000161     0.000088     8.760396
        2  -15.332735   -0.043327     0.000007    -0.000145     0.000112     8.760396

        1'              13.813239     2.001156    -0.620184    -0.143184    -2.696865    -6.421007
 10     1   13.971112   -0.039363     0.040914    -0.223253    -0.292160    -6.956128
        2'             -13.813238    -2.001156     0.620184     0.260694     1.760494     6.016843
        2  -13.971111    0.039363    -0.040914     0.223253    -0.456732     6.253896

        1'               0.000002     8.497686   -16.368027    -9.736802    -0.000025     0.000013
 11     1   18.442307   -0.065947     0.000002    -0.000024    -0.000016    -9.736802
        2'              -0.000002    -8.497686    16.368027     8.449473    -0.000012    -0.000033
        2  -18.442307    0.065947    -0.000002     0.000024    -0.000026     8.449473

        1'               0.000007     2.500028   -15.127552    -7.927817    -0.000038     0.000141
 12     1   15.332690    0.043325     0.000007    -0.000145    -0.000015    -7.927817
        2'              -0.000007    -2.500028    15.127543     8.760363    -0.000088    -0.000161
        2  -15.332677   -0.043326    -0.000007     0.000145    -0.000113     8.760363

        1'              -0.000008    -2.499988   -15.127657    -8.760085     0.000096    -0.000165
 13     1   15.332787   -0.043268    -0.000008     0.000148     0.000121    -8.760085
        2'               0.000008     2.499988    15.127657     7.928565     0.000049     0.000142
        2  -15.332787    0.043268     0.000008    -0.000148     0.000025     7.928565

        1'               0.000001     8.497681    16.367935     9.736562     0.000019     0.000014
 14     1   18.442215   -0.066910    -0.000001     0.000021     0.000010    -9.736562
        2'              -0.000001    -8.497681   -16.367935    -8.449933     0.000007    -0.000027
        2  -18.442215    0.066910     0.000001    -0.000021     0.000019     8.449933
```

4.4 Experimental Model

For simplicity the experimental model was designed with four interior nodes and eight foundation attachments, while consisting of twelve members. The dimensions given for the experimental model are the true measured dimensions, as, there was some discrepancy between the original design dimensions and the finished model. This can be expected, however, from a model of this nature.

a.) Material and Member Properties - The model was made from one fourth inch square steel rods. The geometric properties of the members are as follows:

1.) Polar moment of inertia, I_x*, is

$$I_x = \beta h b^3 ,$$

where

$$\beta \approx \frac{1}{3} - 0.21 \frac{b}{h} \left(1 - \frac{b^4}{12h^4}\right) ,$$

and since b = h for a square section it follows that

$$\beta \approx .1418 ,$$

and if h = 0.25 in.,

$$I_x = .00055 \text{ in.}^4 .$$

---

*(See appendix C, of reference 2) Here I_x is the equivalent polar moment of inertia and is the same as the previously defined, I_N.

2.) Moment of inertia about the y and z axis is

$$I_y = I_z = \frac{b^4}{12} = 0.000326 \text{ in.}^4.$$

3.) Cross-sectional area equals b^2, or

$$\text{Area} = 0.0625 \text{ in.}^2.$$

4.) Young's modulus, E, was determined from a tension test of the material. The results of this test are as follows:

strain = 0.00061 in./in.,

load p = 1200.0 lbs.

therefore,

$$E = \frac{p}{\text{strain x area}} = 31{,}475{,}000 \text{ psi}$$

5.) The shear modulus, G, was assumed as, 12,000,000 psi.

b.) Geometry and Numbering Scheme for the Model

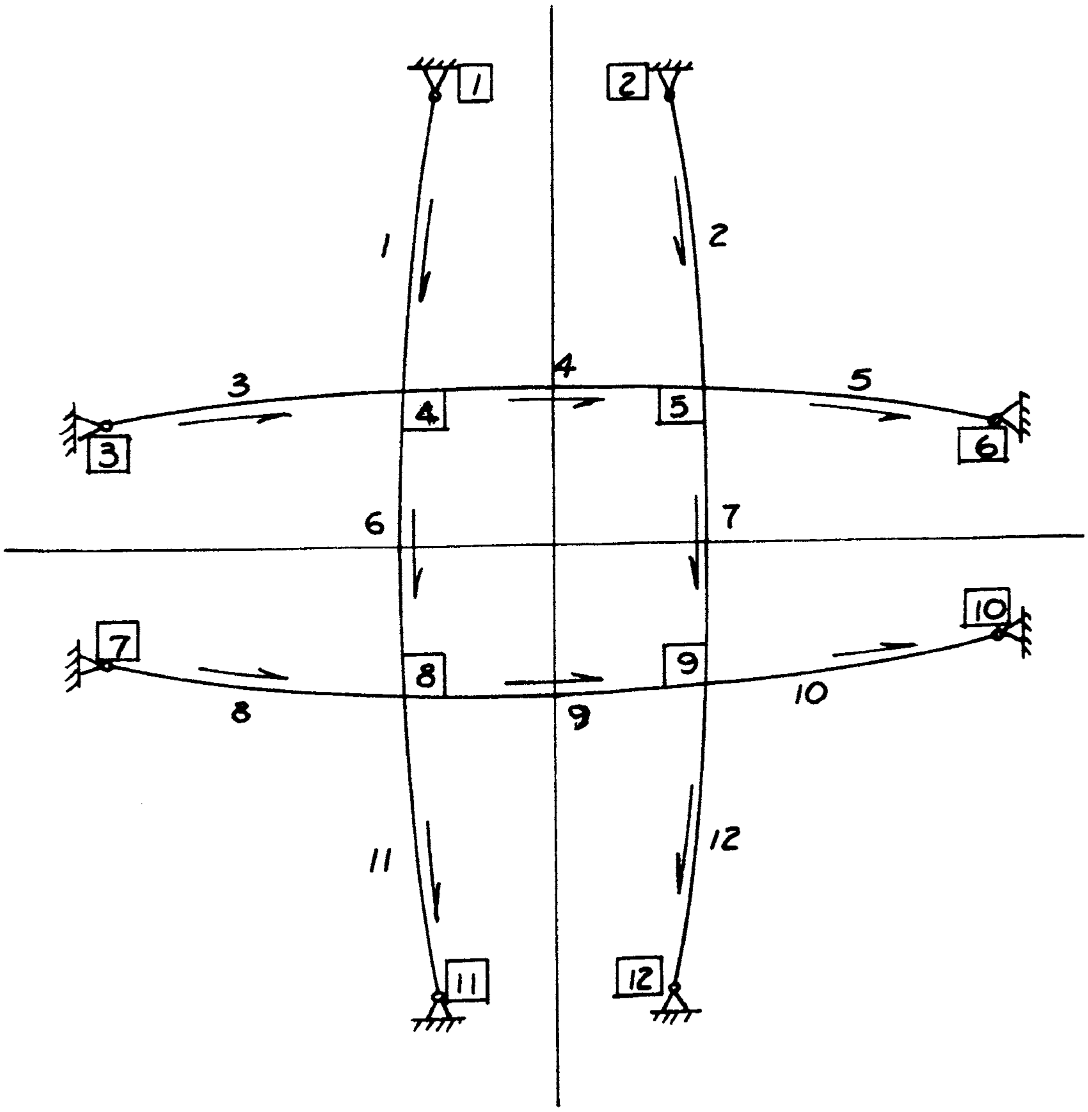


Figure 4.6 Experimental model with pinned foundation attachments.

The coordinates for each of the members are given in Table 4.1.

4.5 Experimental Results

Three tests were run on the experimental model in which it was subjected to both symmetric and unsymmetric loads, for both pinned and fixed end foundation attachments. In each of the tests the strain in member-12 at 6.5 inches from node 4, and the vertical displacement at each of the nodes were measured. Because of the difficulty encountered in measuring the true vertical displacement of the node, these values are not too accurate. The following is a summary of the three tests.

a.) Test No. 1

Foundation attachments: all pinned

Load: 30.0 lbs. at each node

Strain in mem.-12: 175.0×10^{-6} in./in., ten.

Nodal displacement: 0.027 in. ave.

2.) Theoretical calculations:

Member end forces on member-12 at End-1, in member coordinates are

$p_x = 34.05$ lbs. $\quad m_x = 0.0$

$p_y = -1.32$ lbs. $\quad m_y = 1.08$ in.-lbs.

$p_z = -0.071$ lbs. $\quad m_z = -20.06$ in.-lbs., and at End-2,

p_x = -34.05 lbs. m_x = 0.0

p_y = 1.32 lbs. m_y = 0.0

p_z = 0.071 lbs. m_z = 0.0

Nodal displacements: 0.022 in. ave.

3.) Correlation of experimental stress in member-12, to the theoretical stress, neglecting p_z and m_y;

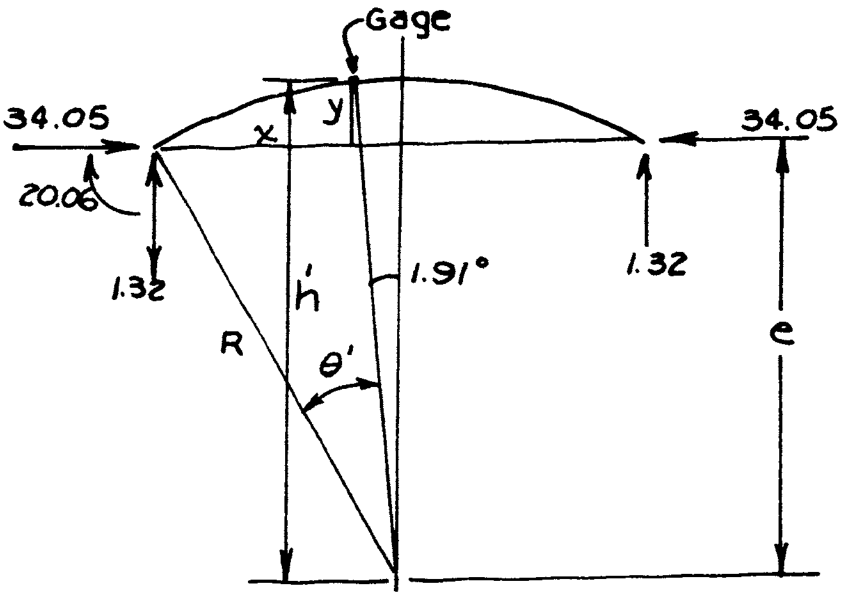


Figure 4.7 Free body diagram of Member-12.

$$\theta' = \frac{S}{R} = \frac{6.5}{35} = .1857 = 10.6^\circ$$

$$\phi - \theta' = 12.51 - 10.6 = 1.91^\circ$$

$$h' = 35 \cos(1.91^\circ) = 34.98 \text{ in.}$$

$e = 35 \sin (77.49°) = 34.17 = 0.81$ in.

$x = R \sin (12.51°) - \sin (1.91°) \quad = 6.41$ in.

The moment at the strain gage is,

$M = 20.06 - 34.05 (.81) - 1.32 (6.41)$

$M = 15.98$ in.-lb.

Axial $= 34.05 \cos (1.91°) - 1.32 \sin (1.91°)$

Axial = 34.0 #, compression.

The resulting stress are,

$$\text{Axial stress} = \frac{34}{.0625} = 544 \text{ psi, C}$$

$$\text{Bending stress} = \frac{15.98\ (.125)}{.000326} = 6127 \text{ psi, T}$$

Total stress = 6127 - 544 = 5583 psi, T

4.) % - Deviation between experimental and theoretical stress:

Exp. stress $= 175.0 \times 10^{-6} (31.475 \times 10^{6})$

" " = 5508 psi,

Therefore,

$$\% \text{ Dev.} = \frac{5583 - 5508}{5508} \times 100 = 1.36\%$$

Table 4.1 Member Coordinates

Mem.	X(I,1)	Y(I,1)	Z(I,1)	X(I,2)	Y(I,2)	Z(I,2)
1	-20.97	0.0	5.87	-7.29	6.25	7.22
2	-20.97	0.0	-6.62	-7.23	6.25	-7.33
3	-6.06	0.0	20.97	-7.29	6.25	7.22
4	-7.29	6.25	7.22	-7.23	6.25	-7.33
5	-7.23	6.25	-7.33	-6.25	0.0	-20.97
6	-7.29	6.25	7.22	7.22	6.25	7.29
7	-7.23	6.25	-7.33	7.19	6.25	-7.19
8	6.06	0.0	20.97	7.22	6.25	7.29
9	7.22	6.25	7.29	7.19	6.25	-7.19
10	7.19	6.25	-7.19	6.12	0.0	-20.97
11	7.22	6.25	7.29	20.97	0.0	6.31
12	7.19	6.25	-7.19	20.97	0.0	-6.31

b.) Summary of Tests - A summary of the experimental results for Test No. 1, as well as Test No. 2 and Test No. 3 are given in Tables 4.2, 4.3 and 4.4 respectively.

Table 4.2 Summary of Test No. 1 - Pinned-End Foundation Symmetric Loading

- Experimental -				
	Nodal Displacements			
Load/node	1	2	3	4
30.0 lbs.	-0.027	-0.029	-0.027	-0.027
	- Theoretical -			
30.0 lbs.	-0.021	-0.023	-0.022	-0.022

Mem.-12 - Strain = 175.0×10^{-6} in./in., T

Experimental Stress = 5508.0 psi., T

Computed Member-12 End Forces

End	p_x	p_y	p_z	m_x	m_y	m_z
1	34.05	-1.32	-0.07	0.0	1.08	-20.06
2	-34.05	1.32	0.07	0.0	0.0	0.0

Theoretical Stress = 5585.0 psi., T

$$\% \text{ Deviation} = \frac{5585 - 5508}{5508} \times 100 = 1.36\%$$

Table 4.3 Summary of Test No. 2 - Fixed-End Foundation Symmetric Loading

- Experimental -				
	Nodal Displacements			
Load/node	1	2	3	4
31.08 lbs.	-0.015	-0.017	-0.017	-0.014
	- Theoretical -			
31.08 lbs.	-0.012	-0.013	-0.012	-0.012

Mem.-12 - Strain = 135.0×10^{-6} in./in., T

Experimental Stress = 4280.0 psi.

Computed Member-12 End Forces

End	p_x	p_y	p_z	m_x	m_y	m_z
1	38.32	-0.15	-0.11	0.69	0.85	-21.06
2	-38.32	0.15	0.11	-0.69	-0.80	18.76

Theoretical Stress = 3729.0 psi.

$$\% \text{ Deviation} = \frac{4280 - 3729}{4280} \times 100 = 12.9\%$$

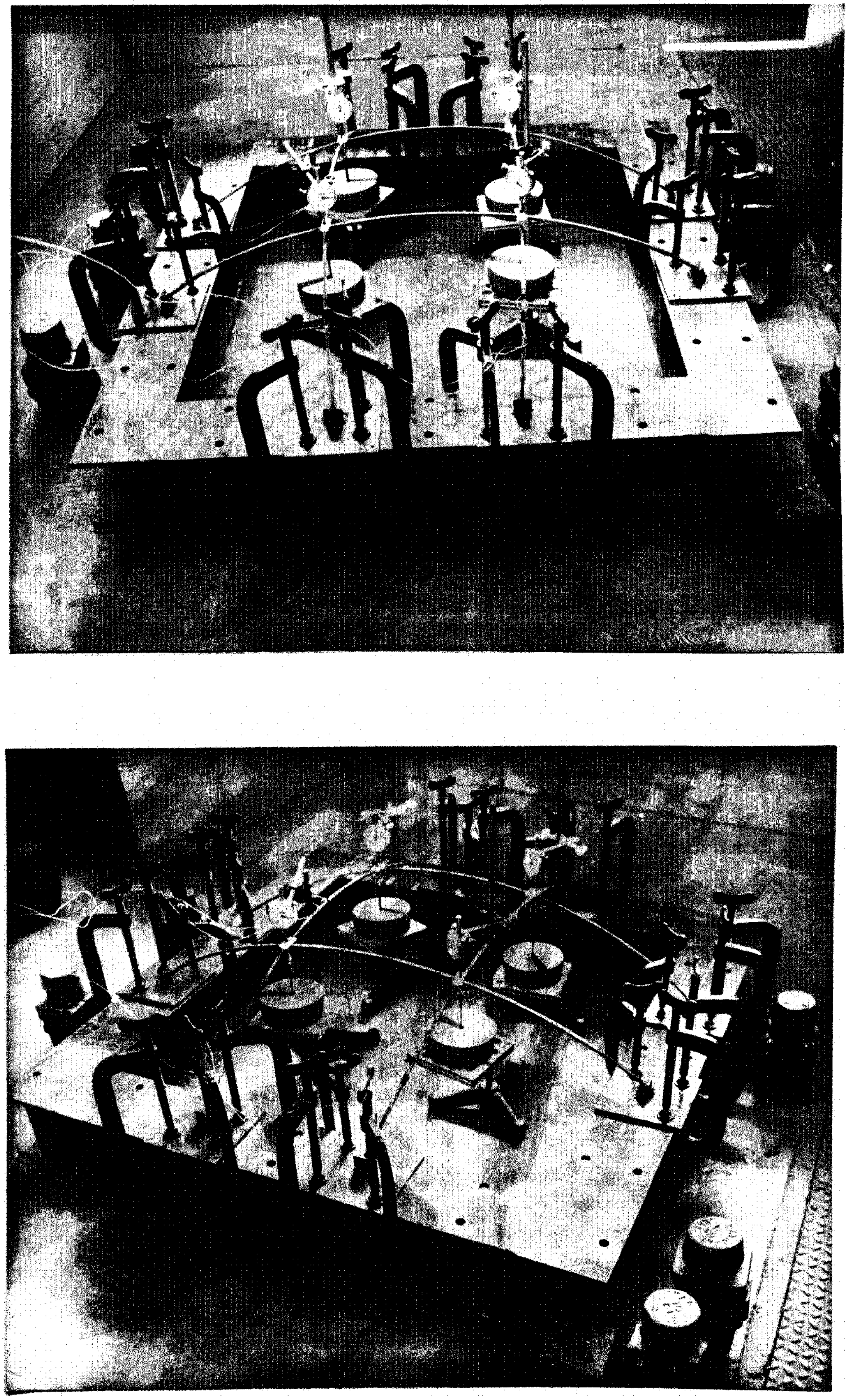


Figure 4.8 Photographs of Experimental Model

Table 4.4 Summary of Test No. 3 - Fixed-End Foundation Unsymmetric Loading, Load Node 4 Only

- Experimental -				
	Nodal Displacements			
Load	1	2	3	4
31.08 lbs.	-0.0240	+0.030	+0.028	-0.051
	-Theoretical -			
31.08 lbs.	-0.020	+0.024	+0.024	-0.041

Mem.-12 - Strain = 55×10^{-6} in./in.

Experimental stress = 1731 psi, T.

Computed Member-12 End Forces

End	p_x	p_y	p_z	m_x	m_y	m_z
1	29.45	1.55	-0.14	0.0	1.06	-4.4
2	-29.45	-1.55	0.14	0.0	1.08	27.87

Theoretical Stress = 1800 psi

$$\% \text{ Deviation} = \frac{1800 - 1731}{1731} \times 100 = 3.98\%$$

The computer solutions for the experimental model is presented in Appendix B.

Chapter 5

COMPUTER PROGRAM FOR CURVILINEAR GRID SYSTEM

The computer program which performs the complex computations required by this or any matrix solution to a large structural system is an integral and extremely important part of the development. This chapter contains a detailed description of the development of the computer program including a complete documentation of the program including user instructions, flow diagrams, summary of program identifiers, and a complete listing of the program and subroutines.

5.1 Introduction to the Program

Matrix Analysis of Curvilinear Systems (MACS), is written in Fortran IV for IBM System 360/40. The formulation of MACS is fundamentally an equilibrium-stiffness formulation. The program has been developed in two main parts; first the main line which consists of a general formulation of the equilibrium-stiffness method adaptable to the solution of any space frame, and second the subroutine package which consists of the necessary routines for performing the required repetitive calculations as well as those routines which enable MACS to be quite flexible as a space frame solver. The details of these routines will be discussed in (5.4).

In order for the engineer to use MACS it is only necessary that he provide MACS with the appropriate input data such as, Node data, geometry data, member properties and loading data as described in (5.2).

5.2 Input Data

The following is a detailed description of the necessary input data.

a) System Indices - NN, NB, LL (Fixed pt. no.)

NN - Number of nodes excluding fixed and foundation attachments.

NB - Number of members in the structure.

LL - Maximum number of members per node.

b) Member Indices

Node_{i1} - Node number at 1-end of member I.

Node_{i2} - Node number at 2-end of member I.

c) Member Coordinates

X_{i1}, Y_{i1}, Z_{i1} - Coordinates of the 1-end of member I in system coordinates.

X_{i2}, Y_{i2}, Z_{i2} - Coordinates of the 2-end of member I in system coordinates.

d) Member Properties

IX_i, IY_i, IZ_i - Moments of inertia about the member X, Y and Z axis.

Area_i - Cross sectional area of member

e) Geometric Properties

R_i - Radius of curvature of member

ϕ_i - One half of central angle described by the member

$ALPH_i$ - The rotation of the member about the member x-axis with respect to a vertical plane through its end points.

f) Elastic Properties

E - Youngs Modulus

G - Shear Modulus

g) Nodal Loads

D_j - Six element vector which describes p_x, p_y, p_z, m_x, m_y, m_z, the six possible components of the applied nodal load vector.

5.3 Output Data

The output data from MACS was designed to give the engineer all the information necessary for establishing the validity of the solution.

a) Input Data - Before any structure can be analyzed correctly the correct input data must be used. This is a common source of error in an analysis of this type where large quantities of data are assembled, coded and finally key punched onto data cards. As a result it is quite easy for human error to be a significant factor. For this reason all of the input data is printed out in a convenient form to enable the engineer to verify that the data read by the computer is the correct data.

b) Link Array[6] - The first computation performed by MACS computes,

Link (J, L) = ± I, where I is the Lth member to be attached to node J. The plus sign indicates that the 1-end of member I is at node J, the minus sign indicates that the 2-end of member I is at node J.

Link (J, L) provides MACS with the necessary member to node reference required for computing which members contribute to the stiffness of a particular node.

c) Member Flexibility, Stiffness and Transformation Matrices - The flexibility, stiffness and transformation matrices for each member are printed out to provide the engineer with information necessary for developing a better understanding of the behavior of the system. The member stiffness matrix, for example, will show the contribution of each of the quantities such as axial, torsional and bending deformations to the overall member stiffness.

d) System Stiffness Matrix - The system stiffness matrix furnishes additional information on the structural system as a whole, being the coefficients of the load-displacement equations for the structural system.

e) <u>Nodal Displacements</u> - After the system stiffness matrix has been generated, the nodal loads and the system stiffness matrix are then solved simultaneously by SØLVE to obtain the nodal displacements. The six components of the displacement of each node are written out as follows,

$$\delta_x \quad \delta_y \quad \delta_z \quad \theta_x \quad \theta_y \quad \theta_z$$

f) <u>Member End Forces</u> - The resultant force vector at each end of the member are first printed out in System Coordinates to facilitate checking the statics of the structure and then printed out in member coordinates which is more convenient for stress analysis.

5.4 MACS Subroutine Package

The following discussion describes the subroutines required by MACS to perform the necessary repetitive calculations. These subroutines have been appropriately named STIFMA, MATRAN, MTXMUL, TRIPRØ AND SØLVE.

a) <u>STIFMA</u> - The member stiffnesses are computed by calculating the member flexibilities from the equations derived in Chapter 2 and inverting the resulting flexibility matrix. STIFMA also computes the equilibrium matrix H, which is described in Chapter 2.

b) MATRAN - The 3-axis rotation transformation matrix T is computed by MATRAN from the member end coordinates and ALPH which was described earlier in this chapter.

c) MTXMUL - Matrix multiplication is performed by MTXMUL; given two matrices A and B. MTXMUL premultiplies B by A and places the resultant AB in the B array making efficient use of storage.

d) TRIPRØ - Matrix Triple Product, premultiplies B by A and then post multiplies AB by the transpose of A to form ABA^t. The resulting array is then returned to the B array storage location which again makes efficient use of storage.

e) SØLVE - This subroutine is a "simultaneous equation solver". SØLVE uses a Jordan Elimination and pivots on the largest element in the coefficient matrix[8], thereby, reducing the roundoff error to a minimum and preserving the accuracy of the solution.

As was mentioned previously in (5.1) this subroutine package enables MACS to be quite flexible as a space frame solver. For example, if a space frame is composed of straight members instead of segmental circular members, the STIFMA which computes the stiffnesses of the circular members can be replaced by a new STIFMA which computes the stiffness of a straight member. In fact, as long as one can derive the flexibility or stiffness matrix for a member, regardless of its shape, and substitute the appropriate STIFMA routine, MACS is capable of analyzing a system composed of these members. In addition, there is also the possibility that a structural system may be composed of both straight and curved members. In this case a stiffness subroutine could be included for each type of member and properly labeled for ready reference.

5.5 MACS User Instructions

It is impossible for any computer program to obtain the correct results unless the correct input data is supplied to the program. For this reason the engineer must be meticulous and systematic in preparing the input data for the computer program.

The data can be divided into two main parts, structure data and load data.

a) Structure Data - It is advisable to begin the preparation of the structure data with a convenient sketch of the structural system. Next, the nodes and members can be numbered in any arbitrary fashion, except that fixed-end foundation attachments are labeled zero. Pinned-end foundation attachments are labeled the same as any other node.

The location of the system coordinate axes can now be placed at any convenient location. The data cards can now be listed in the order in which they appear in the data deck as follows:

1.) 1 Card - contains the system indices NB, NN and LL respectively in an I10 Format.

2.) 2NB/12 Cards - Node (I,1) and Node (I,2) are placed in a 12I6 Format. All values of (I,1) are read first followed immediately by the values of Node (I,2).

3.) NB Cards - The next NB cards contain the joint coordinates at each end of a member and ALPH (I) for each of the members. The order of the data is X(I,1), Y(I,1), Z(I,1) X(L,2), Y(I,2), Z(I,2) and ALPH (I) written in a 7E10.2 Format.

4.) NB Cards - The next NB cards contain the member properties IX(I), IY(I), IZ(I), AREA(I), R(I) and PHI(I) respectively for each member in a 6E10.2 Format.

5.) 1 Card - This card contains E and G in a 2E10.2 Format.

b) Load Data - The preceding data cards were concerned entirely with the structure data, next the load data will be read.

1.) NN Cards - The last NN cards of the data deck contain the nodal loads. There must be one card for every non-zero node with the six components of the load vector entered on the card in a 6E12.4 Format. If a node is not loaded a blank card can be used to represent a zero load vector.

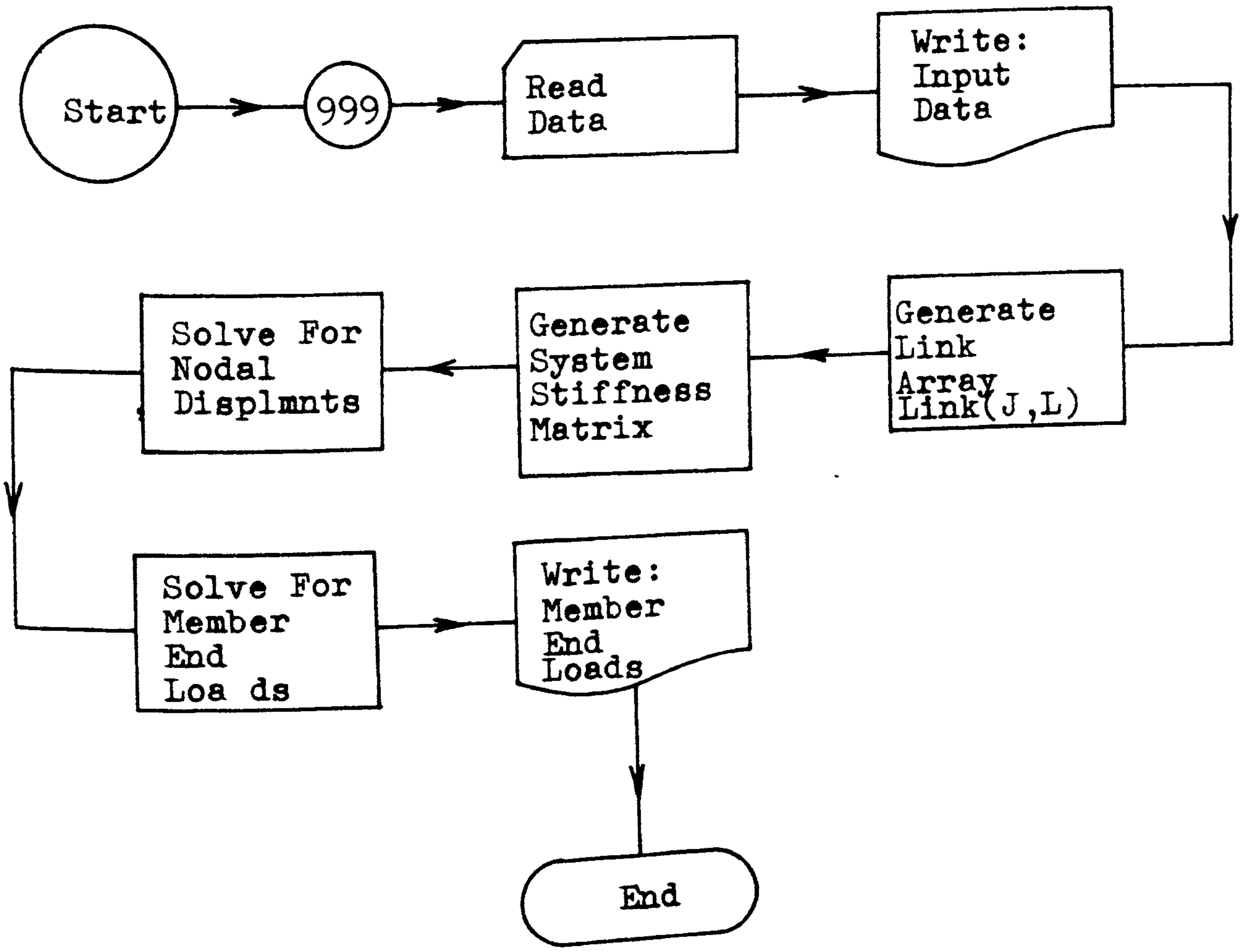
If a member is loaded between nodes the fixed end forces and moments must be computed and then their signs reversed and superimposed on the applied nodal loads as explained in Chapter 2.

5.6 Flow Diagrams and Computer Program

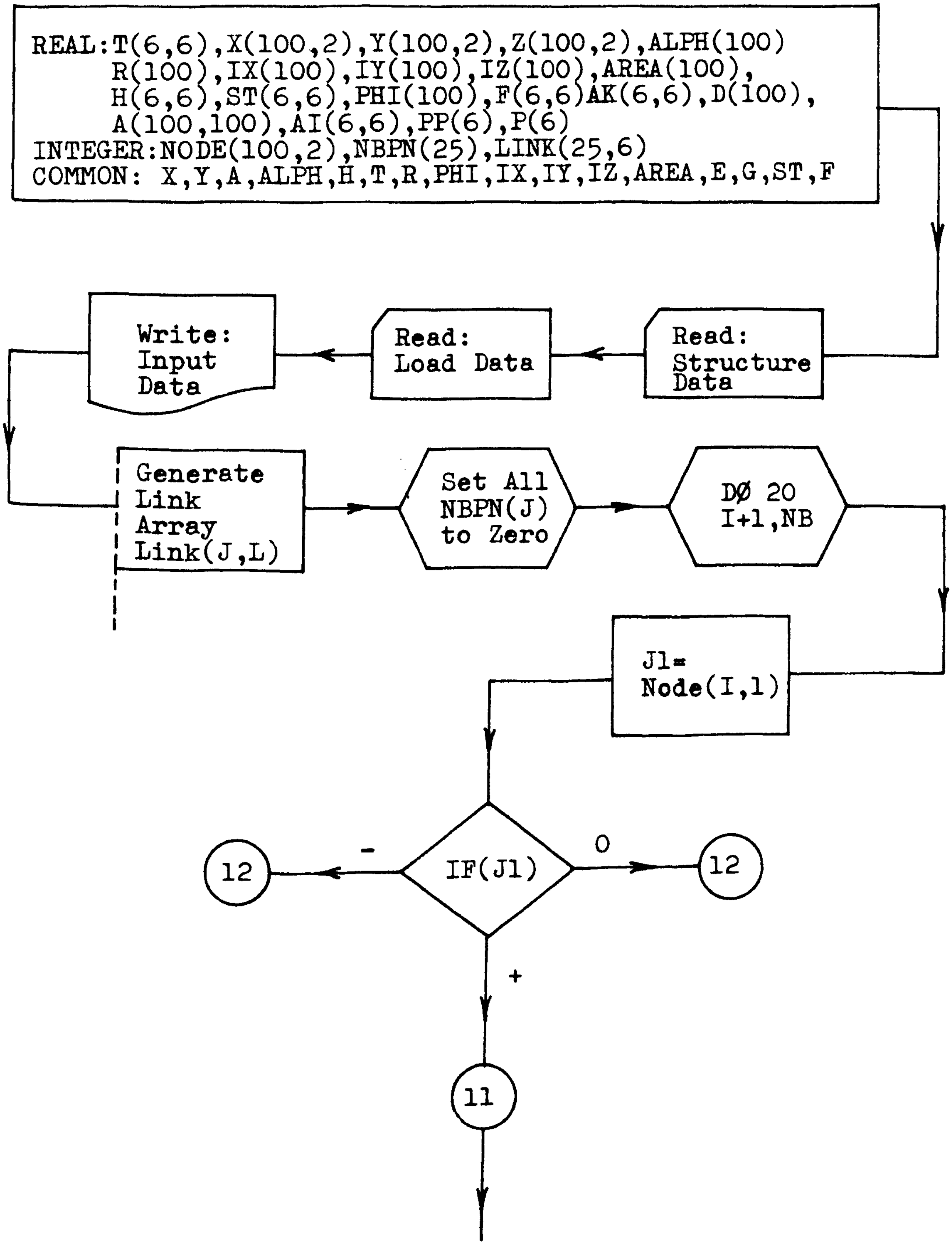
In the development of large, complex computer programs the flow diagram is a necessary and valuable tool. The flow diagram presents to the programmer, in the appropriate order, the various operations and decisions that the computer must make during the execution of the program.

The first flow diagram is a block diagram and represents schematically the major operations performed by the computer.

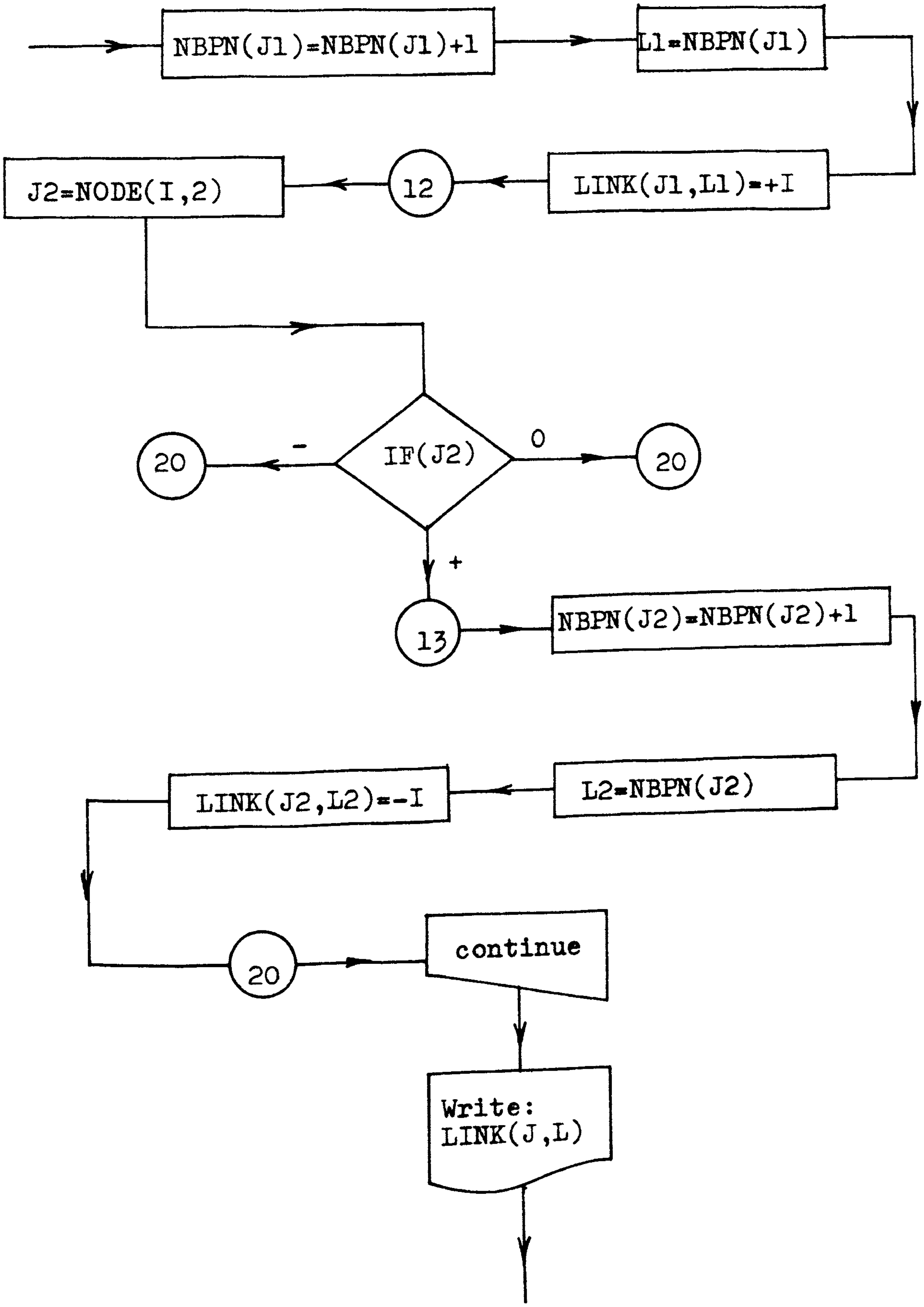
a.) Block Diagram

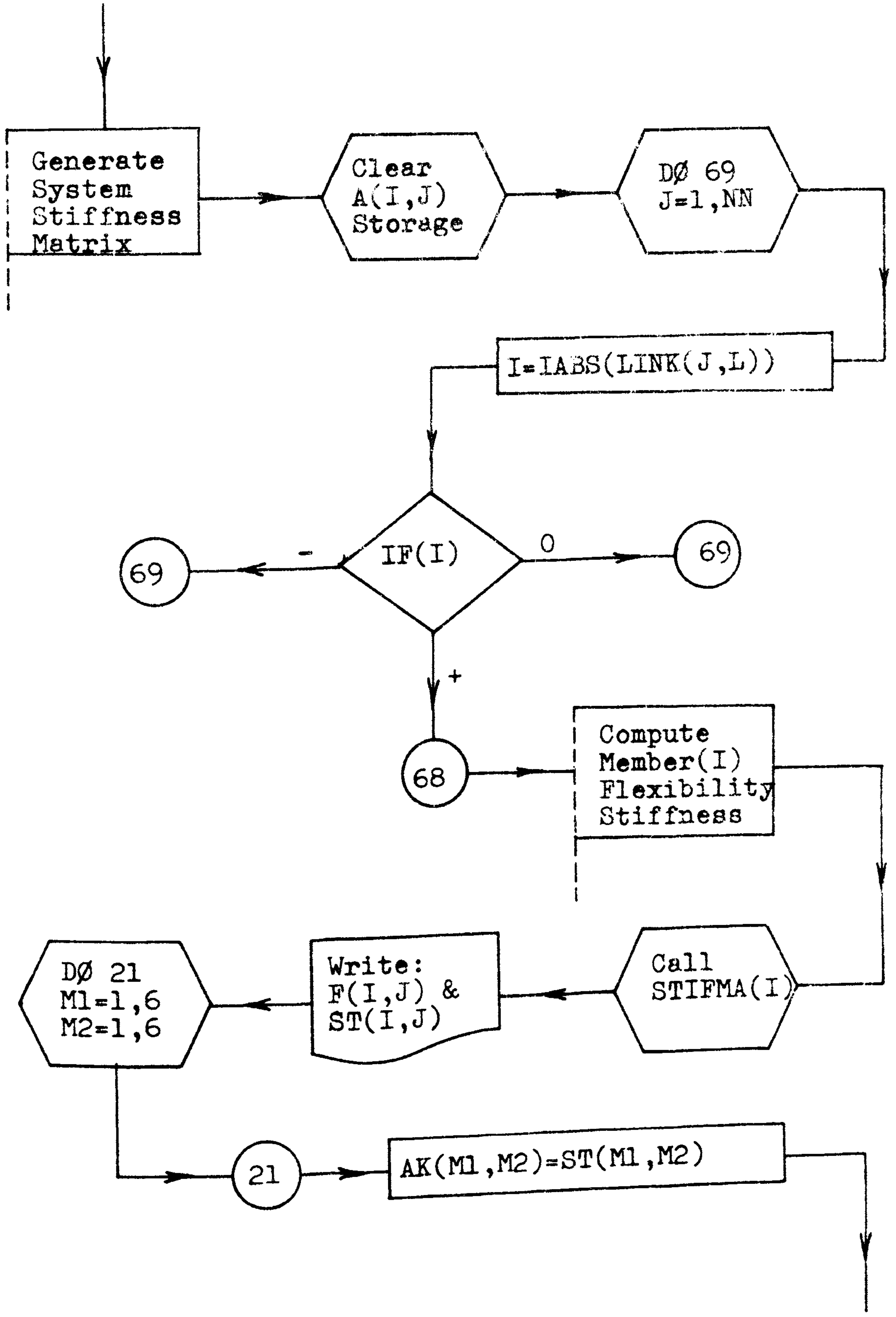


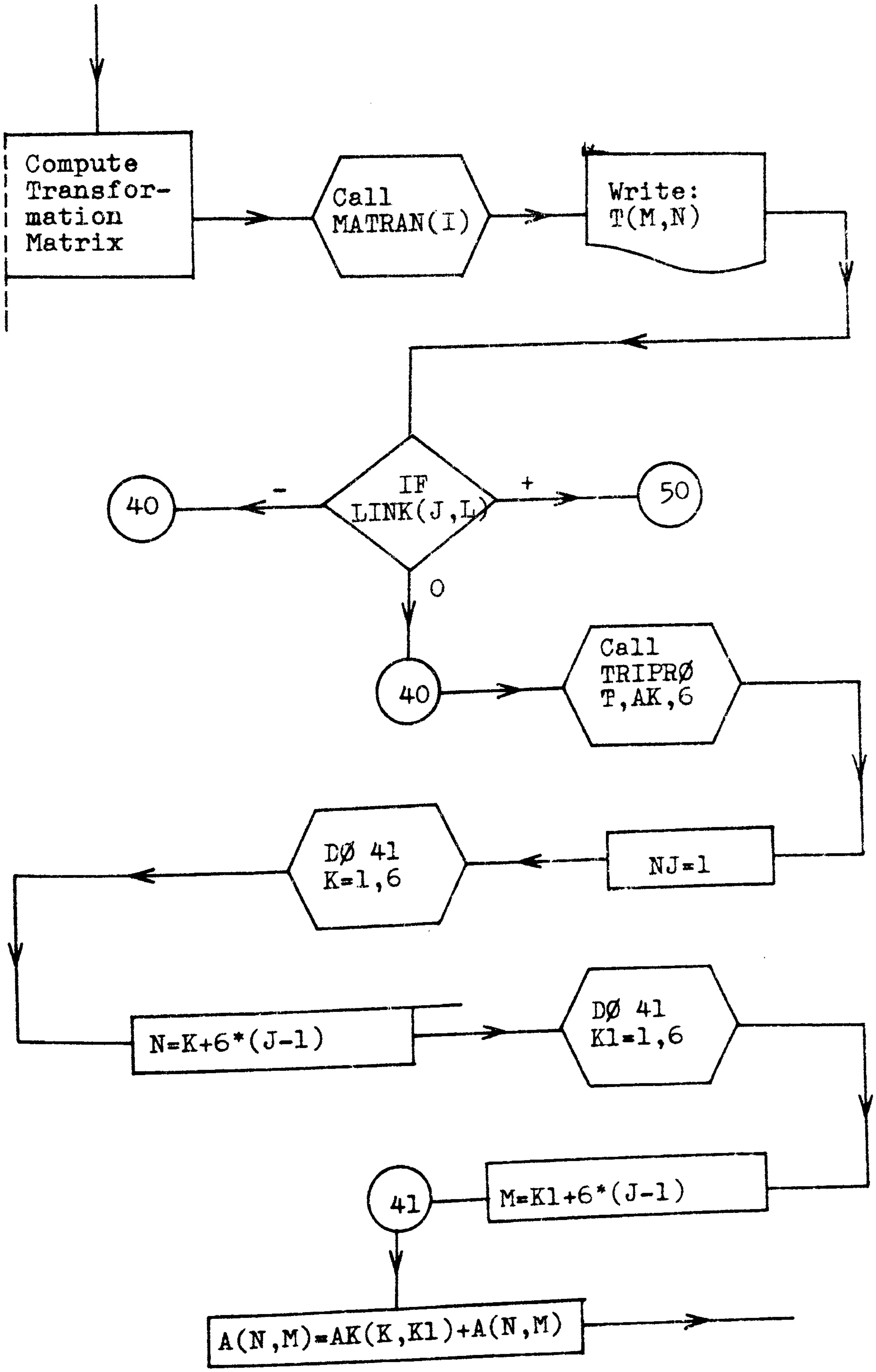
b.) Main Line Flow Diagram.

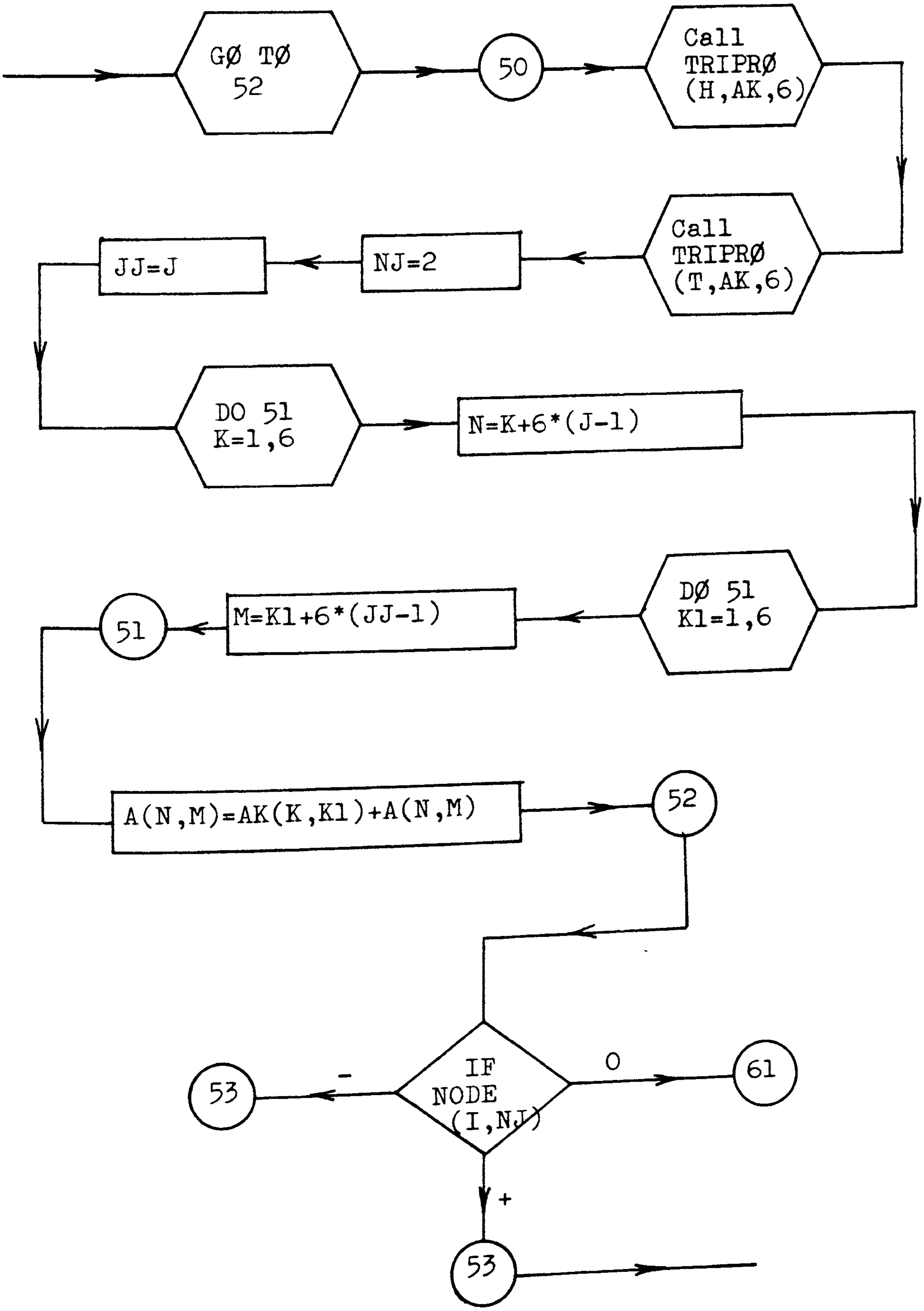


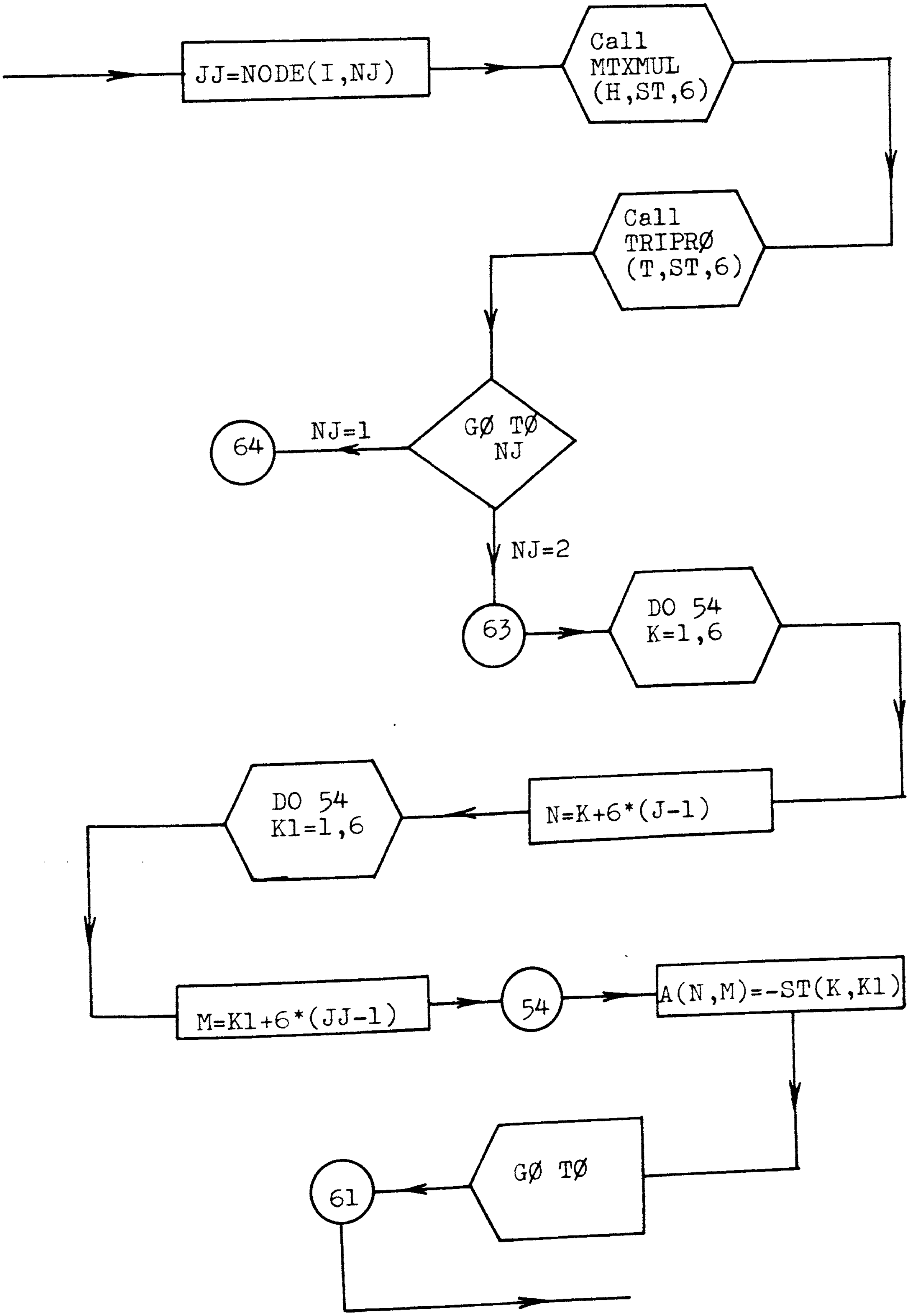
```
REAL:T(6,6),X(100,2),Y(100,2),Z(100,2),ALPH(100)
     R(100),IX(100),IY(100),IZ(100),AREA(100),
     H(6,6),ST(6,6),PHI(100),F(6,6)AK(6,6),D(100),
     A(100,100),AI(6,6),PP(6),P(6)
INTEGER:NODE(100,2),NBPN(25),LINK(25,6)
COMMON: X,Y,A,ALPH,H,T,R,PHI,IX,IY,IZ,AREA,E,G,ST,F
```

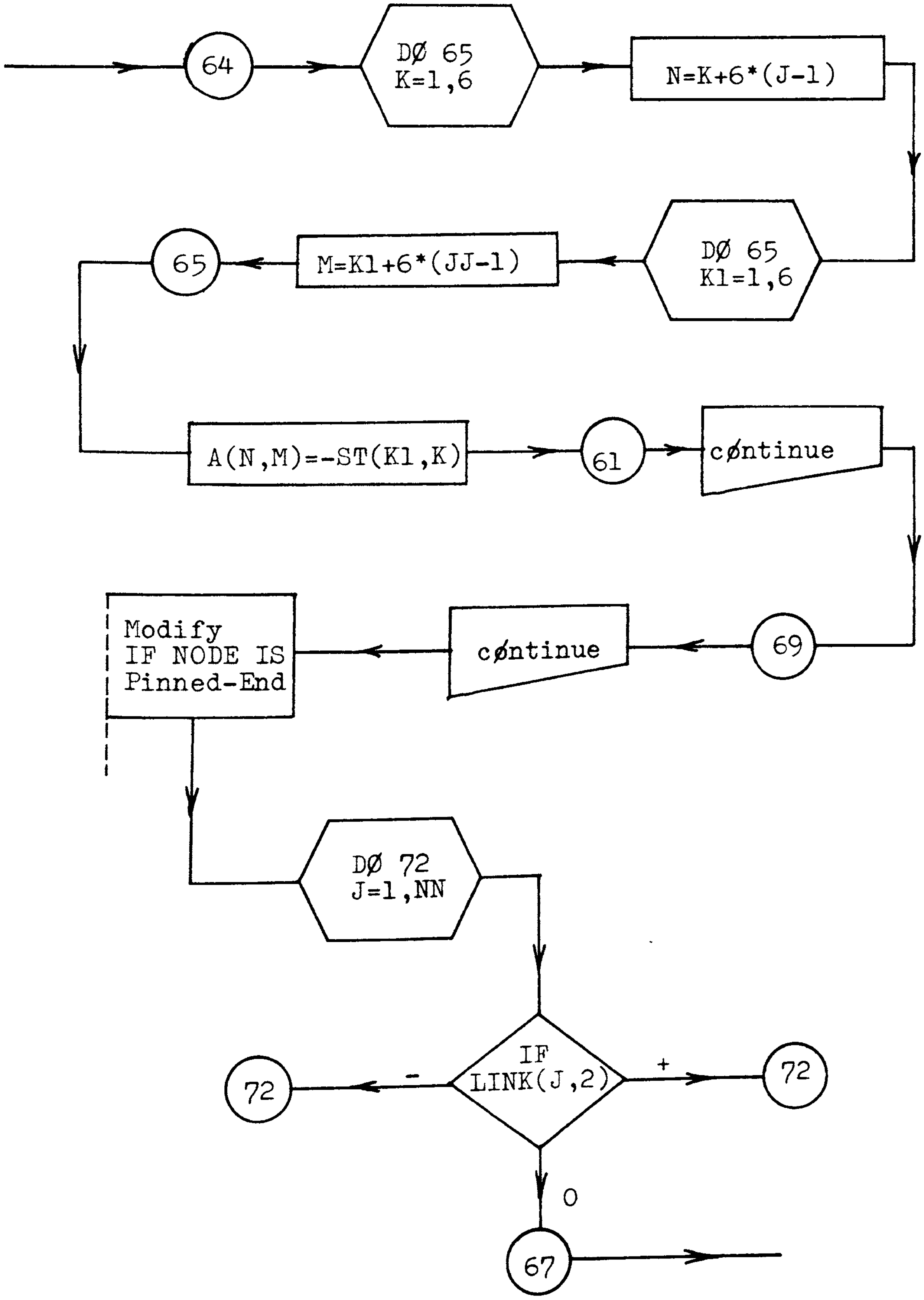

NBPN(J1)=NBPN(J1)+1
L1=NBPN(J1)
LINK(J1,L1)=+I
12
J2=NODE(I,2)
IF(J2)
-
20
0
20
+
13
NBPN(J2)=NBPN(J2)+1
L2=NBPN(J2)
LINK(J2,L2)=-I
20
continue
Write:
LINK(J,L)

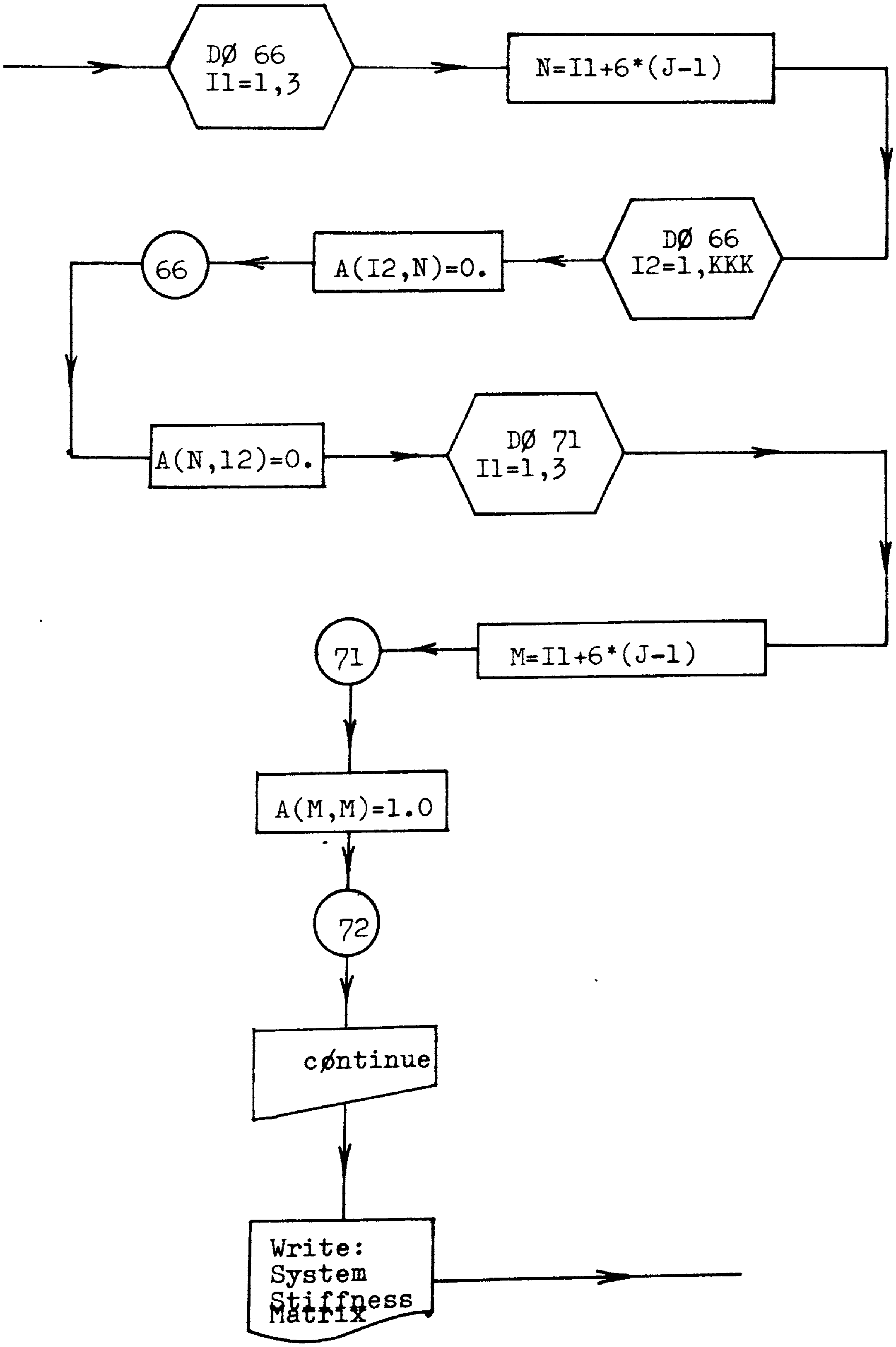

Generate System Stiffness Matrix
Clear A(I,J) Storage
DØ 69 J=1,NN
I=IABS(LINK(J,L))
IF(I)
-
0
+
69
69
68
Compute Member(I) Flexibility Stiffness
Call STIFMA(I)
Write: F(I,J) & ST(I,J)
DØ 21 M1=1,6 M2=1,6
21
AK(M1,M2)=ST(M1,M2)

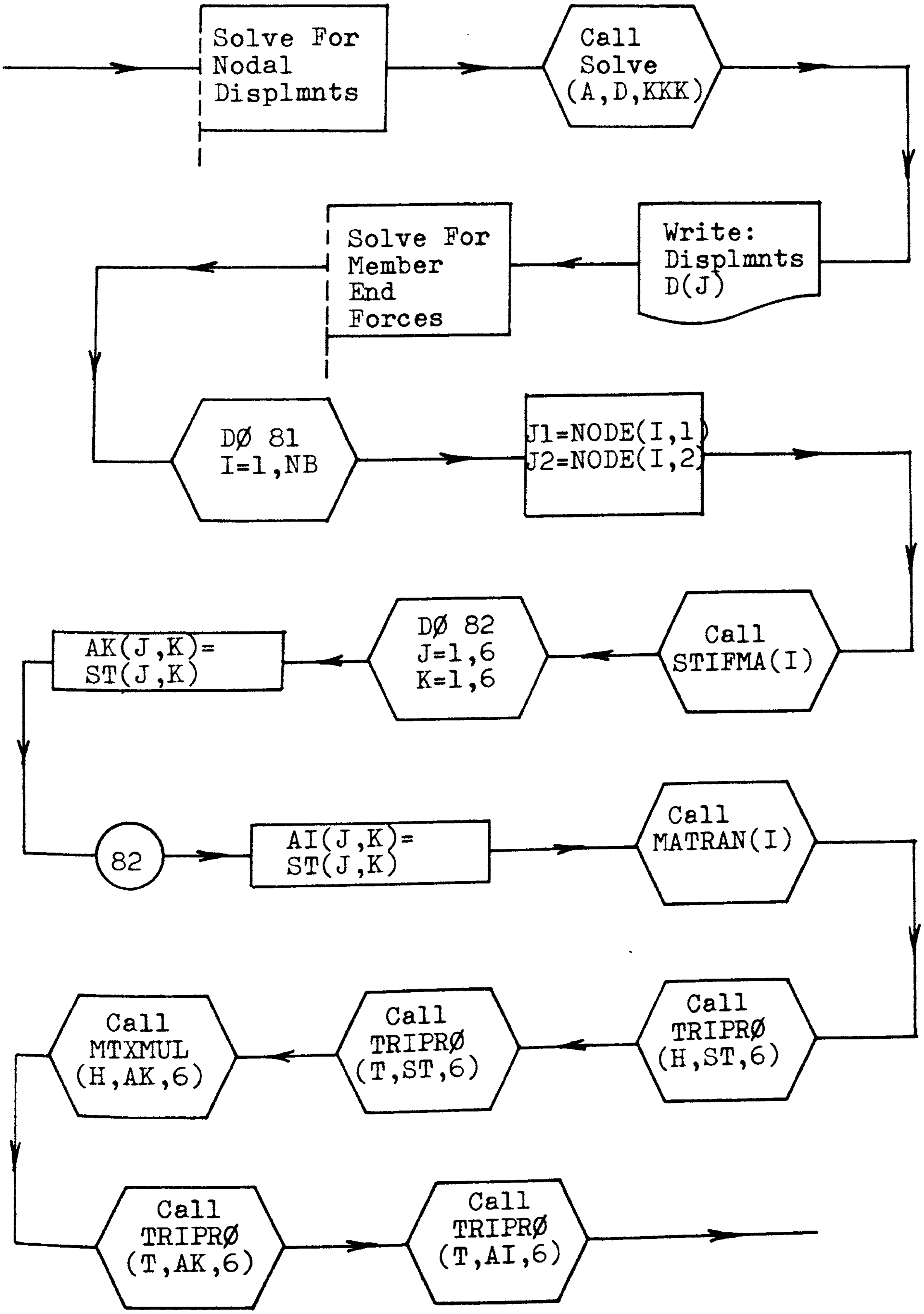

Compute Transformation Matrix
Call MATRAN(I)
Write: T(M,N)
IF LINK(J,L)
-
+
0
40
50
40
Call TRIPRØ T,AK,6
NJ=1
DØ 41 K=1,6
N=K+6*(J-1)
DØ 41 K1=1,6
M=K1+6*(J-1)
41
A(N,M)=AK(K,K1)+A(N,M)

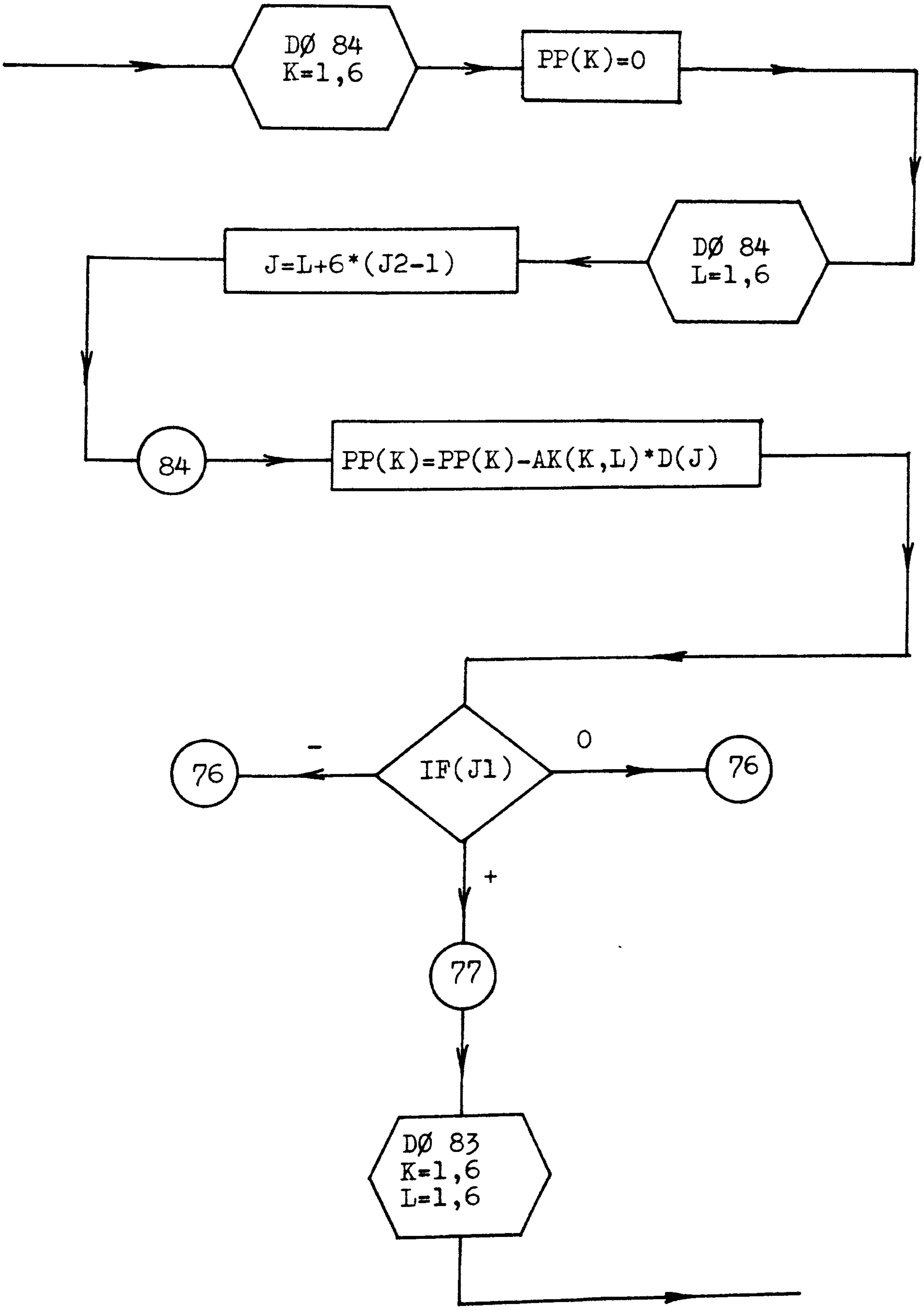

GØ TØ 52
50
Call TRIPRØ (H,AK,6)
Call TRIPRØ (T,AK,6)
NJ=2
JJ=J
DO 51 K=1,6
N=K+6*(J-1)
DØ 51 K1=1,6
M=K1+6*(JJ-1)
51
A(N,M)=AK(K,K1)+A(N,M)
52
IF NODE (I,NJ)
-
53
0
61
+
53

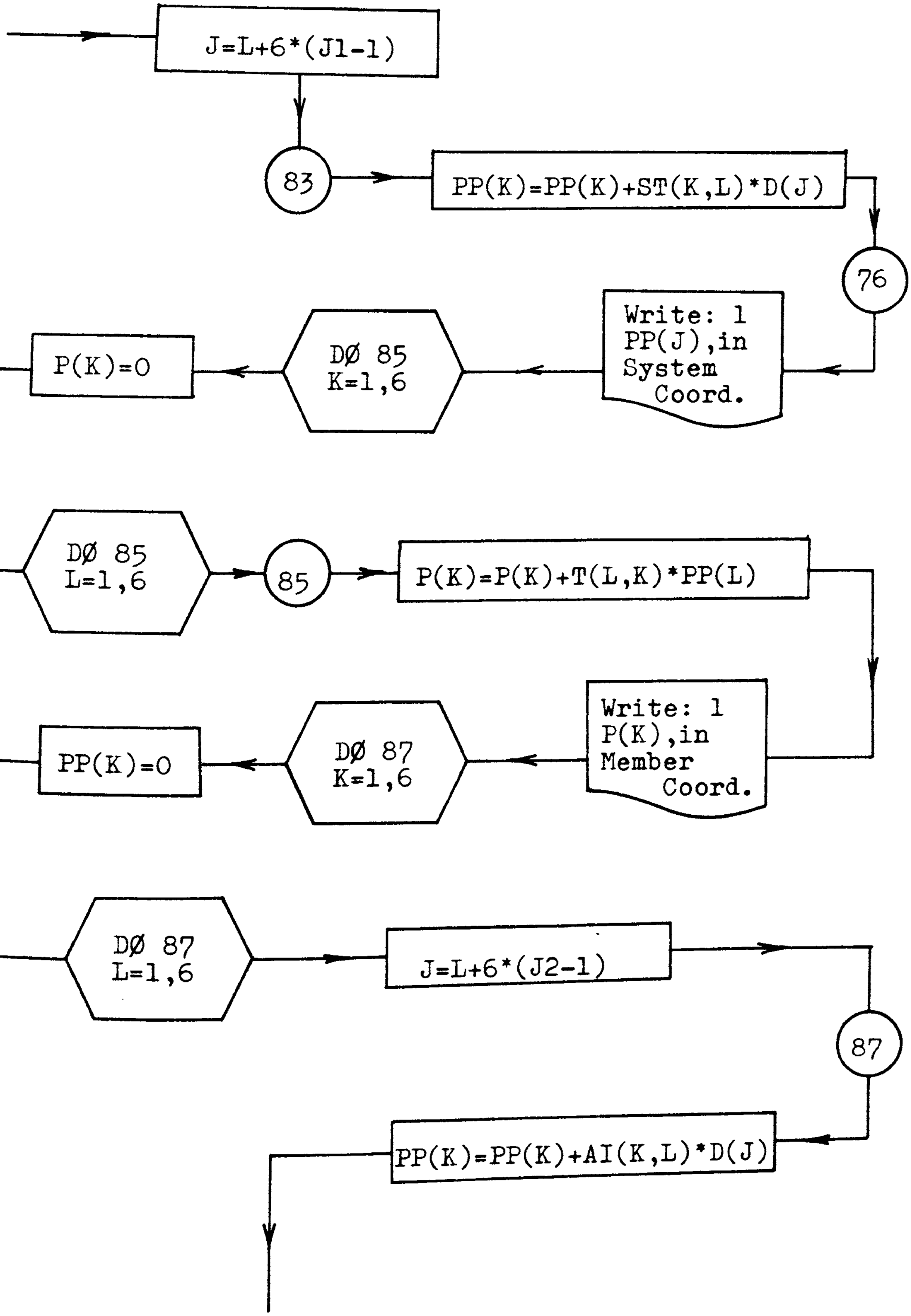

JJ=NODE(I,NJ)
Call MTXMUL (H,ST,6)
Call TRIPRØ (T,ST,6)
GØ TØ NJ
NJ=1
64
NJ=2
63
DO 54 K=1,6
N=K+6*(J-1)
DO 54 K1=1,6
M=K1+6*(JJ-1)
54
A(N,M)=-ST(K,K1)
GØ TØ
61

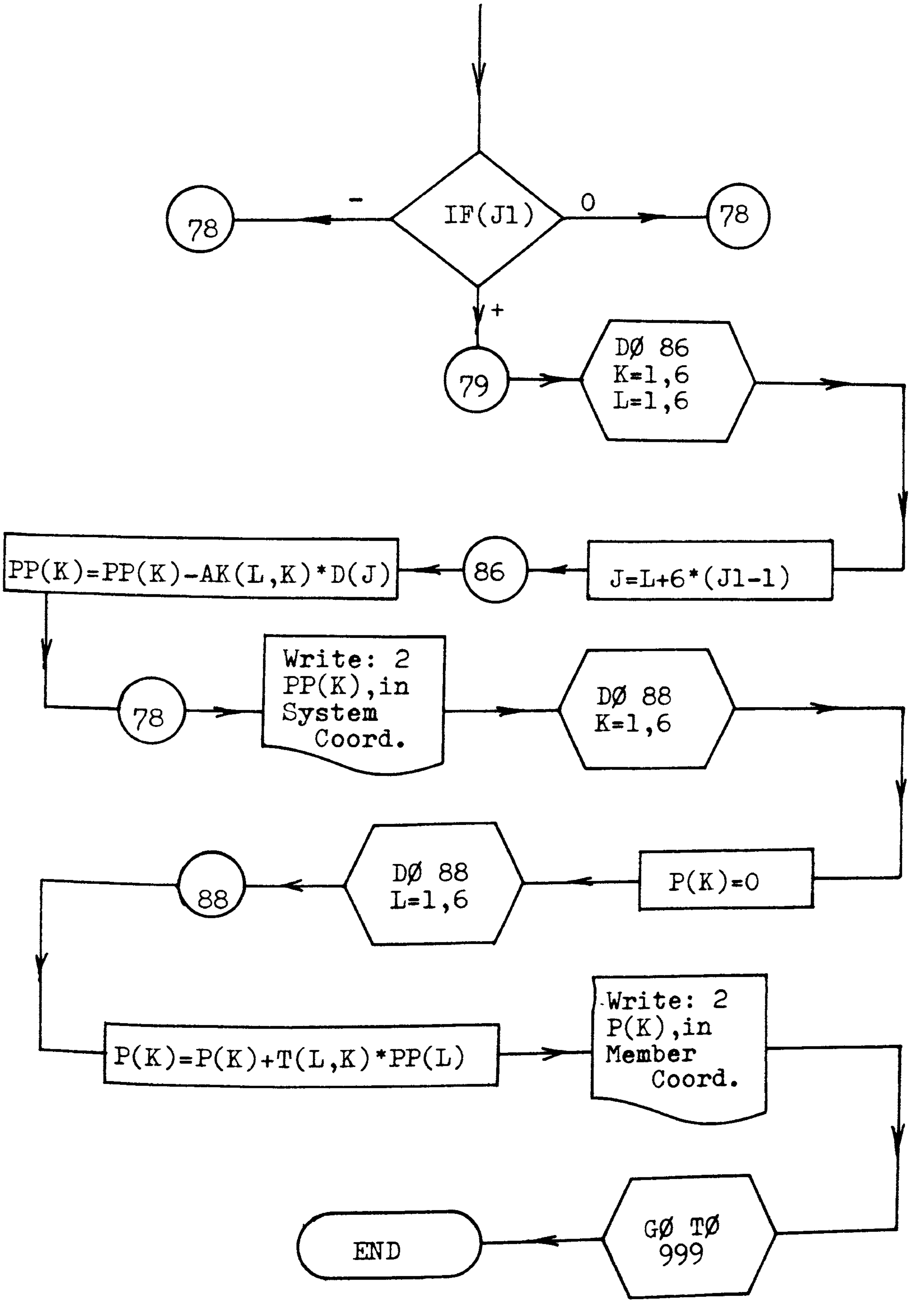

64
DØ 65
K=1,6
N=K+6*(J-1)
DØ 65
K1=1,6
M=K1+6*(JJ-1)
65
A(N,M)=-ST(K1,K)
61
cøntinue
69
cøntinue
Modify
IF NODE IS
Pinned-End
DØ 72
J=1,NN
IF
LINK(J,2)
-
72
+
72
0
67


DØ 66
I1=1,3
N=I1+6*(J-1)
DØ 66
I2=1,KKK
A(I2,N)=0.
66
A(N,I2)=0.
DØ 71
I1=1,3
M=I1+6*(J-1)
71
A(M,M)=1.0
72
cøntinue
Write:
System
Stiffness
Matrix

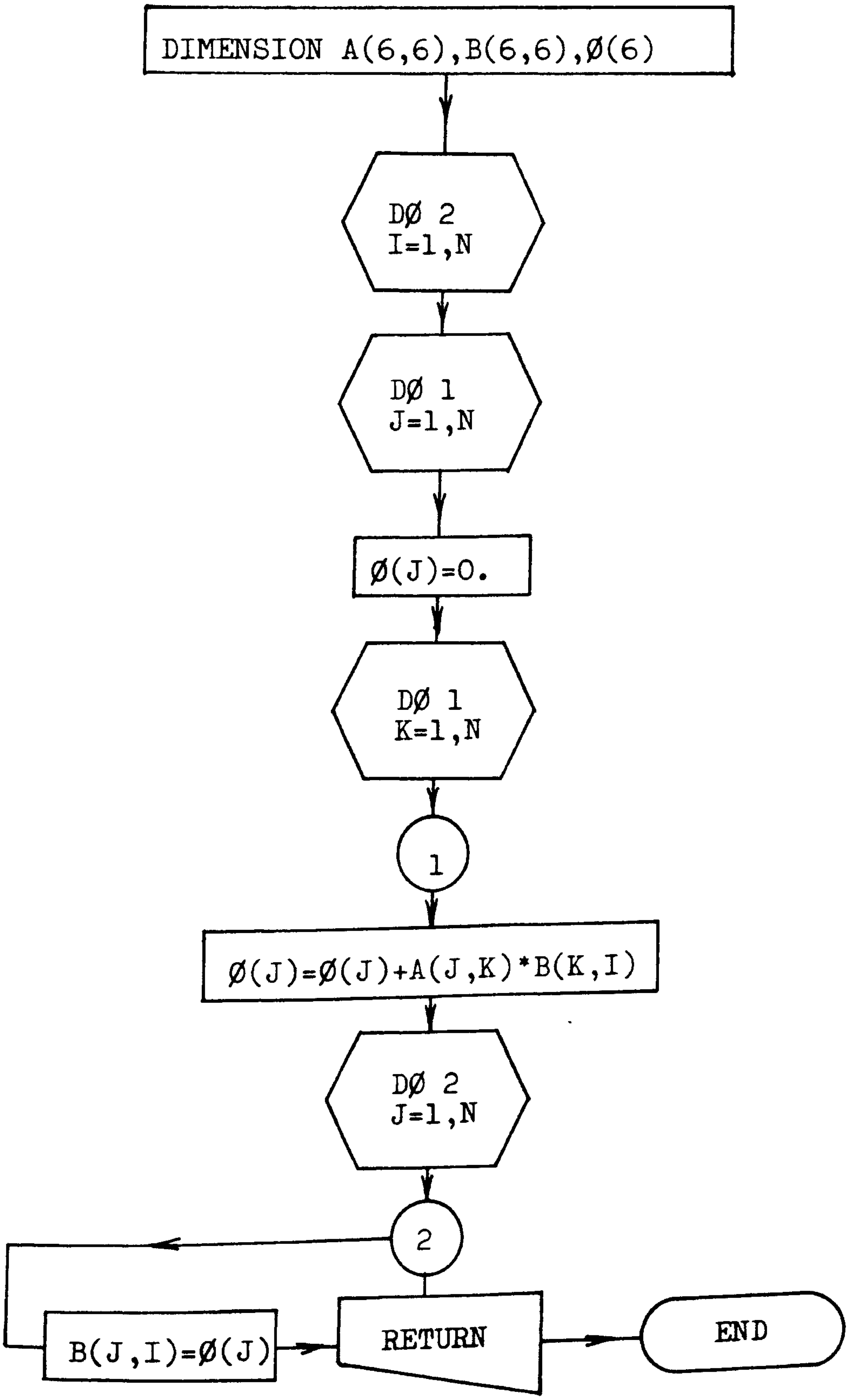

Solve For Nodal Displmnts
Call Solve (A,D,KKK)
Write: Displmnts D(J)
Solve For Member End Forces
DO 81 I=1,NB
J1=NODE(I,1)
J2=NODE(I,2)
Call STIFMA(I)
DO 82 J=1,6 K=1,6
AK(J,K)= ST(J,K)
82
AI(J,K)= ST(J,K)
Call MATRAN(I)
Call TRIPRO (H,ST,6)
Call TRIPRO (T,ST,6)
Call MTXMUL (H,AK,6)
Call TRIPRO (T,AK,6)
Call TRIPRO (T,AI,6)


DØ 84
K=1,6
PP(K)=0
DØ 84
L=1,6
J=L+6*(J2-1)
84
PP(K)=PP(K)-AK(K,L)*D(J)
IF(J1)
-
76
0
76
+
77
DØ 83
K=1,6
L=1,6

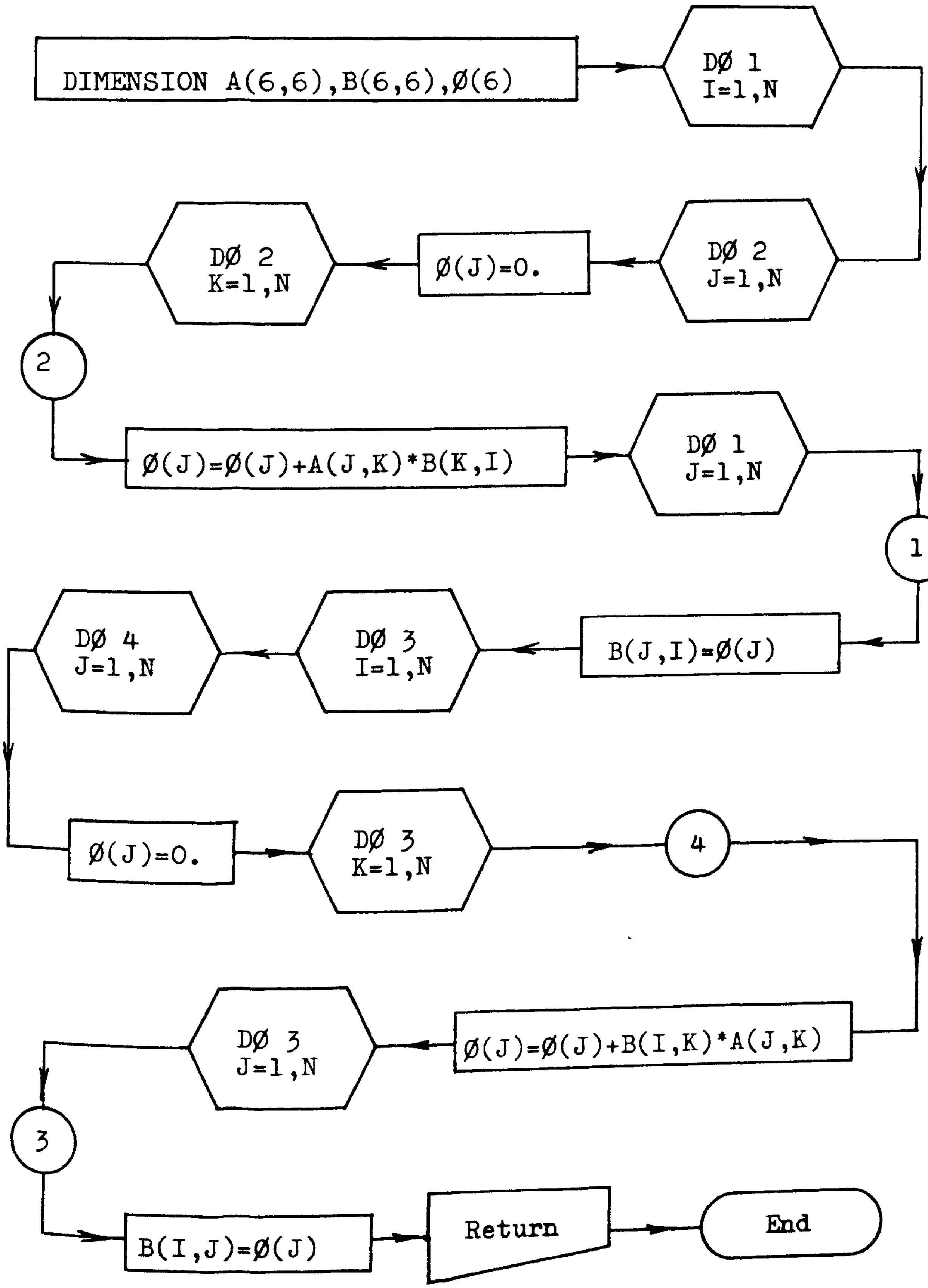

J=L+6*(J1-1)
83
PP(K)=PP(K)+ST(K,L)*D(J)
76
Write: 1 PP(J),in System Coord.
DØ 85 K=1,6
P(K)=0
DØ 85 L=1,6
85
P(K)=P(K)+T(L,K)*PP(L)
Write: 1 P(K),in Member Coord.
DØ 87 K=1,6
PP(K)=0
DØ 87 L=1,6
J=L+6*(J2-1)
87
PP(K)=PP(K)+AI(K,L)*D(J)


IF(J1)
-
0
+
78
78
79
DØ 86
K=1,6
L=1,6
J=L+6*(J1-1)
86
PP(K)=PP(K)-AK(L,K)*D(J)
78
Write: 2
PP(K),in
System
Coord.
DØ 88
K=1,6
P(K)=0
DØ 88
L=1,6
88
P(K)=P(K)+T(L,K)*PP(L)
Write: 2
P(K),in
Member
Coord.
GØ TØ
999
END

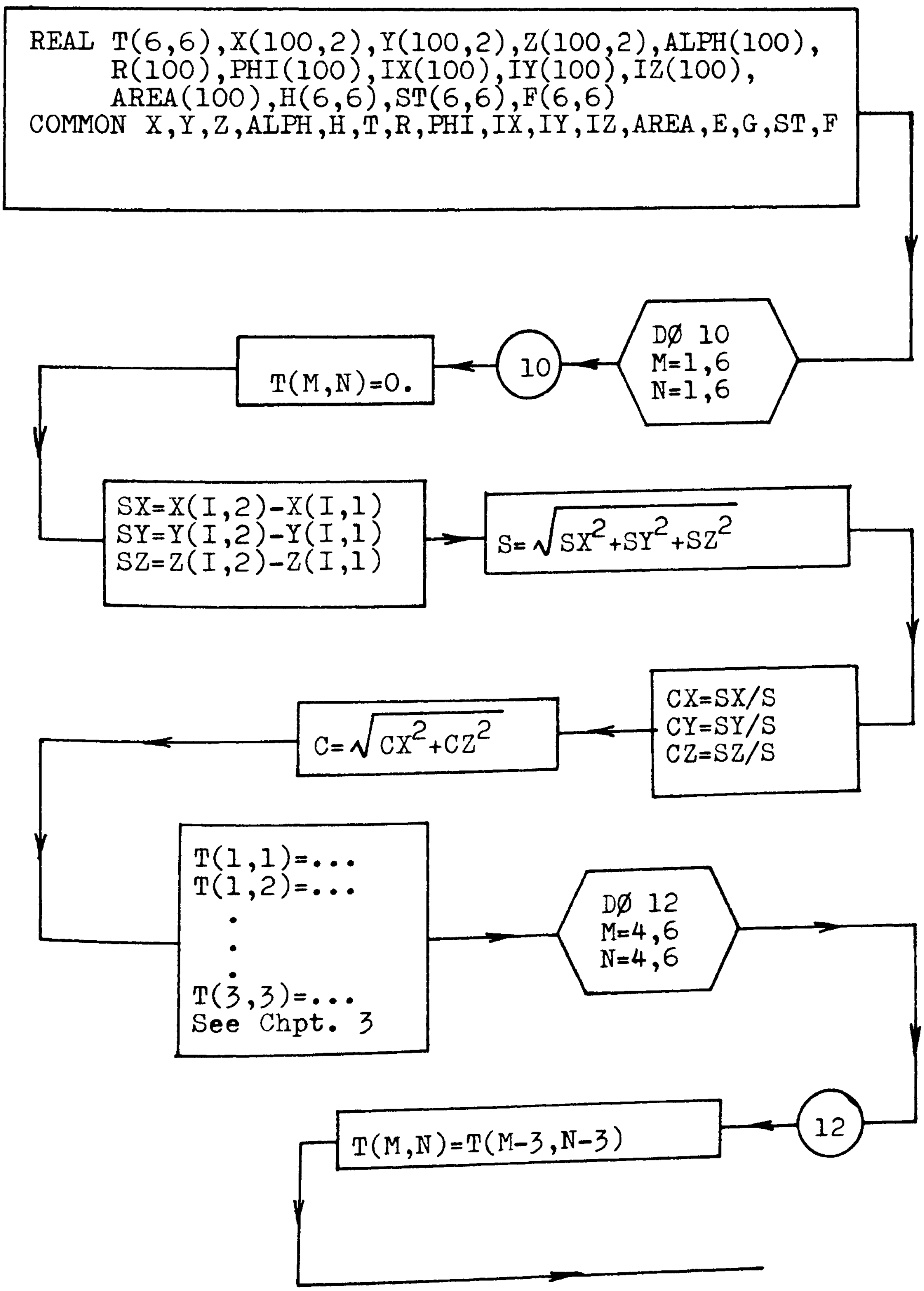
c.) Subroutine MTXMUL Flow Diagram



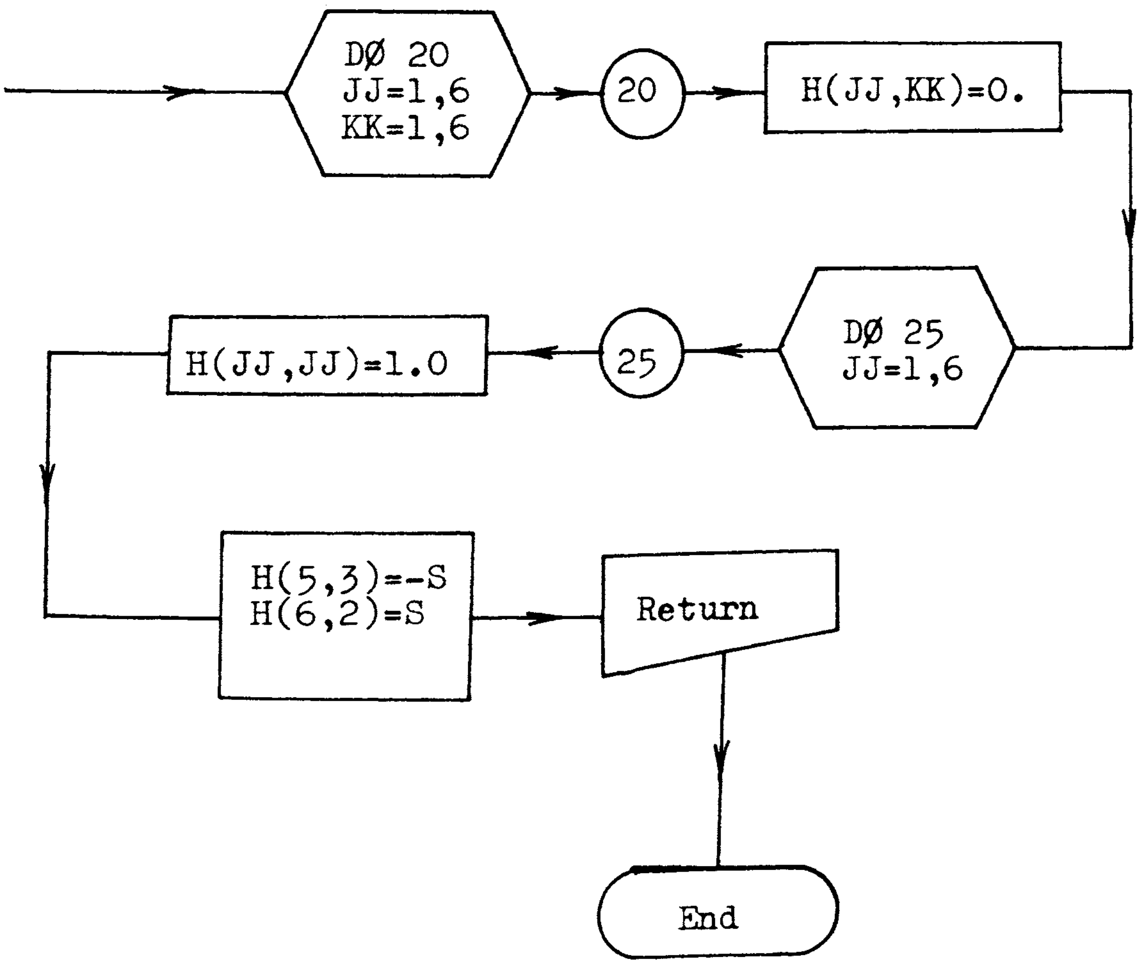
d.) Subroutine TRIPR0 Flow Diagram



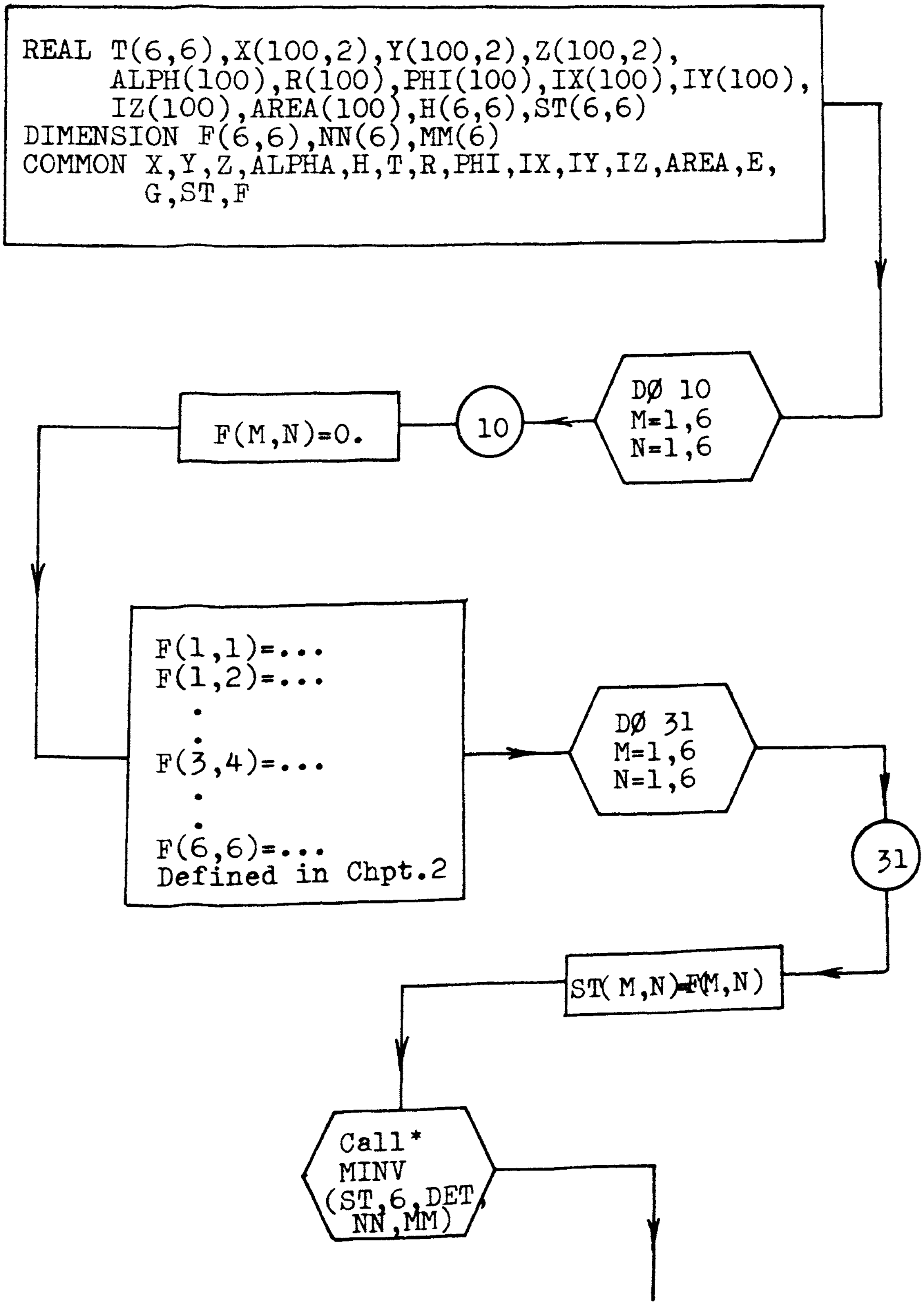
e.) Subroutine MATRAN (I)



```
REAL T(6,6),X(100,2),Y(100,2),Z(100,2),ALPH(100),
     R(100),PHI(100),IX(100),IY(100),IZ(100),
     AREA(100),H(6,6),ST(6,6),F(6,6)
COMMON X,Y,Z,ALPH,H,T,R,PHI,IX,IY,IZ,AREA,E,G,ST,F
```

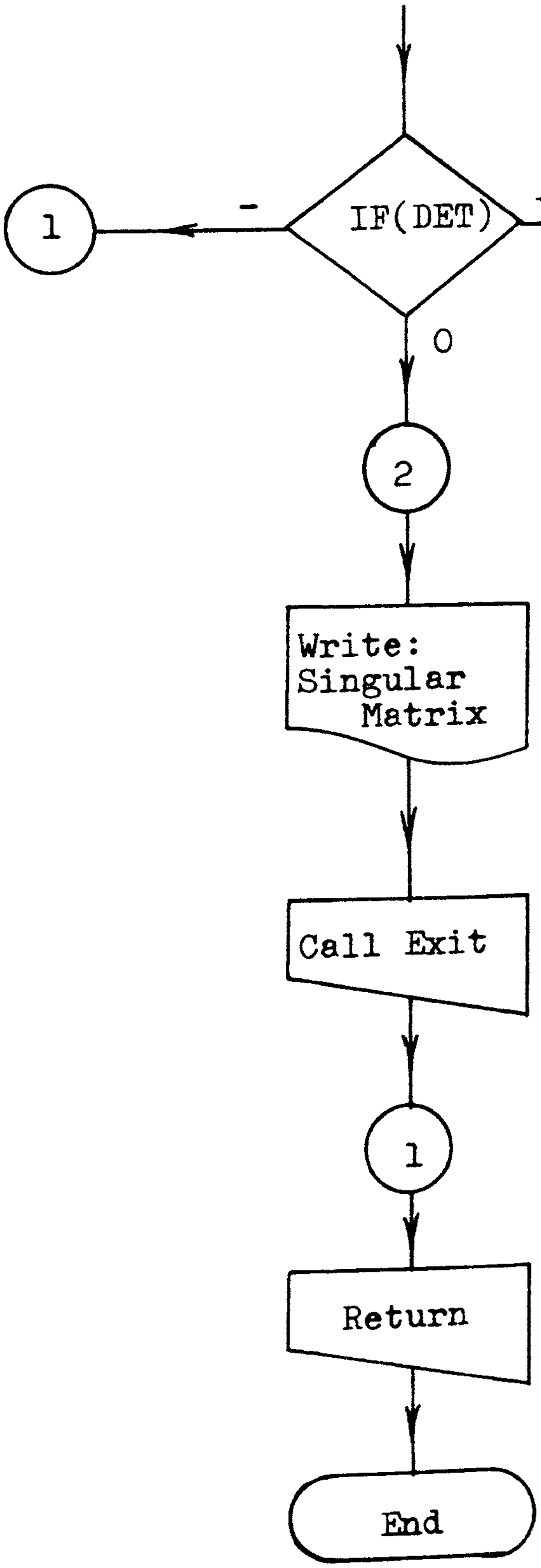

DØ 20
JJ=1,6
KK=1,6
20
H(JJ,KK)=0.
DØ 25
JJ=1,6
25
H(JJ,JJ)=1.0
H(5,3)=-S
H(6,2)=S
Return
End

f.) Subroutine STIFMA (I)

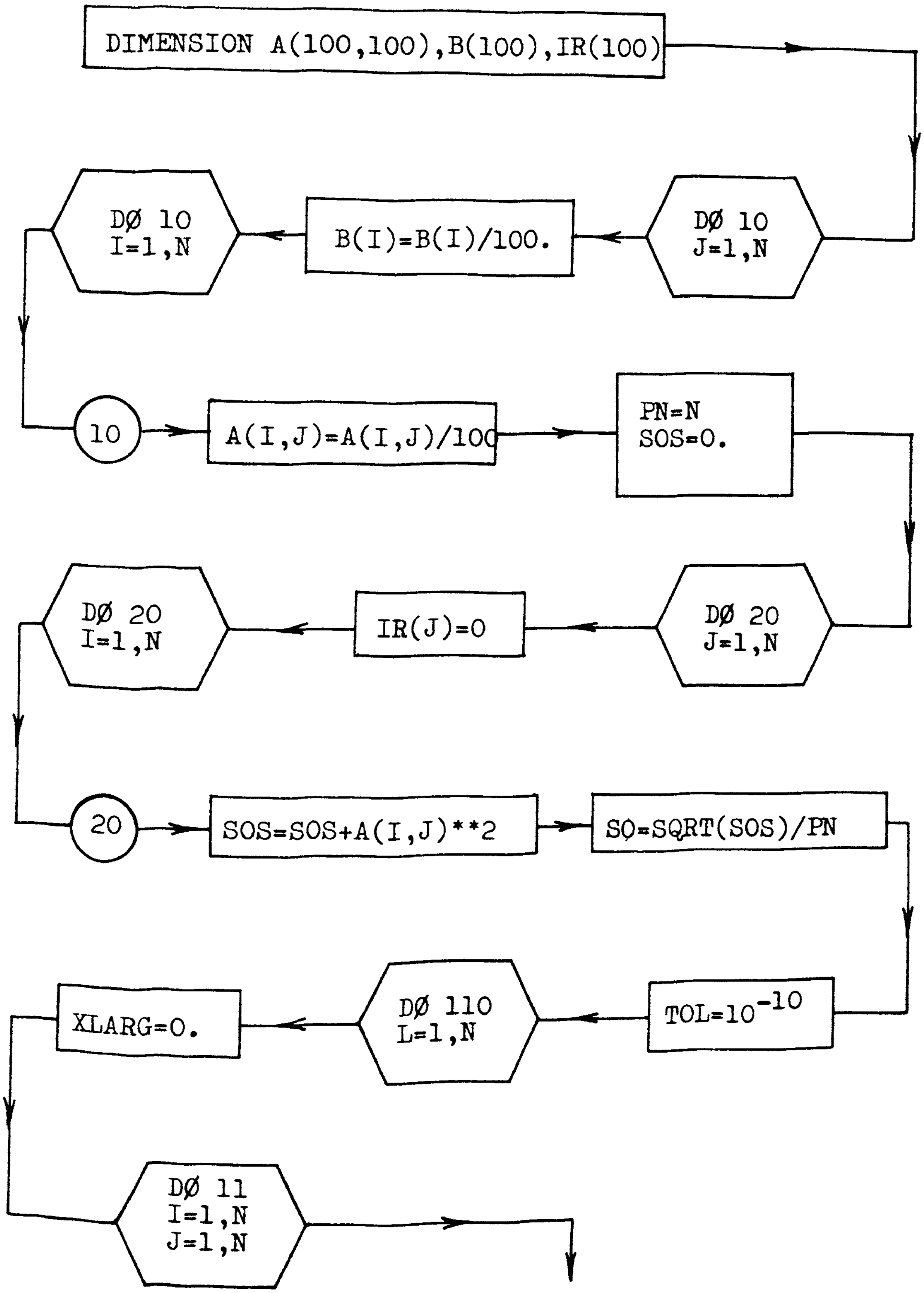


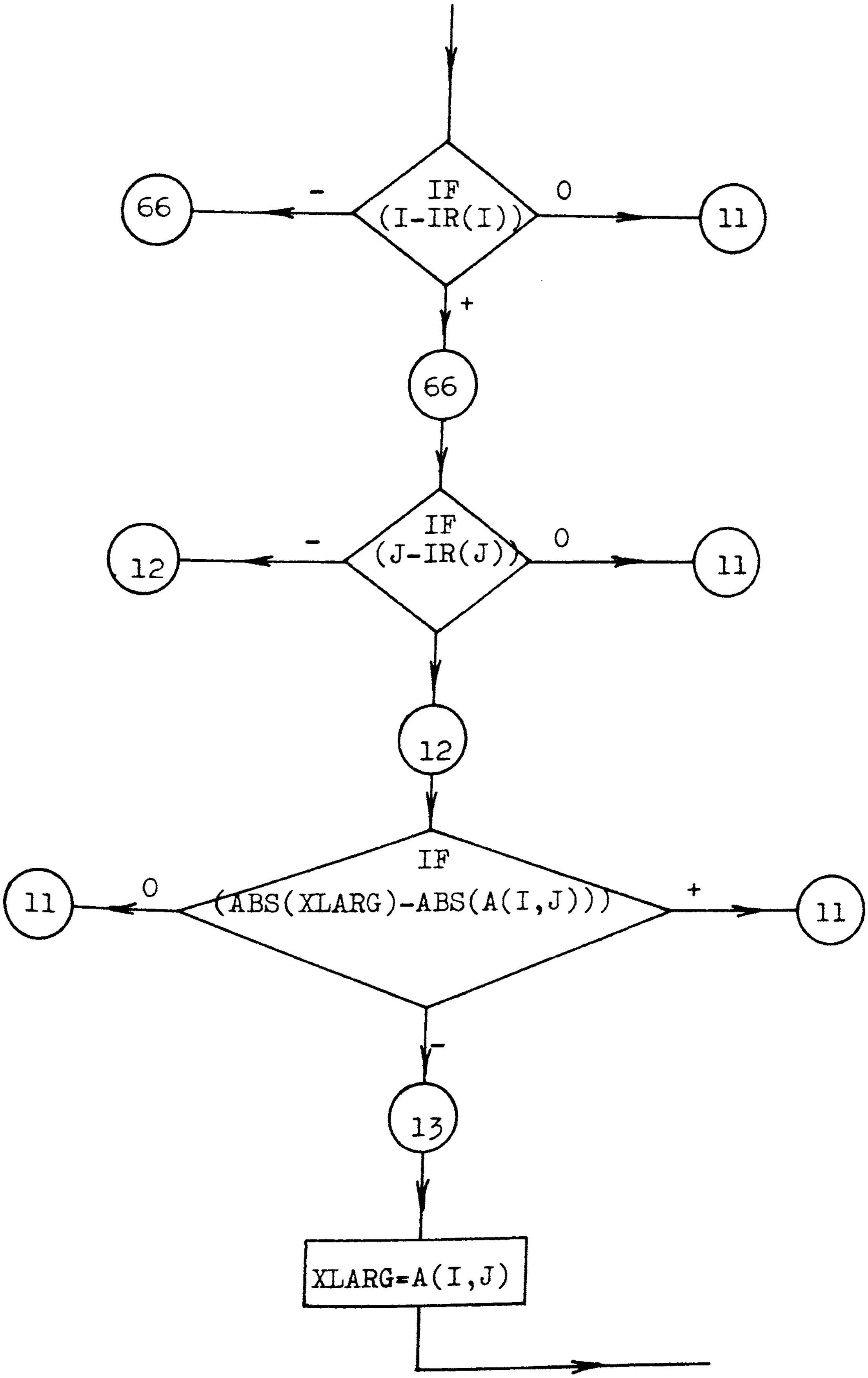
```
REAL T(6,6),X(100,2),Y(100,2),Z(100,2),
     ALPH(100),R(100),PHI(100),IX(100),IY(100),
     IZ(100),AREA(100),H(6,6),ST(6,6)
DIMENSION F(6,6),NN(6),MM(6)
COMMON X,Y,Z,ALPHA,H,T,R,PHI,IX,IY,IZ,AREA,E,
      G,ST,F
```

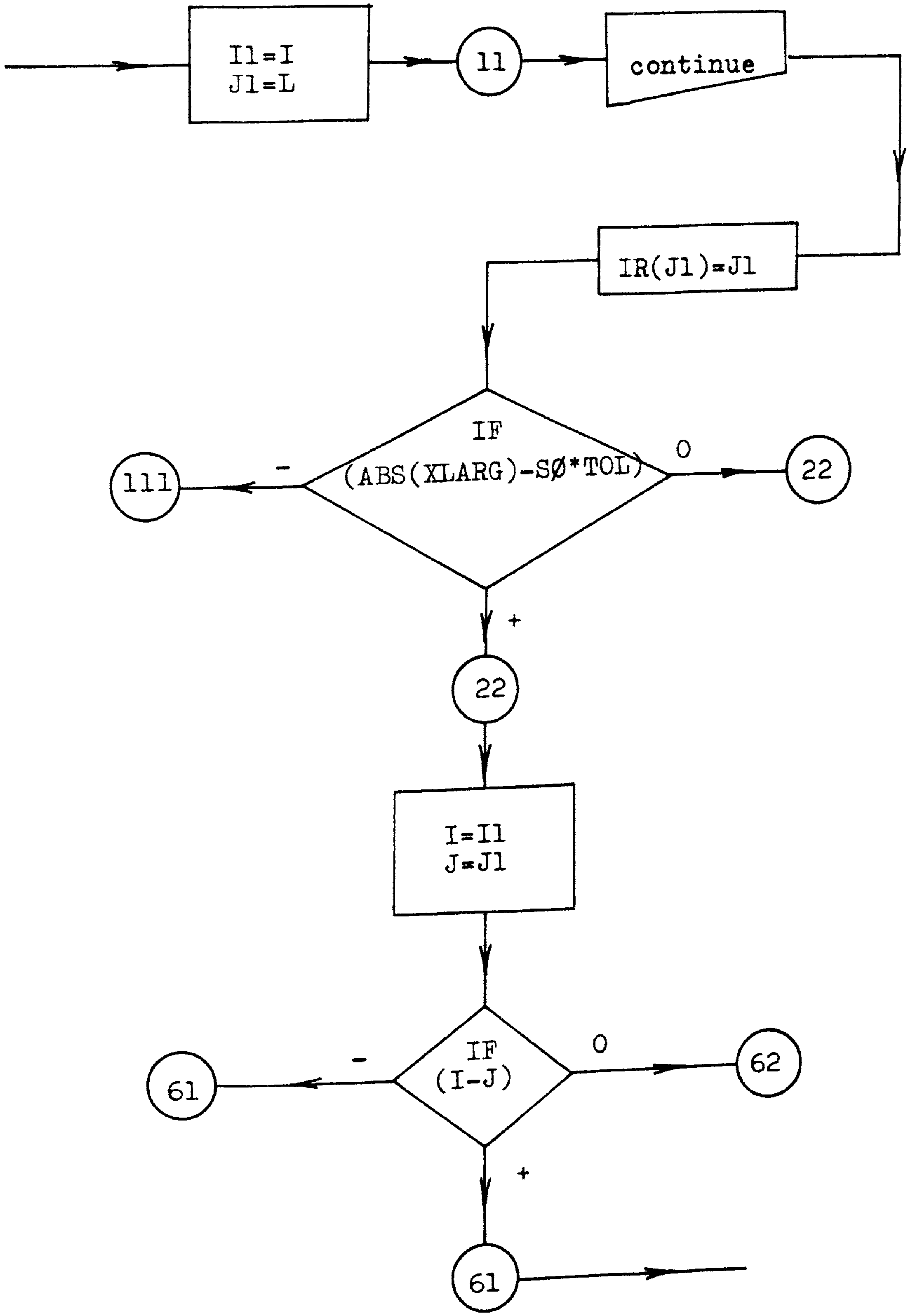
*Machine loaded subroutine

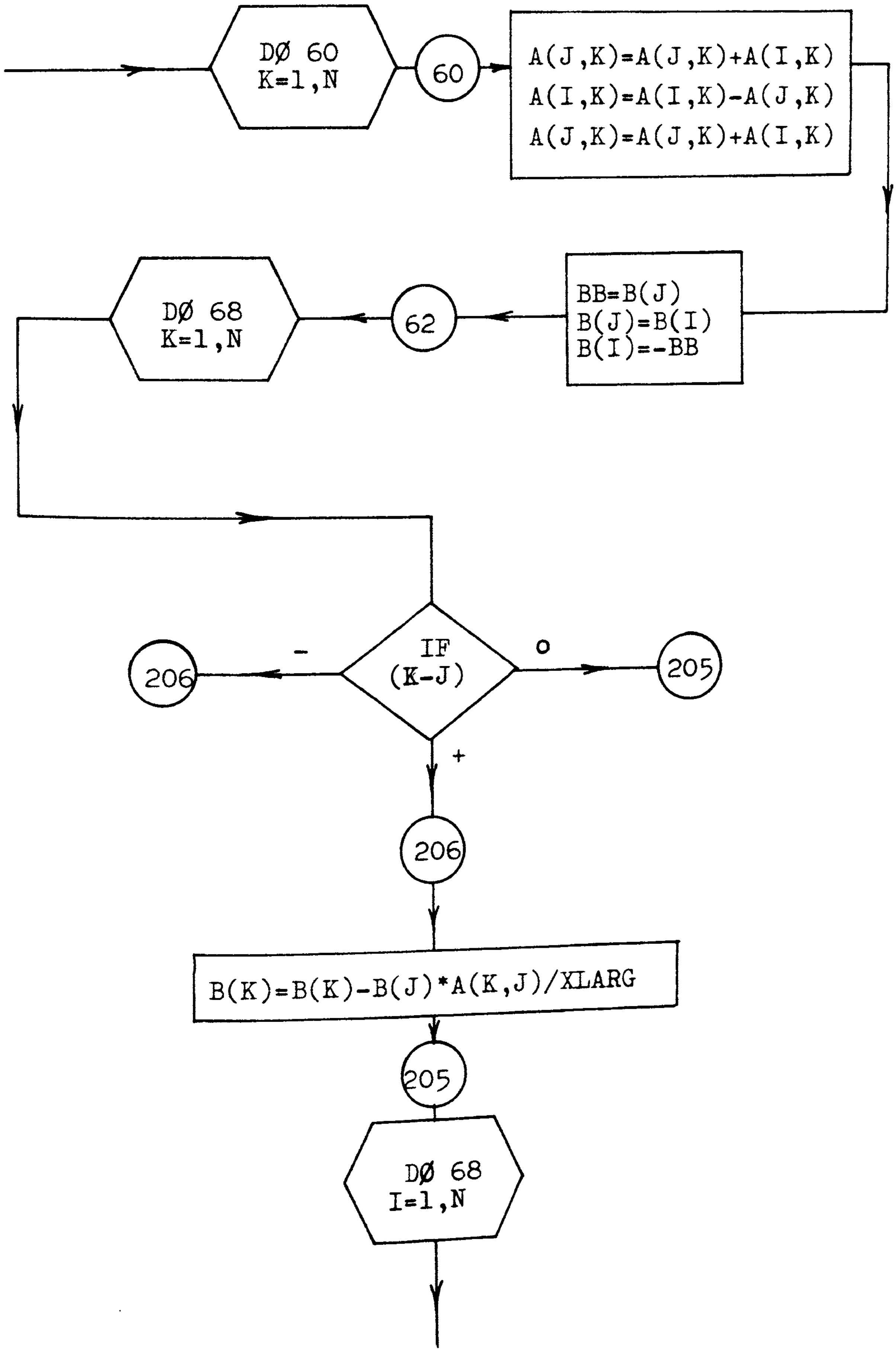

IF(DET)
-
+
0
1
1
2
Write: Singular Matrix
Call Exit
1
Return
End

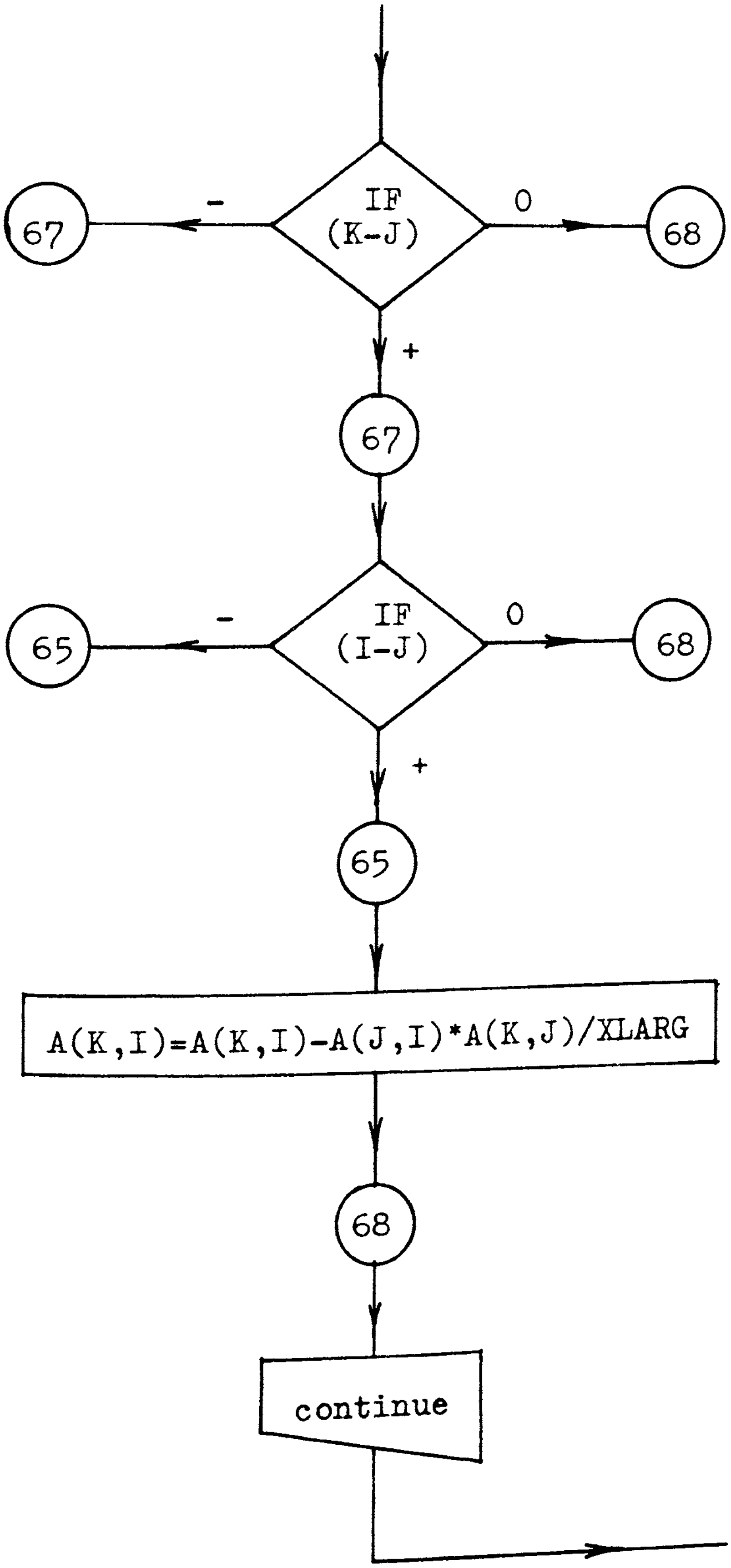
g.) Subroutine SØLVE Flow Diagram

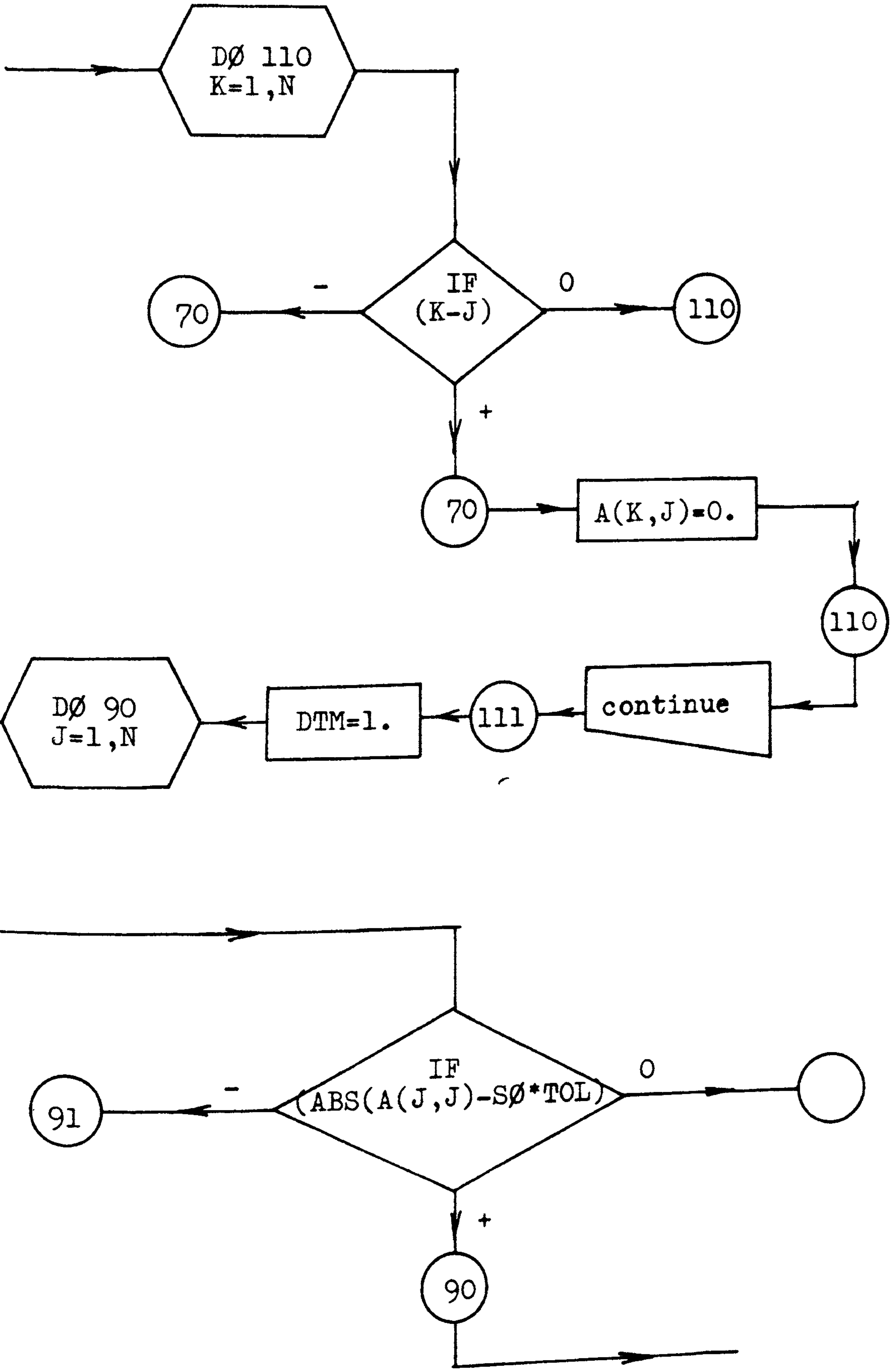



IF
(I-IR(I))
-
0
+
66
11
66
IF
(J-IR(J))
-
0
12
11
12
IF
(ABS(XLARG)-ABS(A(I,J)))
0
+
-
11
11
13
XLARG=A(I,J)


I1=I
J1=L
11
continue
IR(J1)=J1
IF
(ABS(XLARG)-S0*TOL)
-
111
0
22
+
22
I=I1
J=J1
IF
(I-J)
-
61
0
62
+
61


DØ 60
K=1,N
60
A(J,K)=A(J,K)+A(I,K)
A(I,K)=A(I,K)-A(J,K)
A(J,K)=A(J,K)+A(I,K)
BB=B(J)
B(J)=B(I)
B(I)=-BB
62
DØ 68
K=1,N
IF
(K-J)
-
206
0
205
+
206
B(K)=B(K)-B(J)*A(K,J)/XLARG
205
DØ 68
I=1,N


IF
(K-J)
-
0
67
68
+
67
IF
(I-J)
-
0
65
68
+
65
A(K,I)=A(K,I)-A(J,I)*A(K,J)/XLARG
68
continue


DØ 110
K=1,N
IF
(K-J)
-
0
+
70
110
70
A(K,J)=0.
110
continue
111
DTM=1.
DØ 90
J=1,N
IF
(ABS(A(J,J)-SØ*TOL)
-
0
+
91
90

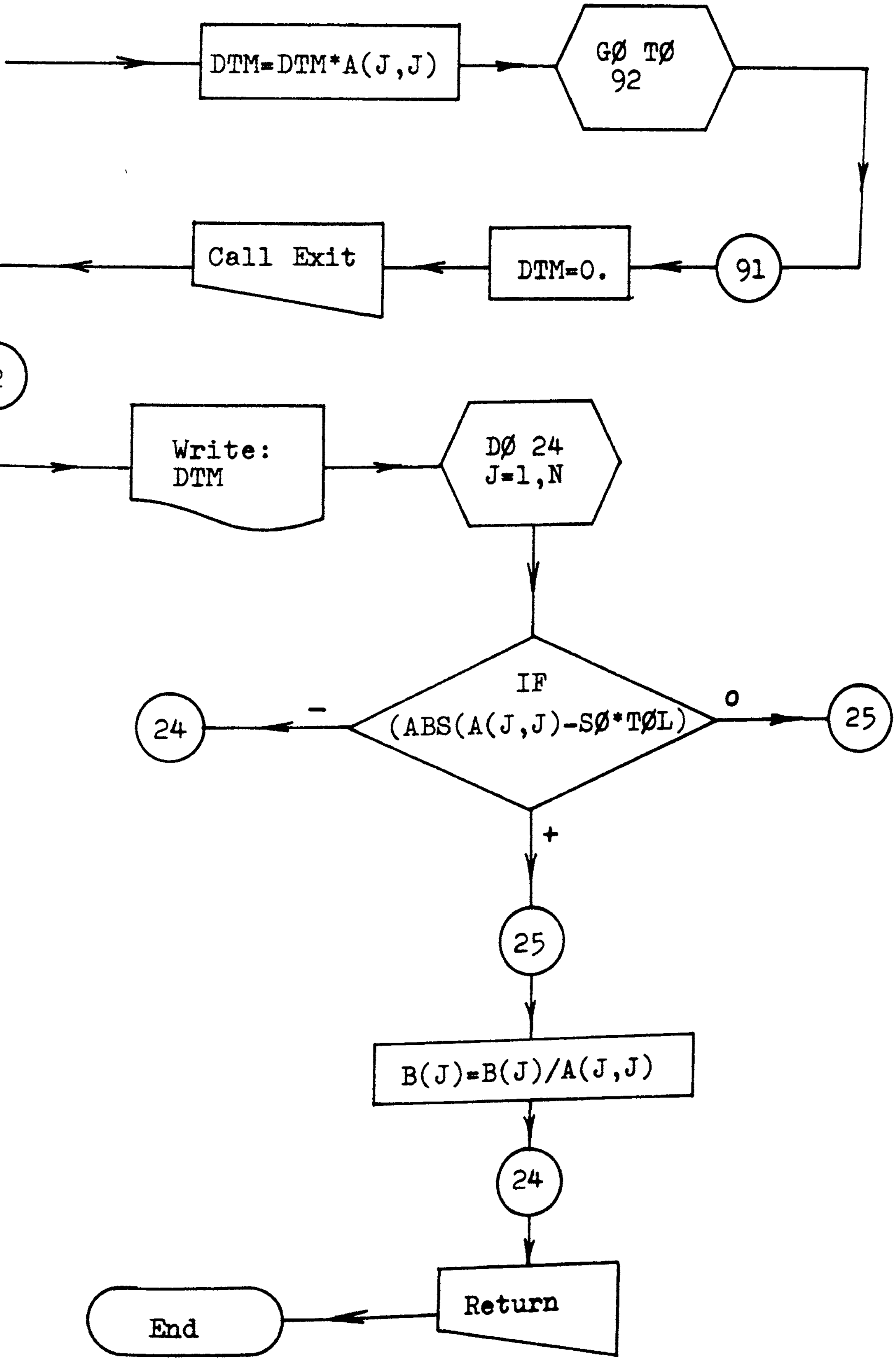

DTM=DTM*A(J,J)
GØ TØ 92
91
DTM=0.
Call Exit
92
Write: DTM
DØ 24 J=1,N
IF (ABS(A(J,J)-SØ*TØL)
-
0
+
24
25
25
B(J)=B(J)/A(J,J)
24
Return
End

Table 5.1 Table of Symbols

Program Symbol	Problem Symbol	Definition
Main Program		
NN		Number of nodes
NB		Number of members
LL		Maximum number of members per node
NLC		Number of the loading condition
NODE		Name for node numbers
X,Y,Z		Geometric Coordinates
ALPH		Rotation of members about member x-axis
IX, IY, IZ	I_N, I_{YN}, I_Z	Principle moments of inertia
AREA	A	Cross-Sectional Area of member
R	R	Radius of curvature of member
PHI	ϕ	One-half central angle of member
E	E	Modulus of elasticity

Table of Symbols (continued)

Program Symbol	Problem Symbol	Definition
Main Program		
G	G	Shear modulus
KKK		Dimension of system matrix
D	,P	Used both as a label for nodal displacements and applied nodal loads
P	P	Member and forces and moments in member coordinates
PP	P'	Member end forces and moments in system coordinates
NPPN		Counter used to count number of members attached to a node
J1		Node number at end-1 of a member
J2		Node number at end-2 of a member
L1		The L^{th} member attached to node
LINK		Name of member to node reference

Table of Symbols (continued)

Program Symbol	Problem Symbol	Definition
Main Program		
A	K"	System stiffness matrix
ST,AK	$K=F^{-1}$	Member stiffness matrix in member coordinates
F	F	Member flexibility matrix
T	T	Transformation matrix
H	H	Equilibrium matrix
NJ		Member and reference
PP		Member end forces in system coordinates
P		Member end forces in member coordinates
MTXMUL		
A		A general six by six matrix
B		A general six by six matrix
0		An operating vector used to store rows of AB back into the used columns of B

Table of Symbols (continued)

Program Symbol	Problem Symbol	Definition
TRIPRØ		
A	T	A general six by six transformation matrix
B		A general six by six matrix
Ø		An operating vector used to store rows of ABA^t back into the used columns of B
MATRAN		
SX		The difference in X-coordinates of the 1-end and 2-end of the member
SY		The difference in Y-coordinates of the 1-end and 2-end of the member
SZ		The difference in Z-coordinates of the 1-end and 2-end of the member
S		Square root of the sum of the squares of SX, SY and SZ
CX CY CZ	a_x a_y a_z	CX,CY,CZ are the direction cosines of the member X-axis

Table of Symbols (continued)

Program Symbol	Problem Symbol	Definition
C		Square root of the sum of the squares of CX and CZ
T	T	Transformation matrix
H	H	Equilibrium matrix
SØLVE		
A	K"	System stiffness matrix
B	P'	Applied nodal loads
IR		Operating vector
N		Size of system stiffness matrix which equals six times the number of nodes
SOS		Sum of the squares of the elements in the system stiffness matrix
SO		Square root of the sum of the squares.
TOL		Tolerance
XLARG		Largest element in system matrix at beginning of each pivot
DTM		Determinant

```
//OS  JOB CEX039,'FENTON D L            '  07/08/67 FORT 0003 0040 0000      15235-
      REAL T(6,6),X(100,2),Y(100,2),Z(100,2),ALPH(100),R(100),PHI(100),
     *IY(100),IZ(100),AREA(100),H(6,5),ST(6,6),IX(100),F(6,6)
      REAL AK(6,6),D(100),A(100,100),AI(6,6),PP(6),P(6)
      INTEGER NODE(100,2),NBPN(25),LINK(25,6)
      COMMON X,Y,Z,ALPH,H,T,R,PHI,IX,IY,IZ,AREA,E,G,ST,F
 9999 READ(1,100)NB,NN,LL,NLC
  100 FORMAT(5I10)
      WRITE(3,201)NN,NB,NLC,LL
  201 FORMAT('1 NUMBER OF NODES'I3/'  NUMBER OF MEMBERS'I3/'  NUMBER OF
     *LOADING CONDITION'     I3/'  MAXIMUM NUMBER OF MEMBERS PER NODE'I3)
      READ(1,200)(NODE(I,1),I=1,NB),(NODE(I,2),I=1,NB)
      DO 3 I=1,NB
    3 READ(1,777)(X(I,J),Y(I,J),Z(I,J),J=1,2),ALPH(I)
      DO 4 I=1,NB
    4 READ(1,777)IX(I),IY(I),IZ(I),AREA(I),R(I),PHI(I)
      READ(1,777)E,G
  777 FORMAT(7F10.2)
      KKK=6*NN
      READ(1,241)(D(IKK),IKK=1,KKK)
  241 FORMAT(6F12.4)
      WRITE(3,202)
  202 FORMAT(//45X' MEMBER COORDINANTS'/5X'MEMBER-I'6X'X(I,1)'9X'X(I,2)'
     *9X'Y(I,1)'9X'Y(I,2)'9X'Z(I,1)'9X'Z(I,2)'/)
  203 FORMAT(I10,7F15.6)
      DO 204 I=1,NB
  204 WRITE(3,203)I,X(I,1),X(I,2),Y(I,1),Y(I,2),Z(I,1),Z(I,2)
      WRITE(3,205)
  205 FORMAT('1'54X'MEMBER PROPERTIES'/ 5X'MEMBER-I'8X'IX'13X'IY'13X'IZ'
     *11X'AREA'10X'RADIUS'12X'PHI'11X'ALPHA'/)
      DO 206 I=1,NB
  206 WRITE(3,203)I,IX(I),IY(I),IZ(I),AREA(I),R(I),PHI(I),ALPH(I)
      WRITE(3,207)
  207 FORMAT('1'46X'APPLIED NODAL LOADS'/6X'NODE'7X'PX'13X'PY'13X'PZ'13X
     *'MX'13X'MY'13X'MZ'/)
      DO 208 I=1,NN
      K=6*I
  208 WRITE(3,203)I,D(K-5),D(K-4),D(K-3),D(K-2),D(K-1),D(K)
      WRITE(3,300)
      WRITE(3,500)
      DO 8 J=1,NN
      DO 8 L=1,LL
    8 LINK(J,L)=0
      DO 9 J=1,NN
    9 NBPN(J)=0
      DO 10 I=1,NB
   10 WRITE(3,600)I,NODE(I,1),NODE(I,2)
C          THE FOLLOWING 16 STATEMENTS DETERMINE WHICH MEMBERS IN A
C     STRUCTURAL NETWORK ARE INCIDENT ON A GIVEN NODE.  INPUT,
C     NODE(I,1)=J1 AND NODE(I,2)=J2, WHERE J1 AND J2 ARE THE NODES
C     AT THE NEAR AND FAR ENDS OF THE MEMBER RESPECTIVELY.
      DO 20 I=1,NB
      J1=NODE(I,1)
      IF(J1)12,12,11
```

```
   11 NBRN(J1)=NBRN(J1)+1
      L1=NBRN(J1)
      LINK(J1,L1)=I
   12 J2=NODE(I,2)
      IF(J2)20,20,13
   13 NBRN(J2)=NBRN(J2)+1
      L2=NBRN(J2)
      LINK(J2,L2)=-I
   20 CONTINUE
      WRITE(3,300)
      WRITE(3,700)
      WRITE(3,800)
      DO 30 J=1,NN
   30 WRITE(3,900)J,NBRN(J),(LINK(J,L),L=1,4)
  200 FORMAT(12I6)
  300 FORMAT(1H1)
  500 FORMAT(5X,'MEMB',2X,'NODE(I,1)',2X,'NODE(I,2)'//)
  600 FORMAT(5X,I3,6X,I3,9X,I3)
  700 FORMAT(5X,'NODE',2X,'NBRN',14X,'LINK')
  800 FORMAT(22X,'1',5X,'2',5X,'3',5X,'4'5X'5'5X'6'//)
  900 FORMAT(5X,I3,3X,I3,6X,I3,3I6)
C     CLEAR SYSTEM STIFFNESS (A) STORAGE LOCATIONS
      DO 62 J=1,KKK
      DO 62 L=1,KKK
   62 A(J,L)=0.
C     ****GENERATE SYSTEM STIFFNESS MATRIX****
      DO 60 J=1,NN
      DO 61 L=1,LL
      I=IABS(LINK(J,L))
      IF(I)60,69,69
C     COMPUTE MEMBER(I) STIFFNESS MATRIX
   69 CALL STIFMA(I)
      WRITE(3,220)I
  220 FORMAT('1'10X'MEMBER'I3//50X'FLEXIBILITY MATRIX'//)
      DO 26 M1=1,6
   26 WRITE(3,440)(F(M1,N),N=1,6)
      WRITE(3,210)
  210 FORMAT(//50X'STIFFNESS MATRIX'//)
      WRITE(3,440)((ST(K1,K2),K2=1,6),K1=1,6)
  440 FORMAT(6F18.8)
      DO 21 M1=1,6
      DO 21 M2=1,6
   21 AK(M1,M2)=ST(M1,M2)
C     COMPUTE MEMBER(I) AXIS ROTATION TRANSFORMATION MATRIX
      CALL MATRAN(I)
      WRITE(3,211)
  211 FORMAT(//50X'TRANSFORMATION MATRIX'//)
      DO 15 M=1,6
   15 WRITE(3,440)(T(M,N),N=1,6)
C     WHICH END OF MEMBER(I) IS AT NODE(J)
      IF(LINK(J,L))40,40,50
C     IF END-2 OF MEMBER(I) IS AT NODE(J) COMPUTE, K'(2,2)= T*K(2,2)*T'
C     DIRECT STIFFNESS AND ADDS IT TO THE APPROPRIATE 6X6 LOCATION ON
C     THE SYSTEM MATRIX DIAGONAL.
```

```
   40 CALL TRIPRO(T,AK,6)
      NJ=1
      DO 41 K=1,6
      N=K+6*(J-1)
      DO 41 K1=1,6
      M=K1+6*(J-1)
   41 A(N,M)=AK(K,K1)+A(N,M)
      GO TO 52
C     IF END-1 OF MEMBER(I) IS AT NODE(J) COMPUTE K'(1,1)=THKH'T'AND
C     ADDS IT TO THE APPROPRIATE 6X6 LOCATION ON THE SYSTEM MATRIX
C     DIAGONAL.
   50 CALL TRIPRO(H,AK,6)
      CALL TRIPRO(T,AK,6)
      NJ=2
      JJ=J
      DO 51 K=1,6
      N=K+6*(J-1)
      DO 51 K1=1,6
      M=K1+6*(JJ-1)
   51 A(N,M)=AK(K,K1)+A(N,M)
C     THE FOLLOWING 16 STATEMENTS LOCATE THE END OF MEMBER(I) NOT
C     INCIDENT ON NODE(J) AND COMPUTE THE APPROPRIATE OFF DIAGONAL 6X6
C     STIFFNESS MATRIX.
   52 IF(NODE(I,NJ))53,61,53
   53 JJ=NODE(I,NJ)
      CALL MTXMUL(H,ST,6)
      CALL TRIPRO(T,ST,6)
      GO TO(64,63),NJ
C     COMPUTE -THKT'
   63 DO 54 K=1,6
      N=K+6*(J-1)
      DO 54 K1=1,6
      M=K1+6*(JJ-1)
   54 A(N,M)=-ST(K,K1)
      GO TO 61
C     COMPUTE -TKH'T'
   64 DO 65 K=1,6
      N=K+6*(J-1)
      DO 65 K1=1,6
      M=K1+6*(JJ-1)
   65 A(N,M)=-ST(K1,K)
   61 CONTINUE
   60 CONTINUE
      DO 72 J=1,NN
      IF(LINK(J,2))72,67,72
   67 DO 66 I1=1,3
      N=I1+6*(J-1)
      DO 66 I2=1,KKK
   70 A(I2,N)=0.
   66 A(N,I2)=0.
      DO 71 I1=1,3
      M=I1+6*(J-1)
   71 A(M,M)=1.0
   72 CONTINUE
```

```
      WRITE(3,212)
  212 FORMAT('1'37X'SYSTEM STIFFNESS MATRIX'//)
      DO 213 I=1,KKK
  213 WRITE(3,214)I,(A(I,J),J=1,KKK)
  214 FORMAT(/'  ROW'I5/(6E17.7))
C     ** SOLVE FOR NODAL DISPLACEMENTS **
      CALL SOLVE(A,D,KKK)
      WRITE(3,216)
  216 FORMAT(40X'NODAL DISPLACEMENTS'//6X'NODE'7X'DELTA-X'8X'DELTA-Y'8X
     *'DELTA-Z'8X'THETA-X'8X'THETA-Y'8X'THETA-Z'/)
      DO 217 I=1,NN
      J=6*I
  217 WRITE(3,203)I,D(J-5),D(J-4),D(J-3),D(J-2),D(J-1),D(J)
C     THE REMAINDER OF THE PROGRAM COMPUTES THE MEMBER END REACTIONS
C     FIRST IN SYSTEM COORDINATES AND THEN TRANSFORMS THEM TO MEMBER
C     COORDINATES.
      WRITE(3,218)
  218 FORMAT('1'37X'MEMBER END FORCES AND MOMENTS'//34X'PPX'12X'PPY'12X
     *'PPZ'12X'MPX'12X'MPY'12X'MPZ'/'  MEMB.  END'/20X'PX'13X'PY'13X'PZ'
     *13X'MX'13X'MY'13X'MZ'//)
      DO 81 I=1,NB
      J1=NODE(I,1)
      J2=NODE(I,2)
      CALL STIFMA(I)
      DO 82 J=1,6
      DO 82 K=1,6
      AK(J,K)=ST(J,K)
   82 AT(J,K)=ST(J,K)
      CALL MATRAN(I)
      CALL TRIPRO(H,ST,6)
      CALL TRIPRO(T,ST,6)
      CALL MTXMUL(H,AK,6)
      CALL TRIPRO(T,AK,6)
      CALL TRIPRO(T,AT,6)
      DO 84 K=1,6
      PP(K)=0.
      DO 84 L=1,6
      J=L+6*(J2-1)
   84 PP(K)=PP(K)-AK(K,L)*D(J)
      IF(J1)76,76,77
   77 DO 83 K=1,6
      DO 83 L=1,6
      J=L+6*(J1-1)
   83 PP(K)=PP(K)+ST(K,L)*D(J)
   76 WRITE(3,189)(PP(J),J=1,6)
  189 FORMAT(10X2H1',14X6E15.6/)
C     FORCES AT END-1 OF MEMBER(I) IN MEMBER COORDINATES.
      DO 85 K=1,6
      P(K)=0.
      DO 85 L=1,6
   85 P(K)=P(K)+T(L,K)*PP(L)
      WRITE(3,187)(P(J),J=1,6),I
  187 FORMAT(10X'1'6E15.6/I5)
      DO 87 K=1,6
```

```
      PP(K)=0.
      DO 87 L=1,6
      J=L+6*(J2-1)
   87 PP(K)=PP(K)+AI(K,L)*D(J)
      IF(J1)78,78,79
   79 DO 86 K=1,6
      DO 86 L=1,6
      J=L+6*(J1-1)
   86 PP(K)=PP(K)-AK(L,K)*D(J)
   78 WRITE(3,190)(PP(J),J=1,6)
  190 FORMAT(10X2H2',14X6F15.6/)
C     FORCES AT END-2 OF MEMBER(I) IN MEMBER COORDINATES.
      DO 88 K=1,6
      P(K)=0.
      DO 88 L=1,6
   88 P(K)=P(K)+T(L,K)*PP(L)
   91 WRITE(3,188)(P(J),J=1,6)
  188 FORMAT(10X'2'6F15.6//)
      GO TO 9999
      END
      SUBROUTINE MTXMUL(A,B,N)
      DIMENSION A(6,6),B(6,6),D(6)
      DO 2 I=1,N
      DO 1 J=1,N
      D(J)=0.
      DO 1 K=1,N
    1 D(J)=D(J)+A(J,K)*B(K,I)
      DO 2 J=1,N
    2 B(J,I)=D(J)
      RETURN
      END
      SUBROUTINE TRIPRO(A,B,N)
      DIMENSION A(6,6),B(6,6),D(6)
      DO 1 I=1,N
      DO 2 J=1,N
      D(J)=0.
      DO 2 K=1,N
    2 D(J)=D(J)+A(J,K)*B(K,I)
      DO 1 J=1,N
    1 B(J,I)=D(J)
      DO 3 I=1,N
      DO 4 J=1,N
      D(J)=0.
      DO 4 K=1,N
    4 D(J)=D(J)+B(I,K)*A(J,K)
      DO 3 J=1,N
    3 B(I,J)=D(J)
      RETURN
      END
      SUBROUTINE MATRAN(I)
      REAL T(6,6),X(100,2),Y(100,2),Z(100,2),ALPH(100),R(100),PHI(100),
     *IY(100),IZ(100),AREA(100),H(6,6),ST(6,6),IX(100),F(6,6)
      COMMON X,Y,Z,ALPH,H,T,R,PHI,IX,IY,IZ,AREA,E,G,ST,F
      USING THE COORDINATES AT EACH OF A MEMBER THIS PROGRAM COMPUTES
```

```
C     THE THREE DIMENSIONAL ROTATION TRANSFORMATION MATRIX WHICH
C     TRANSFORMS ELEMENT COORDINATES TO SYSTEM COORDINATES.
      DO 10 M=1,6
      DO 10 N=1,6
   10 T(M,N)=0.0
      SX=X(I,2)-X(I,1)
      SY=Y(I,2)-Y(I,1)
      SZ=Z(I,2)-Z(I,1)
      S=SQRT(SX**2+SY**2+SZ**2)
      CX=SX/S
      CY=SY/S
      CZ=SZ/S
      C=SQRT(CX**2+CZ**2)
      T(1,1)=CX
      T(1,2)=(-CX*CY*COS(ALPH(I))-CZ*SIN(ALPH(I)))/C
      T(1,3)=(CX*CY*SIN(ALPH(I))-CZ*COS(ALPH(I)))/C
      T(2,1)=CY
      T(2,2)=C*COS(ALPH(I))
      T(2,3)=-C*SIN(ALPH(I))
      T(3,1)=CZ
      T(3,2)=(-CY*CZ*COS(ALPH(I))+CX*SIN(ALPH(I)))/C
      T(3,3)=(CY*CZ*SIN(ALPH(I))+CX*COS(ALPH(I)))/C
      DO 12 M=4,6
      DO 12 N=4,6
   12 T(M,N)=T(M-3,N-3)
      DO 20 JJ=1,6
      DO 20 KK=1,6
   20 H(JJ,KK)=0.0
      DO 25 JJ=1,6
   25 H(JJ,JJ)=1.0
      H(5,3)=-S
      H(6,2)=S
      RETURN
      END
      SUBROUTINE STIFMA(I)
      REAL T(6,6),X(100,2),Y(100,2),Z(100,2),ALPH(100),R(100),PHI(100),
     *IY(100),IZ(100),AREA(100),H(6,6),ST(6,6),IX(100)
      DIMENSION F(6,6),NN(6),MM(6)
      COMMON X,Y,Z,ALPH,H,T,R,PHI,IX,IY,IZ,AREA,E,G,ST,F
      DO 10 M=1,6
      DO 10 N=1,6
   10 F(M,N)=0.0
      F(1,1)=(R(I)/AREA(I)/E)*(PHI(I)+.5*SIN(2.*PHI(I)))
      F(1,1)=F(1,1)+(R(I)**3/E/IZ(I))*(PHI(I)-1.5*SIN(2.*PHI(I)))
      F(1,1)=F(1,1)+(R(I)**3/E/IZ(I))*(2.*PHI(I)*(COS(PHI(I)))**2)
      F(2,2)=(R(I)/AREA(I)/E)*(PHI(I)-.5*SIN(2.*PHI(I)))
      F(2,2)=F(2,2)+(R(I)**3/E/IZ(I))*(PHI(I)-.5*SIN(2.*PHI(I)))
      F(2,2)=F(2,2)+(R(I)**3/E/IZ(I))*(2.*PHI(I)*(SIN(PHI(I)))**2)
      F(3,3)=(R(I)**3/G/IX(I))*(3.*PHI(I)-2.*SIN(2.*PHI(I)))
      F(3,3)=F(3,3)+(R(I)**3/G/IX(I))*(.25*SIN(4.*PHI(I)))
      F(3,3)=F(3,3)+(R(I)**3/E/IY(I))*(PHI(I)-.25*SIN(4.*PHI(I)))
      F(4,4)=(R(I)/G/IX(I))*(PHI(I)+.5*SIN(2.*PHI(I)))
      F(4,4)=F(4,4)+(R(I)/E/IY(I))*(PHI(I)-.5*SIN(2.*PHI(I)))
      F(5,5)=(R(I)/G/IX(I))*(PHI(I)-.5*SIN(2.*PHI(I)))
```

```
      F(5,5)=F(5,5)+(R(I)/E/IY(I))*(PHI(I)+.5*SIN(2.*PHI(I)))
      F(6,6)=(R(I)/E/IZ(I))*2.*PHI(I)
      F(1,2)=(R(I)**3/E/IZ(I))*(2.*(SIN(PHI(I)))**2)
      F(1,2)=F(1,2)+(R(I)**3/E/IZ(I))*(-PHI(I)*SIN(2.*PHI(I)))
      F(2,1)=F(1,2)
      F(1,6)=(R(I)**2/E/IZ(I))*(2.*SIN(PHI(I))-2.*PHI(I)*COS(PHI(I)))
      F(6,1)=F(1,6)
      F(2,6)=(R(I)**2/E/IZ(I))*(2.*PHI(I)*SIN(PHI(I)))
      F(6,2)=F(2,6)
      F(3,4)=(R(I)**2/G/IX(I))*(PHI(I)*COS(PHI(I))-2.*SIN(PHI(I)))
      F(3,4)=F(3,4)+(R(I)**2/G/IX(I))*(.5*COS(PHI(I))*SIN(2*PHI(I)))
      F(3,4)=F(3,4)+(R(I)**2/E/IY(I))*(PHI(I)*COS(PHI(I)))
      F(3,4)=F(3,4)+(R(I)**2/E/IY(I))*(-.5*COS(PHI(I))*SIN(2.*PHI(I)))
      F(4,3)=F(3,4)
      F(3,5)=(-R(I)**2/G/IX(I))*(PHI(I)*SIN(PHI(I))-.5*SIN(PHI(I))
     **SIN(2.*PHI(I)))
      F(3,5)=F(3,5)+(-R(I)**2/E/IY(I))*(PHI(I)*SIN(PHI(I)))
      F(3,5)=F(3,5)+(-R(I)**2/E/IY(I))*(.5*SIN(PHI(I))*SIN(2.*PHI(I)))
      F(5,3)=F(3,5)
      DO 31 M=1,6
      DO 31 N=1,6
   31 ST(M,N)=F(M,N)
      CALL MINV(ST,6,DET,NN,MM)
      IF(DET)1,2,1
    2 WRITE(3,550)
  550 FORMAT('SINGULAR MATRIX')
      CALL EXIT
    1 RETURN
      END
      SUBROUTINE SOLVE(A,B,N)
C     MATRIX INVERSION BY JORDAN ELIMINATION
C     PERFORMING A COMPLETE PIVOT
      DIMENSION A(100,100),B(100),IR(100)
      DO 10 I=1,N
      B(I)=B(I)/100.
      DO 10 J=1,N
   10 A(I,J)=A(I,J)/100.
      PN=N
      SOS=0.
      DO 20 J=1,N
      IR(J)=0
      DO 20 I=1,N
   20 SOS=SOS+A(I,J)**2
      SO=SQRT(SOS)/PN
      TOL=1.E-10
      DO 110 L=1,N
      XLARG=0.
      DO 11 I=1,N
      DO 11 J=1,N
      IF(I-IR(I))66,11,66
   66 IF(J-IR(J))12,11,12
   12 IF(ABS(XLARG)-ABS(A(I,J)))13,11,11
   13 XLARG=A(I,J)
      II=I
```

```
      J1=J
   11 CONTINUE
      IP(J1)=J1
      IF(ABS(XLARG)-SQ*TOL)111,22,22
   22 I=I1
      J=J1
      IF(I-J)61,62,61
   61 DO 60 K=1,N
      A(J,K)=A(J,K)+A(I,K)
      A(I,K)=A(I,K)-A(J,K)
   60 A(J,K)=A(J,K)+A(I,K)
      BB=B(J)
      B(J)=B(I)
      B(I)=-BB
   62 DO 68 K=1,N
      IF(K-J)206,205,206
  206 B(K)=B(K)-B(J)*A(K,J)/XLARG
  205 DO 68 I=1,N
      IF(K-J)67,68,67
   67 IF(I-J)65,68,65
   65 A(K,I)=A(K,I)-A(J,I)*A(K,J)/XLARG
   68 CONTINUE
      DO 110 K=1,N
      IF(K-J)70,110,70
   70 A(K,J)=0.
  110 CONTINUE
  111 DTM=1.0
      DO 90 J=1,N
      IF(ABS(A(J,J))-SQ*TOL)91,90,90
   90 DTM=DTM*A(J,J)
      GO TO 92
   91 DTM=0.
      CALL EXIT
   92 WRITE(3,215)DTM
  215 FORMAT('1  DETERMINANT OF SYSTEM STIFFNESS MATRIX ='E17.7////)
      DO 24 J=1,N
      IF(ABS(A(J,J))-SQ*TOL)24,25,25
   25 B(J)=B(J)/A(J,J)
   24 CONTINUE
      RETURN
      END
```

Chapter 6

CONCLUSIONS AND FUTURE INVESTIGATIONS

6.1 Conclusions

A method of analysis for space frameworks composed of segmental circular members has been developed in this paper along with the computer program to perform all the computations required by the analysis. This analysis is fundamental to a number of noteworthy investigations that could be made in the future, which are discussed in (6.2).

An analysis of this nature would be highly impractical without the aid of the computer, however, with the computer, the analysis of structures such as those described in this paper can be analyzed in a relatively short time. Since analysis described in this paper reflects more closely the true behavior of the structure, a more efficient and economical design of the "curvilinear space grid" should be expected.

An experimental model was built and tested in order that the theoretical solution could be correlated to the observed and measured physical results.

Because of the difficulty encountered in measuring the true vertical displacement of the node points, the correlation between the computed vertical nodal displacement and the measured vertical nodal displacement is rather poor, however, the measured stress at a given point in a member correlates very closely with the stress in that member calculated from the member-end loads computed by the theoretical analysis. It can be concluded from these results that the theoretical analysis does compute the member end loads properly and if the nodal displacements had been measured more accurately the correlation between them would have been much closer.

The analysis of curved structures other than circular, could be made by approximating the curves with circular segments, which would increase the number of node points. This procedure, however, is suggested only in the case where the derivation of the actual flexibility is not feasible, since the addition of nodal points increases the number of equilibrium equations which must be solved and reduces the efficiency of analysis.

6.2 Topics for Further Investigation

a.) Temperature Affect - The affect of temperature on the structure can be included in the analysis with little difficulty. If the change in temperature is equal to "t", the change in length of a member from its unstressed length and consequently the change in internal stress can be computed if the coefficient of thermal expansion for the material is known. The internal forces resulting from this change in length can then be included in the member load-displacement equations in general as,

$$p_1 = K_{11}\delta_1 + K_{12}\delta_2 + p_{t1}$$
$$p_2 = K_{21}\delta_1 + K_{22}\delta_2 + p_{t2}, \qquad (6\text{-}1)$$

where p_{t1} and p_{t2} are the member end-loads resulting from the thermal expansion when the end-displacements are prevented.

The load-displacement equations for the structure can be assembled as was explained in Chapter 2 if equations (6-1) are first transformed into system coordinates as follows,

$$p'_1 = K'_{11}\delta'_1 + K'_{12}\delta'_2 + p'_{t1},$$

and $$p'_2 = K'_{21}\delta'_1 + K'_{22}\delta'_2 + p'_{t2}.$$

It is often desired to study the affects of temperature independent of any externally applied loads. This can be done in a straightforward manner from the following equation;

$$0 = K'\delta' + p'_t. \qquad (6\text{-}2)$$

The results of equation (6-2) can then be superimposed on the normal solution.

b.) Foundation Movements - The effects of foundation movements on the curvilinear space grid can easily be taken into account in the analysis by modifying the appropriate displacements in the load-displacement equations.

c.) Optimum Design - It would also be interesting to see an optimum design study made for the lattice dome. Since the method of analysis described in this paper neglects only the shear energy in the general energy derivation, more efficient use is being made of the structural framework and the engineer is able to preduct its behavior more accurately. It is therefore possible to study the effect of the grid spacing on the size of the material and arrive at a more efficient, economical design for the lattice dome.

d.) Dynamic Loading - The problem of dynamic loading on the curvilinear space grid can now be studied. The generation of the system stiffness matrix is as fundamental a step to the formulation of the equations of motion for the dynamic system as it was to the formulation of the equilibrium equations for the static system. The loading vector is a function of time and the mass of the structure can be treated as a series of lumped masses and rotational inertias concentrated at the node points. The problem can finally be reduced to the general eligenvalue problem.

e.) Computational Problems - A discussion of the computational problems involved in analysis of this type are discussed in reference (3). There is, however, additional work needed in developing methods by which very large structural systems can be handled effectively such as by the substructure method, where the larger systems are divided into smaller units which can be handled more efficiently.[3]

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VITA

The author, David L. Fenton, was born on March 20, 1941 in Murphysboro, Illinois. He received his primary and secondary education in the Dupo, Illinois Public School System graduating from high school in May, 1959.

He entered the University of Missouri at Rolla in September, 1959 and graduated in May, 1963 with a B.S. Degree in Civil Engineering. While employed as a stress analyst for McDonnell Aircraft Corporation he began graduate study at St. Louis University night school in September, 1963 and continued until February, 1964.

In September 1964 he entered the graduate school of the University of Missouri at Rolla. He received an M.S. Degree in Civil Engineering in January, 1966 and continued work towards the Doctor of Philosophy Degree in Civil Engineering. He has held a National Science Foundation Engineering Traineeship during the period from September, 1964 to August, 1967.

He is married to the former Janice A. Bieller and they have two children, David Scott and Susan Lynn.

APPENDIX A

COMPUTER SOLUTIONS FOR THE MATHEMATICAL MODEL

```
NUMBER OF NODES  9
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                                MEMBER COORDINANTS
MEMBER-I       X(I,1)           X(I,2)          Y(I,1)          Y(I,2)          Z(I,1)           Z(I,2)

     1      -36.000000       -20.784988       0.0             20.784988       0.0              20.784988
     2      -36.000000       -25.455994       0.0             25.455994       0.0               0.0
     3      -36.000000       -20.784988       0.0             20.784988       0.0             -20.784988
     4        0.0            -20.784988       0.0             20.784988      36.000000         20.784988
     5      -20.784988       -25.455994      20.784988        25.455994      20.784988          0.0
     6      -25.455994       -20.784988      25.455994        20.784988       0.0             -20.784988
     7        0.0            -20.784988       0.0             20.784988     -36.000000        -20.784988
     8      -20.784988         0.0           20.784988        25.455994      20.784988         25.455994
     9      -25.455994         0.0           25.455994        36.000000       0.0               0.0
    10      -20.784988         0.0           20.784988        25.455994     -20.784988        -25.455994
    11        0.0              0.0            0.0             25.455994      36.000000         25.455994
    12        0.0              0.0           25.455994        36.000000      25.455994          0.0
    13        0.0              0.0           36.000000        25.455994       0.0             -25.455994
    14        0.0              0.0            0.0             25.455994     -36.000000        -25.455994
    15        0.0             20.784988      25.455994        20.784988      25.455994         20.784988
    16        0.0             25.455994      36.000000        25.455994       0.0               0.0
    17        0.0             20.784988      25.455994        20.784988     -25.455994        -20.784988
    18        0.0             20.784988       0.0             20.784988      36.000000         20.784988
    19       20.784988        25.455994      20.784988        25.455994      20.784988          0.0
    20       25.455994        20.784988      25.455994        20.784988       0.0             -20.784988
    21        0.0             20.784988       0.0             20.784988     -36.000000        -20.784988
    22       36.000000        20.784988       0.0             20.784988       0.0              20.784988
    23       36.000000        25.455994       0.0             25.455994       0.0               0.0
    24       36.000000        20.784988       0.0             20.784988       0.0             -20.784988


                                                       MEMBER PROPERTIES
MEMBER-I        IX              IY              IZ              AREA           RADIUS          PHI             ALPHA

     1       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670        1.297000
     2       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
     3       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670       -1.297000
     4       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670       -1.297000
     5       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742       -0.831423
     6       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742       -0.831423
     7       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670        1.297000
     8       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742        0.831423
     9       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    10       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742       -0.831423
    11       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    12       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    13       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    14       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    15       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742        0.831423
    16       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    17       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742       -0.831423
    18       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670        1.297000
    19       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742        0.831423
    20       0.000550        0.000326        0.000326        0.062500       36.000000       0.307742        0.831423
    21       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670       -1.297000
    22       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670       -1.297000
    23       0.000550        0.000326        0.000326        0.062500       36.000000       0.392700        0.0
    24       0.000550        0.000326        0.000326        0.062500       36.000000       0.477670        1.297000


MEMB   NODE(I,1)   NODE(I,2)

   1      0           1
   2      0           2
   3      0           3
   4      0           1
   5      1           2
   6      2           3
   7      0           3
   8      1           4
   9      2           5
  10      3           6
  11      0           4
  12      4           5
  13      5           6
  14      0           6
  15      4           7
  16      5           8
  17      6           9
  18      0           7
  19      7           8
  20      8           9
  21      0           9
  22      0           7
  23      0           8
  24      0           9


NODE   NBPN               LINK
                  1      2      3      4      5      6

  1     4        -1     -4      5      8
  2     4        -2     -5      6      9
  3     4        -3     -6     -7     10
  4     4        -8    -11     12     15
  5     4        -9    -12     13     16
  6     4       -10    -13    -14     17
  7     4       -15    -18     19    -22
  8     4       -16    -19     20    -23
  9     4       -17    -20    -21    -24
```

```
                                                  APPLIED NODAL LOADS
 NODE      PX              PY                 PZ                 MX                 MY                 MZ
   1       0.0             0.0                0.0                0.0                0.0                0.0
   2       0.0             0.0                0.0                0.0                0.0                0.0
   3       0.0           -40.000000           0.0                0.0                0.0                0.0
   4       0.0             0.0                0.0                0.0                0.0                0.0
   5       0.0             0.0                0.0                0.0                0.0                0.0
   6       0.0             0.0                0.0                0.0                0.0                0.0
   7       0.0             0.0                0.0                0.0                0.0                0.0
   8       0.0             0.0                0.0                0.0                0.0                0.0
   9       0.0             0.0                0.0                0.0                0.0                0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.1562867E 61


                                           NODAL DISPLACEMENTS
 NODE      DELTA-X          DELTA-Y          DELTA-Z          THETA-X          THETA-Y          THETA-Z
   1      0.055598         0.016225        -0.058159        -0.000824        -0.001359        -0.001427
   2      0.076831        -0.051099        -0.072508        -0.009165        -0.001020        -0.005183
   3     -0.078971        -0.292373        -0.078972         0.019052         0.000000        -0.019052
   4      0.039066         0.015078         0.026792         0.002409        -0.002674        -0.000036
   5      0.049578         0.043357         0.049578        -0.002420         0.000000         0.002420
   6     -0.072508        -0.051099         0.076829         0.005183         0.001020         0.009165
   7      0.033001        -0.000746         0.033000         0.002105        -0.000000        -0.002105
   8      0.026793         0.015078         0.039066         0.000036         0.002674        -0.002409
   9     -0.058159         0.016225         0.055597         0.001427         0.001359         0.000824


                                     MEMBER END FORCES AND MOMENTS
 MEMB.  END                  PPX             PPY             PPZ             MPX             MPY             MPZ
                  PX          PY              PZ              MX              MY              MZ

         1'                -0.100601        0.018927        0.277201        3.033314       -2.267633        1.572212
   1     1      0.139715    0.210358        0.153456        0.957667       -2.490432        3.113770
         2'                 0.100601       -0.018927       -0.277201        2.334890       -4.040339        3.806744
         2     -0.139715   -0.210358       -0.153456       -0.957659       -2.598740        3.848771

         1'                 1.543047        3.993134       -0.145719        0.935995        0.376390       -4.593622
   2     1      4.279674    0.102487       -0.145719        0.705923       -0.720713       -4.593680
         2'                -1.543047       -3.993134        0.145719       -4.645429        1.160076        7.417776
         2     -4.279674   -0.102487        0.145719       -0.705924        4.735763        7.417776

         1'                12.369619       16.554779      -15.044730       21.613632      -61.914749      -44.032039
   3     1     25.529633   -0.862700        0.951612       -0.728577      -13.375275      -78.358932
         2'               -12.369619      -16.554779       15.044730        9.772490       33.718430       32.711914
         2    -25.529633    0.862700       -0.951612        0.728546      -18.121643       49.805054

         1'                 0.720789       -0.836330        0.702132        3.565194        4.674881        2.133312
   4     1     -1.300581    0.128121       -0.063611       -0.286561        1.392272        6.094996
         2'                -0.720789        0.836330       -0.702132       -1.696170       -1.047219        0.262107
         2      1.300581   -0.128121        0.063611        0.286553        0.723141       -1.954406

         1'                 0.508847       -0.654749        1.445124        1.368699       -0.592475        1.443096
   5     1     -1.626452   -0.344078       -0.110757       -1.800800       -0.894636        0.529341
         2'                -0.508847        0.654735       -1.445142       -8.229461       -3.234150       -0.767196
         2      1.626466    0.344063        0.110746        1.800805        3.313615       -8.034474

         1'                 0.410646        3.445484        2.264769       21.767334       -9.237518        8.682226
   6     1     -2.808366    1.298932        2.755906       -1.633978      -23.712646        8.340817
         2'                -0.410692       -3.445453       -2.264860       39.268677       -9.875831        3.322716
         2      2.808437   -1.298853       -2.755914        1.633979      -36.391953       19.988037

         1'               -15.044777       16.554810       12.369680       44.933243       61.914993      -21.413632
   7     1     25.529709   -0.862727       -0.951596        0.728548       13.375160      -78.359314
         2'                15.044777      -16.554810      -12.369680      -39.711700      -33.718338       -0.772327
         2    -25.529709    0.862727        0.951596       -0.728553       18.121429       49.804871

         1'                 0.111362       -0.162628       -0.465691       -2.007455        5.681580       -2.517738
   8     1     -0.028438   -0.461748       -0.204200       -1.235548        2.612046       -5.856612
         2'                -0.111346        0.162627        0.465705        0.591839        4.517731       -1.282438
         2      0.028456    0.461753        0.204210        1.235541        1.841456       -4.213515

         1'                 1.641373       -0.106963       -0.965406       -8.893685       11.311266      -15.333076
   9     1      1.475502   -0.726937       -0.965406       -3.888159       13.853685      -15.333076
         2'                -1.641383        0.106953        0.965406       -1.285555       13.264101       -4.696280
         2     -1.475515    0.726931        0.965406        3.888164       12.746421       -4.696280
```

10	1'		-2.264221	-3.445461	-0.410675	-9.329819	9.875580	-39.269562
	1	-2.807835	-1.299064	-2.755915	1.634019	36.392441	-19.989731	
	2'		2.264282	3.445455	0.410681	-8.682240	9.237925	-21.766739
	2	2.807890	1.299037	2.755914	-1.634032	23.712524	-8.340111	
11	1'		-0.096559	0.341775	-0.126125	-1.300026	0.970115	1.424407
	1	0.364025	0.014264	-0.096559	0.351185	1.687223	-1.300026	
	2'		0.096559	-0.341775	0.126125	1.693009	0.048007	1.033606
	2	-0.364025	-0.014264	0.096559	-0.351184	0.973301	1.693009	
12	1'		0.072367	0.107008	-0.748080	-2.245688	-1.805844	-1.255922
	1	0.732087	-0.187410	0.072367	0.469269	-2.148999	-2.245688	
	2'		-0.072367	-0.107004	0.748075	-2.918265	-0.036328	0.492885
	2	-0.732082	0.187412	-0.072367	-0.469270	0.155053	-2.918265	
13	1'		0.965409	0.106982	-1.641309	4.696555	-13.264152	1.285570
	1	1.475435	0.726930	0.965409	3.888168	-12.746473	4.696555	
	2'		-0.965409	-0.106974	1.641296	15.332772	-11.311292	8.893700
	2	-1.475428	-0.726917	-0.965409	-3.888163	-13.853715	15.332772	
14	1'		-0.145716	3.993148	1.543066	4.593898	-0.376377	-0.936025
	1	4.279694	0.102473	0.145716	-0.705923	0.720746	-4.593898	
	2'		0.145716	-3.993148	-1.543066	-7.417620	-1.160054	4.645371
	2	-4.279694	-0.102473	-0.145716	0.705922	-4.735703	7.417620	
15	1'		-0.057155	0.072006	0.156277	-0.039003	-2.759240	1.604104
	1	-0.103362	0.137803	0.056574	0.210228	-0.722257	3.101973	
	2'		0.057142	-0.071996	-0.156268	-0.354634	-0.221834	-0.374632
	2	0.103345	-0.137796	-0.056575	-0.210229	-0.511619	-0.096824	
16	1'		0.748101	-0.107026	-0.072370	-0.492891	0.036358	2.918026
	1	0.732114	0.187401	-0.072370	-0.469278	-0.155023	2.918026	
	2'		-0.748091	0.107017	0.072370	1.255952	1.805894	2.245742
	2	-0.732101	-0.187406	0.072370	0.469278	2.149056	2.245742	
17	1'		-1.445042	0.654774	-0.508866	0.757240	3.234162	8.228302
	1	-1.626384	0.344132	0.110762	1.800812	-3.310493	8.034377	
	2'		1.445043	-0.654786	0.508879	-1.448779	0.592723	-1.368682
	2	1.626390	-0.344149	-0.110762	-1.800806	0.894803	-0.529149	
18	1'		-0.122284	-0.072073	0.023379	-0.613709	0.482272	1.022332
	1	-0.132797	-0.047159	-0.028905	-0.551570	0.740519	-0.893144	
	2'		0.122284	0.072073	-0.023379	0.003047	0.892317	0.023271
	2	0.132797	0.047158	0.028905	0.551564	0.216182	-0.667700	
19	1'		-0.156329	-0.072066	0.057467	0.374863	0.221547	0.354631
	1	-0.103684	-0.137783	-0.056569	-0.210238	0.511588	0.097192	
	2'		0.156328	0.072073	-0.057465	-1.604377	2.759485	0.038091
	2	0.103683	0.137789	0.056563	0.210244	0.722222	-3.102336	
20	1'		0.465777	0.162693	-0.111044	1.382535	-4.512055	-0.591705
	1	-0.028774	0.461753	0.204215	1.235541	-1.941594	4.213935	
	2'		-0.465796	-0.162711	0.111072	2.517452	-5.691467	[illegible]
	2	0.028755	-0.461797	-0.204214	-1.235534	-2.612174	5.856331	
21	1'		0.277227	0.018945	-0.100587	-1.572144	2.267593	-3.033356
	1	0.139749	0.210362	-0.153461	-0.957667	2.400488	3.113719	
	2'		-0.277227	-0.019945	0.100587	-0.896797	4.041059	-2.334972
	2	-0.139749	-0.210360	0.153461	0.957661	2.598322	3.848007	
22	1'		0.023353	-0.072046	-0.122257	-1.020348	-0.492405	0.613944
	1	-0.132751	-0.047163	0.028904	0.551578	-0.740503	-0.893333	
	2'		-0.023353	0.072046	0.122257	-0.023246	-0.892312	-0.003048
	2	0.132751	0.047163	-0.028904	-0.551572	-0.216163	-0.667693	
23	1'		-0.125134	0.341783	-0.096559	-1.424390	-0.970122	1.300112
	1	0.364035	0.014260	0.096559	-0.351197	-1.687211	-1.300112	
	2'		0.125134	-0.341783	0.096559	-1.033606	-0.047994	-1.692991
	2	-0.364035	-0.014260	-0.096559	0.351196	-0.973296	1.692991	
24	1'		0.702182	-0.936303	0.720849	-2.130356	-4.675122	-3.665300
	1	-1.300681	0.129125	0.063612	0.286555	-1.382277	6.095320	
	2'		-0.702192	0.936303	-0.720849	-0.262191	1.049661	1.606280
	2	1.300681	-0.129125	-0.063612	-0.286543	-0.773153	-1.854579	

```
                                              APPLIED NODAL LOADS
NODE        PX            PY              PZ            MX            MY            MZ

  1        0.0           0.0             0.0           0.0           0.0           0.0
  2        0.0         -20.000000        0.0           0.0           0.0           0.0
  3        0.0           0.0             0.0           0.0           0.0           0.0
  4        0.0         -20.000000        0.0           0.0           0.0           0.0
  5        0.0           0.0             0.0           0.0           0.0           0.0
  6        0.0         -20.000000        0.0           0.0           0.0           0.0
  7        0.0           0.0             0.0           0.0           0.0           0.0
  8        0.0         -20.000000        0.0           0.0           0.0           0.0
  9        0.0           0.0             0.0           0.0           0.0           0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =    0.1562867E 61


                                    NODAL DISPLACEMENTS

NODE      DELTA-X       DELTA-Y       DELTA-Z       THETA-X       THETA-Y       THETA-Z

  1     -0.041308     -0.036021      0.041308     -0.004453     -0.000000     -0.004453
  2      0.079362     -0.089245     -0.000000     -0.000000      0.000000     -0.007350
  3     -0.041309     -0.036021     -0.041309      0.004453      0.000000     -0.004453
  4      0.000000     -0.089245     -0.079361     -0.007350     -0.000000     -0.000000
  5     -0.000000      0.116130      0.000001     -0.000000     -0.000000     -0.000000
  6     -0.000000     -0.089245      0.079361      0.007350     -0.000000     -0.000000
  7      0.041309     -0.036021      0.041309     -0.004453     -0.000000      0.004453
  8     -0.079361     -0.089245      0.000001      0.000000      0.000000      0.007350
  9      0.041308     -0.036021     -0.041307      0.004453      0.000000      0.004453


                                 MEMBER END FORCES AND MOMENTS
                          PPX           PPY           PPZ           MPX           MPY           MPZ
MO.  END
                 PX            PY            PZ            MX            MY            MZ

      1'                  0.820569      0.850127      0.523771     -3.071856      6.346787     -3.629516
      1      1.230669    -0.212025     -0.186927      0.294003      2.538904     -7.506739
 1    2'                 -0.820569     -0.850127     -0.523771     -3.711434      2.739515     -0.492309
      2     -1.230669     0.212026      0.186927     -0.294015      3.649120     -2.850664

      1'                  7.543934     18.299774      0.000001      0.000018     -0.000005    -33.066376
      1     10.703671     0.073324      0.000001      0.000003     -0.000018    -33.066376
 2    2'                 -7.543934    -18.299774     -0.000001      0.000015     -0.000009     33.983917
      2    -10.703671    -0.073394     -0.000001     -0.000003     -0.000017     33.983917

      1'                  0.820561      0.850120     -0.523761      3.071875     -6.346756     -3.628477
      1      1.230666    -0.212026      0.186929     -0.294800     -2.538932     -7.506692
 3    2'                 -0.820561     -0.850120      0.523761      3.711457     -2.739534     -0.492303
      2     -1.230666     0.212026     -0.186929      0.294911     -3.648147     -2.850677

      1'                 -0.523744      0.850107     -0.820551     -3.622444     -6.346719     -3.071858
      1      1.233327    -0.212026      0.186923     -0.294005     -2.538923     -7.506640
 4    2'                  0.523744     -0.850107      0.820551     -3.492376     -2.739610     -3.711469
      2     -1.233327     0.212226     -0.186923      0.294290     -3.649146     -2.850790

      1'                 -1.523400      0.250112     -1.920465      3.077123      9.650946      3.226479
      1      0.245[illegible]     1.563300     -0.452944     -1.217193      6.655591      7.663324
 5    2'                  1.523425     -0.250100      1.920475      4.183625     13.599386     -0.381424
      2     -0.245[illegible]    -1.563306      0.452950      1.217136      3.333000     15.417293

      1'                  1.523256     -0.250073     -1.220224     -2.188369    -13.599737     -3.381433
      1      0.245101    -1.563306      0.452947      1.217196     -3.333935    -15.417075
 6    2'                 -1.523350      0.250073      1.220192     -0.077333     -0.650331      3.226439
      2     -0.245101     1.563300     -0.452941     -1.217211     -6.655498     -7.663388

      1'                 -0.523700      0.850146      0.820694      3.623607      6.346773     -3.071827
      1      1.230667    -0.212027     -0.186924      0.294[illegible]     2.538931     -7.516858
 7    2'                  0.523700     -0.850146     -0.820694      3.492270      2.739516     -3.711447
      2     -1.230667     0.212027      0.186924     -0.294003      3.648145     -2.850646

      1'                  1.920145      0.850042      1.523332      3.226430     -0.651140      3.377333
      1      0.24[illegible]     1.053307      0.452278      1.217194     -6.655613      7.663634
 8    2'                 -1.920145     -0.850051     -1.52334      -3.381431    -13.599993      0.108360
      2     -0.24[illegible]    -1.053322     -0.452236     -1.217197     -3.333382     15.416333

      1'                  4.407143      0.000303     -0.000006     -0.000021      0.000063    -33.821336
      1      4.104[illegible]    -1.733900     -0.000005      0.000004      0.000066    -33.821336
 9    2'                 -4.407164     -0.000053      0.000006     -0.000035      0.000073    -13.594597
      2     -4.104[illegible]     1.733376      0.000005     -0.000034      0.000081    -13.594597
```

	1'		1.820171	0.850050	-1.523337	-3.226437	9.651086	0.977324
10	1	2.242989	1.058309	-0.452937	-1.217192	6.655619	7.663540	
	2'		-1.820161	-0.850057	1.523345	0.081434	13.509062	8.188224
	2	-2.242982	-1.058321	0.452938	1.217192	3.222987	15.416857	
	1'		-0.000001	18.299805	-7.543853	-33.066483	0.000005	0.000019
11	1	19.793716	0.033278	-0.000001	-0.000003	0.000019	-33.066483	
	2'		0.000001	-18.299805	7.543853	33.983978	0.000010	0.000015
	2	-19.793716	-0.033278	0.000001	0.000003	0.000018	33.983978	
	1'		0.000005	0.000087	-4.497155	-33.821411	-0.000058	-0.000022
12	1	4.154974	-1.720876	0.000005	-0.000002	-0.000062	-33.821411	
	2'		-0.000005	-0.000099	4.497165	-13.594635	-0.000075	-0.000033
	2	-4.154889	1.720868	-0.000005	0.000002	-0.000082	-13.594635	
	1'		0.000000	-0.000057	-4.497087	13.594836	0.000013	-0.000015
13	1	4.154800	1.720877	0.000000	0.000008	0.000018	13.594836	
	2'		-0.000000	0.000057	4.497071	33.821167	-0.000020	0.000017
	2	-4.154786	-1.720871	-0.000000	-0.000008	-0.000025	33.821167	
	1'		-0.000001	18.299835	7.543866	33.066589	0.000010	0.000013
14	1	19.793747	0.033279	0.000001	0.000014	-0.000008	-33.066589	
	2'		0.000001	-18.299835	-7.543866	-33.983948	-0.000018	0.000007
	2	-19.793747	-0.033278	-0.000001	-0.000014	-0.000013	33.983948	
	1'		1.820295	-0.850069	-1.523369	-0.081422	13.509340	-8.188356
15	1	2.243118	-1.058305	-0.452946	-1.217212	3.223083	-15.417150	
	2'		-1.820235	0.850069	1.523369	3.226445	9.651039	-0.977305
	2	-2.243061	1.058323	0.452946	1.217205	6.655602	-7.663494	
	1'		4.497111	-0.000074	-0.000001	-0.000022	0.000005	13.594778
16	1	4.154829	1.720871	-0.000001	-0.000022	-0.000004	13.594778	
	2'		-4.497096	0.000074	0.000001	0.000033	0.000023	33.821213
	2	-4.154815	-1.720865	0.000001	0.000022	0.000034	33.821213	
	1'		1.820137	-0.850057	1.523334	0.081452	-13.508987	-8.188297
17	1	2.243014	-1.058303	0.452930	1.217177	-3.222883	-15.416854	
	2'		-1.820152	0.850057	-1.523334	-3.226361	-9.650845	-0.977324
	2	-2.242971	1.058316	-0.452930	-1.217171	-6.655437	-7.663367	
	1'		0.523780	0.850141	-0.820579	-3.628567	6.346868	3.071899
18	1	1.230006	-0.312027	-0.186930	0.294002	2.538939	-7.506836	
	2'		-0.523780	-0.850141	0.820579	-0.492775	2.739522	3.711464
	2	-1.230006	0.312027	0.186930	-0.294005	3.649162	-2.850651	
	1'		1.523336	0.850038	-1.820152	0.977374	-9.651072	-3.226429
19	1	2.242947	1.058305	0.452946	1.217198	-6.655567	7.663561	
	2'		-1.523335	-0.850027	1.820162	8.188234	-13.509074	0.081432
	2	-2.242972	-1.058294	-0.452952	-1.217189	-3.222982	15.416866	
	1'		-1.523356	-0.850076	-1.820357	-8.189372	13.509235	0.081428
20	1	2.243176	-1.058288	-0.452940	-1.217191	3.223085	-15.417177	
	2'		1.523366	0.850076	1.820266	-0.977207	9.650799	-3.226395
	2	[illegible]	1.058315	0.452939	1.217179	6.655438	-7.663347	
	1'		0.523730	0.850098	0.820535	3.628355	-6.346622	3.071833
21	1	[illegible]	-0.312021	0.186929	-0.294010	-2.538917	-7.506506	
	2'		-0.523729	-0.850098	-0.820535	0.492375	-2.739603	3.711458
	2	[illegible]	0.312021	-0.186923	0.294914	-3.649143	-2.850780	
	1'		-0.820549	0.850098	0.523738	-3.071880	-6.346738	3.628460
22	1	[illegible]	-0.312028	0.186929	-0.294926	-2.538940	-7.506668	
	2'		0.820549	-0.850098	-0.523739	-3.711482	-2.739673	0.492411
	2	-1.230029	0.312028	-0.186929	0.294903	-3.649153	-2.850854	
	1'		-7.543851	18.299789	-0.000002	-0.000035	-0.000011	33.066513
23	1	19.793761	0.033274	0.000002	0.000004	-0.000037	-33.066513	
	2'		7.543851	-18.299789	0.000002	-0.000017	-0.000011	-33.983887
	2	-19.793761	-0.033274	-0.000002	-0.000004	-0.000020	33.983887	
	1'		-0.820593	0.850168	-0.523813	3.071957	6.346917	3.628633
24	1	[illegible]	-0.312024	-0.186926	0.294910	2.538886	-7.506911	
	2'		0.820593	-0.850168	0.523813	3.711394	2.739387	0.492210
	2	[illegible]	0.312024	0.186926	-0.294916	3.648098	-2.850498	

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NUMBER OF NODES  9
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  6

                                                MEMBER COORDINANTS
MEMBER-I      X(I,1)         X(I,2)         Y(I,1)          Y(I,2)         Z(I,1)         Z(I,2)

     1     -33.369995     -18.369995     0.0              9.740000     13.500000      18.369995
     2     -36.000000     -20.129990     0.0             13.250000      0.0             0.0
     3     -33.369995     -18.369995     0.0              9.740000    -13.500000     -18.369995
     4     -13.500000     -18.369995     0.0              9.740000     33.369995      18.369995
     5     -18.369995     -20.129990     9.740000        13.250000     18.369995       0.0
     6     -20.129990     -18.369995    13.250000         9.740000      0.0           -18.369995
     7     -13.500000     -18.369995     0.0              9.740000    -33.369995     -18.369995
     8     -18.369995      0.0           9.740000        13.250000     18.369995      20.129990
     9     -20.129990      0.0          13.250000        18.000000      0.0             0.0
    10     -18.369995      0.0           9.740000        13.250000    -18.369995     -20.129990
    11       0.0           0.0           0.0             13.250000     36.000000      20.129990
    12       0.0           0.0          13.250000        18.000000     20.129990       0.0
    13       0.0           0.0          18.000000        13.250000      0.0           -20.129990
    14       0.0           0.0           0.0             13.250000    -36.000000     -20.129990
    15       0.0          18.369995     13.250000         9.740000     20.129990      18.369995
    16       0.0          20.129990     18.000000        13.250000      0.0             0.0
    17       0.0          18.369995     13.250000         9.740000    -20.129990     -18.369995
    18      13.500000     18.369995      0.0              9.740000     33.369995      18.369995
    19      18.369995     20.129990      9.740000        13.250000     18.369995       0.0
    20      20.129990     18.369995     13.250000         9.740000      0.0           -18.369995
    21      13.500000     18.369995      0.0              9.740000    -33.369995     -18.369995
    22      33.369995     18.369995      0.0              9.740000     13.500000      18.369995
    23      36.000000     20.129990      0.0             13.250000      0.0             0.0
    24      33.369995     18.369995      0.0              9.740000    -13.500000     -18.369995
```

```
                                                     MEMBER PROPERTIES
MEMBER-I        IX            IY            IZ            AREA          RADIUS          PHI          ALPHA

     1       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430      0.761490
     2       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
     3       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430     -0.761490
     4       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430     -0.761490
     5       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200     -0.505970
     6       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200     -0.505970
     7       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430      0.761490
     8       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200      0.505970
     9       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    10       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200     -0.505970
    11       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    12       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    13       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    14       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    15       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200      0.505970
    16       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    17       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200     -0.505970
    18       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430      0.761490
    19       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200      0.505970
    20       0.000550      0.000326      0.000326      0.062500      45.000000      0.210200      0.505970
    21       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430     -0.761490
    22       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430     -0.761490
    23       0.000550      0.000326      0.000326      0.062500      45.000000      0.231870      0.0
    24       0.000550      0.000326      0.000326      0.062500      45.000000      0.207430      0.761490
```

```
MEMB   NODE(I,1)   NODE(I,2)

  1        0           1
  2        0           2
  3        0           3
  4        0           1
  5        1           2
  6        2           3
  7        0           3
  8        1           4
  9        2           5
 10        3           6
 11        0           4
 12        4           5
 13        5           6
 14        0           6
 15        4           7
 16        5           8
 17        6           9
 18        0           7
 19        7           8
 20        8           9
 21        0           9
 22        0           7
 23        0           8
 24        0           9
```

```
NODE   NMBR                  LINK
                  1       2       3       4       5       6

  1      4       -1      -4       5       8
  2      4       -2      -5       6       9
  3      4       -3      -6      -7      10
  4      4       -8     -11      12      15
  5      4       -9     -12      13      16
  6      4      -10     -13     -14      17
  7      4      -15     -18      19     -22
  8      4      -16     -19      20     -23
  9      4      -17     -20     -21     -24
```

```
                                          APPLIED NODAL LOADS
  NODE        PX            PY            PZ            MX            MY            MZ

    1        0.0           0.0           0.0           0.0           0.0           0.0
    2        0.0           0.0           0.0           0.0           0.0           0.0
    3        0.0      -40.000000         0.0           0.0           0.0           0.0
    4        0.0           0.0           0.0           0.0           0.0           0.0
    5        0.0           0.0           0.0           0.0           0.0           0.0
    6        0.0           0.0           0.0           0.0           0.0           0.0
    7        0.0           0.0           0.0           0.0           0.0           0.0
    8        0.0           0.0           0.0           0.0           0.0           0.0
    9        0.0           0.0           0.0           0.0           0.0           0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =    0.0


                                  NODAL DISPLACEMENTS
  NODE     DELTA-X       DELTA-Y       DELTA-Z       THETA-X       THETA-Y       THETA-Z

    1    -0.063337      0.068161      0.063201      0.004961      0.001831      0.001690
    2    -0.038445      0.047327      0.069505     -0.008413     -0.005350      0.000042
    3     0.111500     -0.132741      0.111496      0.004755      0.000003     -0.004749
    4    -0.041259     -0.025325     -0.020060     -0.001324      0.003648     -0.004492
    5    -0.022588     -0.023661     -0.022578      0.001791      0.000000     -0.001792
    6     0.069506      0.047311     -0.038432     -0.000042      0.005347      0.008409
    7    -0.041040     -0.045679     -0.041041     -0.003167     -0.000000      0.003167
    8    -0.020072     -0.025340     -0.041266      0.004494     -0.003649      0.001324
    9     0.063213      0.068175     -0.063347     -0.001693     -0.001830     -0.004963


                                 MEMBER END FORCES AND MOMENTS
                             PPX           PPY           PPZ           MPX           MPY           MPZ
MEMB.  END       PX          PY            PZ            MX            MY            MZ

        1'               -1.766142     -3.023878     -1.949082     -3.710666      8.506456    -12.909464
        1   -3.530247    -1.897206      0.000872     -1.924691      0.415458    -15.776762
  1     2'                1.766142      3.023878      1.949082     -0.547315     12.128990    -15.246680
        2    3.530247     1.897206     -0.000872      1.924678     -0.431345    -19.390198

        1'               -1.580640     -2.349012     -0.933435     -4.144855      8.326646     -6.003715
        1   -2.718819    -0.790136     -0.933435      2.154827      9.048185     -6.003715
  2     2'                1.580640      2.349012      0.933435     -8.223157      6.486975    -10.331823
        2    2.718819     0.790136      0.933435     -2.154828     10.249780    -10.331823

        1'               26.812057     20.379120    -10.894502     -2.484541      3.562072      6.394213
        1   35.268066     3.008282     -0.009400     -1.818328      0.176939      7.511064
  3     2'              -26.812057    -20.379120     10.894502     -4.382036     29.289563     33.143326
        2  -35.268066    -3.008282      0.009400      1.818317     -0.002121     48.251022

        1'               -2.417501      5.756901    -10.452099    -16.529233    -12.924923     -3.964692
        1   12.118405    -1.160170      0.176468      0.757106     -1.336848    -21.291519
  4     2'                2.417501     -5.756901     10.452099      1.079031     -1.714655     -1.525210
        2  -12.118405     1.160170     -0.176468     -0.757094     -1.934405     -0.213994

        1'               -1.153997      2.187143    -12.903726     -3.284698     -1.134145    [illegible]
        1   13.135491    -0.277646     -0.060197     -0.596377      0.704665     -3.423712
  5     2'                1.153996     -2.187129     12.903726     -1.830854     -0.377777     -2.406304
        2  -13.135480     0.277658      0.060203      0.586377      0.426422     -1.723174

        1'               -0.548379     -0.378389    -15.367086      7.296263     11.997755      0.025061
        1   15.046972     3.141318     -0.559045     -2.212254      5.532582     12.266349
  6     2'                0.548379      0.378434     15.367085     38.993133     26.112519     -3.515626
        2  -15.046970    -3.141278      0.559067      2.212199      4.268697     46.745102

        1'              -10.893972     20.377975     26.812119     -6.386791     -3.560705      2.483037
        1   35.267380     3.007253      0.009656      1.816352     -0.178679      7.503610
  7     2'               10.893972    -20.377975    -26.812119    -38.128738    -29.272569      4.383045
        2  -35.267380    -3.007253     -0.009656     -1.816404     -0.001996     48.234875

        1'               -3.028272      0.545901      0.502679      2.762594     -9.270930     15.373739
        1   -2.812281     1.336432      0.161755      2.379883     -1.514104     17.692062
  8     2'                3.028272     -0.545899     -0.502681     -1.958875     -5.294064      5.584562
        2    2.812291    -1.336431     -0.161758     -2.379882     -1.524922      7.413022

        1'               -2.186592      0.216810      1.527975      2.056959    -17.117844      2.993564
        1   -2.078355     0.713186      1.527975     -1.929293    -17.132706      9.902569
  9     2'                2.186577     -0.216825     -1.527975      5.200912    -13.640267      4.949415
        2    2.078338    -0.713197     -1.527975      1.929285    -14.470125      4.949415
```

10	1'		15.367833	0.377543	0.548442	3.517219	-26.119980	-39.010284
	1	15.047538	-3.142228	0.558693	2.213904	-4.967407	-46.763779	
	2'		-15.367832	-0.377547	-0.548445	-0.927705	-11.001536	-7.993570
	2	-15.047539	3.142227	-0.558698	-2.213938	-5.527942	-12.261002	
11	1'		0.463893	-0.322708	0.765434	3.767108	-4.515789	-2.013635
	1	-0.794391	0.242846	0.463893	-1.348439	-4.756975	3.767108	
	2'		-0.463893	0.322708	-0.765434	1.253481	-2.846193	-4.132946
	2	0.794391	-0.242846	-0.463893	1.348442	-4.833611	1.253481	
12	1'		-0.474916	-0.216680	1.133637	-0.023618	6.242937	0.858182
	1	-1.153099	0.049462	-0.474916	0.598504	6.273164	-0.023618	
	2'		0.474916	0.216686	-1.133657	1.046471	3.317116	1.397664
	2	1.153119	-0.049460	0.474915	-0.598500	3.549441	1.046471	
13	1'		-1.527936	-0.216686	2.186391	-4.847777	13.642657	-5.200234
	1	-2.078188	-0.713020	-1.527936	1.928078	14.472296	-4.847777	
	2'		1.527936	0.216702	-2.186400	-9.999059	17.114685	-2.957459
	2	2.078193	0.713038	1.527936	-1.928082	17.129745	-9.899059	
14	1'		-0.933450	-2.348261	-1.579997	6.002417	-8.325890	4.146371
	1	-2.717843	-0.789971	0.933450	-2.153173	-9.048570	-6.002417	
	2'		0.933450	2.348261	1.579997	10.329549	-6.487979	0.221840
	2	2.717843	0.789971	-0.933450	2.153173	-10.249706	-10.329549	
15	1'		-2.089021	0.439911	0.134381	0.729396	1.888395	-2.319015
	1	-2.137666	0.004320	-0.077235	0.576775	0.696611	-2.935320	
	2'		2.089005	-0.439881	-0.134379	-0.426853	-0.680193	3.367391
	2	2.137644	-0.004297	0.077222	-0.576782	0.753707	3.015240	
16	1'		-1.133809	0.216801	0.475173	-1.399177	-3.319502	1.344238
	1	-1.153294	-0.049384	0.475173	-0.599424	-3.552112	-1.046209	
	2'		1.133830	-0.216816	-0.475173	-0.957899	-6.245716	[illegible]
	2	1.153317	0.049374	-0.475173	0.599428	-6.275801	0.925996	
17	1'		12.903961	-2.187189	1.154101	0.497491	0.375699	1.830667
	1	13.135749	0.277606	0.060268	0.587741	-0.427049	1.791991	
	2'		-12.903931	2.187131	-1.154099	-0.529374	1.134613	3.294119
	2	-13.135699	-0.277652	-0.060293	-0.587747	-0.704249	3.423408	
18	1'		0.033549	-0.439606	1.920324	8.499897	-5.875457	[illegible]
	1	-1.776176	0.851193	0.051920	1.249863	-0.540779	13.556661	
	2'		-0.033549	0.439606	-1.920324	2.629765	-3.979914	[illegible]
	2	1.776176	-0.851193	-0.051920	-1.249879	-0.421924	5.219036	
19	1'		-0.134279	-0.439780	2.088927	-3.059959	0.603326	[illegible]
	1	-2.137442	-0.004200	0.077264	-0.576697	-0.754455	-3.016647	
	2'		0.134278	0.439780	-2.088927	2.311421	-1.889613	[illegible]
	2	2.137442	0.004200	-0.077265	0.576693	-0.626914	2.937999	
20	1'		-0.592763	-0.545787	3.028896	-5.587534	6.288414	[illegible]
	1	-2.812805	-1.336591	-0.161879	-2.380536	1.526445	-7.419175	
	2'		0.592763	0.545757	-3.028871	-15.063664	1.777137	[illegible]
	2	2.812804	1.336472	0.161893	2.380535	1.513698	-17.687166	
21	1'		-1.949217	-3.924102	-1.766679	12.909535	-9.590516	[illegible]
	1	-3.530838	-1.897113	-0.999835	1.925294	-0.415930	[illegible]	
	2'		1.949217	3.924102	1.766679	15.244516	-12.120391	[illegible]
	2	3.530839	1.897113	0.999835	-1.925192	0.439414	[illegible]	
22	1'		1.912764	-0.439358	0.033759	[illegible]	[illegible]	[illegible]
	1	-1.775537	0.851137	-0.052010	-1.249949	[illegible]	[illegible]	
	2'		-1.912764	0.439358	-0.033759	-0.135253	3.999334	[illegible]
	2	1.775537	-0.851137	0.052010	1.249946	0.429912	[illegible]	
23	1'		0.765591	-0.322564	0.463979	2.012653	[illegible]	[illegible]
	1	-0.794411	0.243050	-0.463979	1.349279	4.257656	[illegible]	
	2'		-0.765591	0.322564	-0.463979	4.134260	[illegible]	[illegible]
	2	0.794411	-0.243050	0.463979	-1.349279	4.834656	[illegible]	
24	1'		-10.452179	5.756692	-2.417387	3.065674	[illegible]	[illegible]
	1	12.118330	-1.161415	-0.176428	-0.759136	1.336734	[illegible]	
	2'		10.452172	-5.756692	2.417387	0.524331	1.715031	[illegible]
	2	-12.118330	1.161425	0.176428	0.759140	1.333976	-0.315592	

```
                                                  APPLIED NODAL LOADS
  NODE        PX            PY                PZ               MX                MY                MZ

    1         0.0       -10.000000           0.0              0.0               0.0               0.0
    2         0.0       -10.000000           0.0              0.0               0.0               0.0
    3         0.0       -10.000000           0.0              0.0               0.0               0.0
    4         0.0       -10.000000           0.0              0.0               0.0               0.0
    5         0.0       -10.000000           0.0              0.0               0.0               0.0
    6         0.0       -10.000000           0.0              0.0               0.0               0.0
    7         0.0       -10.000000           0.0              0.0               0.0               0.0
    8         0.0       -10.000000           0.0              0.0               0.0               0.0
    9         0.0       -10.000000           0.0              0.0               0.0               0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =      0.0


                                          NODAL DISPLACEMENTS
  NODE       DELTA-X        DELTA-Y          DELTA-Z          THETA-X          THETA-Y          THETA-Z

    1        0.000404      -0.005442        -0.000404        -0.000988         0.000000        -0.000988
    2       -0.000705      -0.008026         0.000000         0.000000        -0.000000        -0.001477
    3        0.000404      -0.005443         0.000404         0.000989         0.000000        -0.000988
    4       -0.000000      -0.008026         0.000705        -0.001477         0.000000         0.000000
    5        0.000000      -0.019827        -0.000000         0.000000        -0.000000         0.000000
    6       -0.000000      -0.008026        -0.000705         0.001477        -0.000000         0.000000
    7       -0.000404      -0.005443        -0.000404        -0.000988        -0.000000         0.000989
    8        0.000705      -0.008026         0.000000         0.000000         0.000000         0.001477
    9       -0.000404      -0.005443         0.000404         0.000989        -0.000000         0.000989


                                       MEMBER END FORCES AND MOMENTS
                                PPX              PPY              PPZ              MPX              MPY              MPZ
MEMB.  END        PX             PY               PZ               MX               MY               MZ

        1*                    0.809340         6.314215         3.091253        -0.917822         5.141374        -6.160755
        1     12.068126      -0.084451        -0.042371         0.340245         0.374179        -8.060725
  1     2*                   -0.809340        -6.314215        -3.091253         0.276457        -3.738749         5.330047
        2    -12.068126       0.084451         0.042371        -0.340244         0.411143         6.495291

        1*                   12.018438         9.871697         0.000011         0.000067        -0.000038       -13.072556
        1     15.552426      -0.124810         0.000011         0.000027        -0.000071       -13.072556
  2     2*                  -12.018438        -9.871697        -0.000011         0.000078        -0.000136        10.492196
        2    -15.552426       0.124810        -0.000011        -0.000027        -0.000154        10.492196

        1*                    0.809475         6.314322        -3.091294         0.917771        -5.141487        -6.160791
        1     12.068301      -0.084440         0.042384        -0.340360        -0.374249        -8.060741
  3     2*                   -0.809475        -6.314322         3.091294        -0.276336         3.738341         5.331182
        2    -12.068301       0.084440        -0.042384         0.340359        -0.411226         6.495521

        1*                   -3.091231         6.314174        -0.809276        -6.160711        -5.141342        -0.917812
        1     12.068044      -0.084451         0.042373        -0.340248        -0.374179        -8.060671
  4     2*                    3.091231        -6.314174         0.809276         5.330012         3.738722         0.276454
        2    -12.068044       0.084451        -0.042373         0.340247        -0.411139         6.495252

        1*                   -0.608820         1.314141        -7.326797        -5.640506        -3.194822         0.233214
        1      7.467549      -0.117222         0.041054        -0.099101        -0.306459        -6.476133
  5     2*                    0.608821        -1.314141         7.326797         4.064279         1.473736        -1.299141
        2     -7.467547       0.117220        -0.041053         0.099102        -0.674757         4.274219

        1*                    0.608816        -1.314186        -7.326754        -4.064378        -1.473356        -1.299101
        1      7.467514       0.117176        -0.041079         0.099081         0.075142        -4.274116
  6     2*                   -0.608817         1.314186         7.326759         5.632476         3.194447         0.233121
        2     -7.467520      -0.117176         0.041077        -0.099080         0.306520         6.476241

        1*                   -3.091237         6.314181         0.809377         6.161016         5.141513        -0.917736
        1     12.068123      -0.084501        -0.042360         0.340272         0.374111        -8.061012
  7     2*                    3.091237        -6.314181        -0.809377        -5.330355        -3.738460         0.276441
        2    -12.068133       0.084501         0.042360        -0.340271         0.411031         6.494657

        1*                    7.326756         1.314136         0.608817         0.233213         3.194213        -6.640466
        1      7.467505      -0.117219        -0.041055         0.099102         0.306460        -6.476336
  8     2*                   -7.326756        -1.314136        -0.608817        -1.299143        -1.473727         4.064275
        2     -7.467505       0.117217         0.041054        -0.099103         0.674764         4.274232

        1*                   10.803742         0.000001         0.000018         0.000049        -0.001224       -10.073742
        1     11.086206      -0.047311         0.000018        -0.000004        -0.000222       -10.073747
  9     2*                  -10.800735        -2.499909        -0.000018         0.001138        -0.000145         0.005254
        2    -11.086200       0.047311        -0.000018         0.000004        -0.001150         0.005254
```

10	1'		7.326942	1.314161	-0.608833	-0.033159	-3.184820	-5.640677
	1	7.467695	-0.117227	0.041051	-0.099031	-0.096388	-6.476290	
	2'		-7.326941	-1.314161	0.608833	0.209078	1.473704	4.064315
	2	-7.467694	0.117227	-0.041051	0.099031	-0.674788	4.274227	
11	1'		-0.000011	9.871700	-12.018441	-13.072544	0.000041	0.000069
	1	15.552430	-0.124810	-0.000011	-0.000027	0.000075	-13.072544	
	2'		0.000011	-9.871700	12.018441	10.492209	0.000139	0.000081
	2	-15.552430	0.124810	0.000011	0.000027	0.000159	10.492209	
12	1'		-0.000017	2.499994	-10.800718	-10.073741	0.000211	0.000048
	1	11.086182	-0.047311	-0.000017	0.000002	0.000216	-10.073741	
	2'		0.000017	-2.499992	10.800712	9.095231	0.000132	0.000033
	2	-11.086175	0.047312	0.000017	-0.000002	0.000136	9.095231	
13	1'		0.000016	-2.500008	-10.800703	-9.095321	-0.000124	0.000030
	1	11.086170	0.047296	0.000016	-0.000001	-0.000128	-9.095321	
	2'		-0.000016	2.500008	10.800689	10.073504	-0.000200	0.000047
	2	-11.086157	-0.047292	-0.000016	0.000001	-0.000205	10.073504	
14	1'		-0.000012	9.871642	12.018409	13.072691	-0.000047	0.000072
	1	15.552368	-0.124834	0.000012	0.000025	-0.000082	-13.072691	
	2'		0.000012	-9.871642	-12.018409	-10.491845	-0.000144	0.000099
	2	-15.552369	0.124834	-0.000012	-0.000025	-0.000166	10.491845	
15	1'		7.326725	-1.314182	-0.608816	-0.209200	1.473370	-4.064382
	1	7.467484	0.117171	0.041078	-0.099081	-0.675133	-4.274127	
	2'		-7.326731	1.314182	0.608816	0.033189	-3.184418	5.640664
	2	-7.467490	-0.117173	-0.041077	0.099081	-0.096520	6.475135	
16	1'		10.800701	-2.500006	-0.000017	0.000035	0.000138	-9.095312
	1	11.086167	0.047297	-0.000017	0.000002	0.000142	-9.095312	
	2'		-10.800687	2.500006	0.000017	0.000048	0.000213	10.073520
	2	-11.086154	-0.047294	0.000017	-0.000002	0.000210	10.073520	
17	1'		7.326950	-1.314217	0.608837	0.209130	-1.473365	-4.064449
	1	7.467713	0.117180	-0.041074	0.099015	0.675156	-4.274194	
	2'		-7.326956	1.314218	-0.608837	-0.033139	3.184474	5.639852
	2	-7.467719	-0.117179	0.041074	-0.099014	0.096437	6.475275	
18	1'		3.091311	6.314359	-0.809535	-6.169757	5.141520	0.017791
	1	12.068374	-0.084442	-0.042385	0.340360	0.374250	-8.060813	
	2'		-3.091311	-6.314359	0.809535	5.331195	-3.733050	[illegible]
	2	-12.068374	0.084442	0.042385	-0.340361	0.411299	6.405536	
19	1'		0.608836	1.314164	-7.326949	-5.640666	3.184222	[illegible]
	1	7.467702	-0.117225	-0.041059	0.099033	0.096377	-6.476271	
	2'		-0.608836	-1.314164	7.326949	4.064337	-1.473720	[illegible]
	2	-7.467702	0.117225	0.041059	-0.099033	0.674777	4.274252	
20	1'		-0.608837	-1.314220	-7.326949	-4.064477	1.473372	[illegible]
	1	7.467714	0.117177	-0.041076	-0.099015	-0.675162	-4.274212	
	2'		0.608839	1.314220	7.326955	5.640922	-3.184474	[illegible]
	2	-7.467720	-0.117178	-0.041075	0.099016	-0.096452	6.475349	
21	1'		3.091293	6.314321	0.809566	6.161033	-5.141601	[illegible]
	1	12.068374	-0.084494	0.042375	-0.340382	-0.274185	[illegible]	
	2'		-3.091293	-6.314321	-0.809566	-5.331586	3.739555	[illegible]
	2	-12.068374	0.084494	-0.042375	0.340382	-0.411164	6.404872	
22	1'		-0.809438	6.314221	3.091254	-0.017905	-5.141556	[illegible]
	1	12.068209	-0.084502	0.042362	-0.340272	-0.374115	[illegible]	
	2'		0.809438	-6.314221	-3.091254	0.276440	3.739429	[illegible]
	2	-12.068209	0.084502	-0.042362	0.340272	-0.411007	[illegible]	
23	1'		-12.018426	9.871656	0.000012	[illegible]	[illegible]	[illegible]
	1	15.552391	-0.124834	-0.000012	-0.000025	0.000078	[illegible]	
	2'		12.018426	-9.871656	-0.000012	[illegible]	0.000141	-10.491071
	2	-15.552391	0.124834	0.000012	0.000025	[illegible]	10.491071	
24	1'		-0.809519	6.314289	-3.091277	0.017755	5.141655	[illegible]
	1	12.068316	-0.084426	-0.042374	0.340383	0.374181	[illegible]	
	2'		0.809519	-6.314289	3.091277	-0.276286	-3.739441	[illegible]
	2	-12.068316	0.084426	0.042374	-0.340382	0.411153	[illegible]	

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                                                   APPLIED NODAL LOADS
 NODE        PX              PY              PZ              MX              MY              MZ

   1         0.0             0.0             0.0             0.0             0.0             0.0
   2         0.0           -20.000000        0.0             0.0             0.0             0.0
   3         0.0             0.0             0.0             0.0             0.0             0.0
   4         0.0           -20.000000        0.0             0.0             0.0             0.0
   5         0.0             0.0             0.0             0.0             0.0             0.0
   6         0.0           -20.000000        0.0             0.0             0.0             0.0
   7         0.0             0.0             0.0             0.0             0.0             0.0
   8         0.0           -20.000000        0.0             0.0             0.0             0.0
   9         0.0             0.0             0.0             0.0             0.0             0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.0


                                          NODAL DISPLACEMENTS

 NODE      DELTA-X         DELTA-Y         DELTA-Z         THETA-X         THETA-Y         THETA-Z

   1      -0.025608        0.021983        0.025608       -0.002299       -0.000000       -0.002299
   2       0.053598       -0.072127       -0.000003        0.000003        0.000002        0.001319
   3      -0.025611        0.021987       -0.025609        0.002297       -0.000002       -0.002299
   4       0.000003       -0.072127       -0.053598        0.001319       -0.000002        0.000003
   5      -0.000000        0.136364        0.000002       -0.000000        0.000000       -0.000000
   6       0.000004       -0.072134        0.053604       -0.001319        0.000002        0.000003
   7       0.025608        0.021987        0.025611       -0.002299        0.000002        0.002297
   8      -0.053604       -0.072135       -0.000003        0.000003       -0.000002       -0.001319
   9       0.025613        0.021992       -0.025613        0.002297       -0.000000        0.002297


                                      MEMBER END FORCES AND MOMENTS

                             PFX             PPY             PPZ             MPX             MPY             MPZ
 MEMB.  END      FX          PY              PZ              MX              MY              MZ

        1*                 5.782206        2.682667        1.019309       -1.232420        3.587083      -10.230175
        1     6.267[illegible]  -1.122499      -0.056876        0.927092        0.434253      -13.378896
   1    2*                -5.782206       -2.682667       -1.019309       -1.898405        4.277123       -5.855178
        2    -6.267[illegible]   1.122499       0.056876       -0.927098        0.570292       -7.427784

        1*                15.424018       14.635236        0.000039       -0.000637       -0.000859       -3.697555
        1    31.310674     1.349191        0.000039       -0.001040       -0.000251       -3.697555
   2    2*               -15.424018      -14.635236       -0.000039        0.001156        0.000737       31.590576
        2   -31.310674    -1.349191       -0.000039        0.001040       -0.000559       31.590576

        1*                 5.783126        2.681909       -1.019494        1.233364       -8.586854      -10.231027
        1     6.256115    -1.122683        0.056877       -0.825094       -0.484197      -13.379559
   3    2*                -5.783126       -2.681909        1.019434        1.897709       -4.279311       -5.857356
        2    -6.256115     1.122683       -0.056877        0.825382       -0.570334       -7.430697

        1*                -1.019913        2.682694       -5.782915      -10.230149       -8.587109       -1.232438
        1     6.267263    -1.122486        0.056888       -0.827098       -0.484774      -13.378893
   4    2*                 1.019913       -2.682694        5.782915       -5.855286       -4.277170       -1.898438
        2    -6.267263     1.122486       -0.056888        0.827098       -0.570364       -7.427717

        1*                -1.083267        2.682662       -6.746752        7.426047        0.793286        0.265279
        1     7.294419     1.021652       -0.512170        0.869005        4.274015       11.249217
   5    2*                 1.083369       -2.682662        6.746751       13.111074       14.766967        1.974835
        2    -7.294419     1.021653        0.512190       -0.869896        4.446230       22.970718

        1*                 1.083122       -2.692379       -6.746231      -18.112715      -14.769959        1.075336
        1     7.294[illegible]  -1.021496       0.512101       -0.868561       -4.642242      -22.973175
   6    2*                -1.083138        2.682376        6.746277       -7.432212       -9.786971        0.264547
        2    -7.294[illegible]   1.021[illegible]  -0.512105   0.869069       -4.971333      -11.241027

        1*                -1.022142        2.683005        6.782663       10.222049        3.585575       -1.232143
        1     6.267381    -1.122226       -0.056917        0.827135        0.484373      -13.376335
   7    2*                 1.022142       -2.683005       -6.782663        5.850230        4.273766       -1.897847
        2    -6.267381     1.122226        0.056917       -0.827137        0.570539       -7.421756

        1*                 6.746607        2.682637        1.983356        0.265313       -0.793354        7.488048
        1     7.294663     1.021655        0.512180       -0.869893       -4.274031       11.240285
   8    2*                -6.746607       -2.682636       -1.983358        1.274024      -14.767015       18.111649
        2    -7.294663    -1.021657       -0.512182        0.868870       -4.646292       22.970718

        1*                11.457971       -0.000025       -0.000189        0.000269        0.002641      -35.540353
        1    11.151617    -2.621431       -1.000189        0.000967        0.002530      -35.540359
   9    2*               -11.457045        0.000033        0.000189       -0.001167        0.001171      -18.884979
        2   -11.151[illegible]   2.641437       0.000189       -0.000867        0.001432      -18.884979
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     1'                      6.745107     2.682724    -1.983243    -0.265842     9.792044     7.490111
10   1         7.284179      1.921782    -0.512036     0.867929     4.973021    11.250444
     2'                     -6.745107    -2.682723     1.983244    -1.973747    14.767141    18.112961
     2        -7.284179     -1.921782     0.512037    -0.867917     4.645561    22.971924

     1'                     -0.000041    14.635203   -15.423984    -3.697471     0.000871    -0.000627
11   1        21.219528      1.349178    -0.000041     0.001039     0.000266    -3.697471
     2'                      0.000041   -14.635203    15.423984    31.590591    -0.000227     0.001164
     2       -21.219528     -1.349179     0.000041    -0.001039     0.000571    31.590591

     1'                      0.000195     0.000014   -11.457994   -35.540527    -0.002698     0.000262
12   1        11.151746     -2.631421     0.000195    -0.000875    -0.002566   -35.540527
     2'                     -0.000195    -0.000000    11.457968   -18.884857    -0.001228    -0.001188
     2       -11.151717      2.631428    -0.000195     0.000875    -0.001469   -18.884857

     1'                     -0.000199     0.000032   -11.458273    18.887329     0.001262    -0.001202
13   1        11.1[illegible]7      2.631529    -0.000199     0.000880     0.001505    18.887329
     2'                      0.000199    -0.000032    11.458380    35.539154     0.002743     0.000257
     2       -11.1[illegible]111     -2.631554     0.000199    -0.000880     0.002611    35.539154

     1'                     -0.000043    14.635242    15.423875     3.696330    -0.000896    -0.000616
14   1        21.21[illegible]7      1.349277     0.000043    -0.001047    -0.000293    -3.696330
     2'                      0.000043   -14.635242   -15.423875   -31.591476     0.000209     0.001189
     2        [illegible]     -1.349277    -0.000043     0.001047    -0.000601    31.591476

     1'                      6.746703    -2.682475    -1.983179     1.975329    14.770069   -18.113297
15   1         7.[illegible]     -1.921413    -0.512102     0.868949     4.648252   -22.973618
     2'                     -6.746766     2.682472     1.983183     0.264565     9.786782    -7.482021
     2         7.[illegible]      1.921401     0.512107    -0.868952     4.972010   -11.240817

     1'                     11.458233     0.000033     0.000193    -0.001173    -0.001207    18.887329
16   1        11.15[illegible]      2.631535     0.000193    -0.000864    -0.001445    18.887329
     2'                    -11.458403    -0.000033    -0.000193     0.000254    -0.002685    35.539307
     2       -11.1[illegible]     -2.631550    -0.000193     0.000864    -0.002555    35.539307

     1'                      6.746423    -2.682429     1.983004    -1.974280   -14.770056   -18.114166
17   1         7.[illegible]     -1.[illegible]     0.511962    -0.868008    -4.647514   -22.974365
     2'                     -6.746486     2.682425    -1.983008    -0.265112    -9.785846    -7.484486
     2        -7.[illegible]      1.921546    -0.511968     0.868012    -4.973169   -11.242542

     1'                      1.919426     2.691910    -5.782032   -10.231092     8.586987     1.233372
18   1         7.[illegible]     -1.122696    -0.056869     0.825978     0.484186   -13.379631
     2'                     -1.919455    -2.691910     5.782032    -5.857388     4.279350     1.897720
     2         7.[illegible]      1.122696     0.056869    -0.825980     0.570347    -7.430748

     1'                      1.[illegible]     2.682700    -6.746045     7.490314    -9.792196    -0.265852
19   1         7.[illegible]      1.921775     0.512048    -0.867927    -4.973051    11.250600
     2'                     -1.[illegible]    -2.682700     6.746045    18.113007   -14.767147    -1.973742
     2         7.[illegible]     -1.921776    -0.512049     0.867915    -4.645544    22.971954

     1'                     -1.[illegible]    -2.682308    -6.745420   -18.114243    14.770018    -1.974246
20   1         7.[illegible]     -1.921633    -0.511974     0.867998     4.647539   -22.974426
     2'                      1.[illegible]     2.682305     6.745465    -7.484517     9.785781    -0.265121
     2        -7.[illegible]      1.921631     0.511980    -0.867988     4.973126   -11.242539

     1'                      1.[illegible]     2.682393     5.782104    10.231362    -8.585777     1.233163
21   1        [illegible]     -1.[illegible]     0.056872    -0.826019    -0.484315   -13.377570
     2'                     -1.[illegible]    -2.682393    -5.782104     5.852587    -4.276014     1.897161
     2        [illegible]      1.[illegible]    -0.056872     0.826019    -0.570261    -7.424979

     1'                     -5.792274     2.682806     1.920043    -1.232130    -8.585572    10.227946
22   1        [illegible]      1.[illegible]     0.056914    -0.827120    -0.484356   -13.376191
     2'                      5.792475    -2.682806    -1.920043    -1.837976    -4.273969     5.850520
     2        [illegible]      1.[illegible]    -0.056914     0.827130    -0.570524    -7.422110

     1'                    -15.424039    14.635390     0.000041    -0.000621     0.000879     3.696457
23   1        21.21[illegible]      1.349279    -0.000041     0.001040     0.000277    -3.696457
     2'                     15.424039   -14.635390    -0.000041     0.001160    -0.000222   -31.591660
     2       -21.21[illegible]     -1.349279     0.000041    -0.001040     0.000670    31.591660

     1'                     -5.791564     2.682300    -1.919773     1.233126     8.585675    10.229215
24   1         7.356747     -1.122256    -0.055993     0.826033     0.484309   -13.377397
     2'                      5.791564    -2.682300     1.919773     1.837180     4.275334     5.852528
     2        -7.[illegible]      1.122256     0.056093    -0.826035     0.570282    -7.424916
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NUMBER OF NODES  9
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                            MEMBER COORDINANTS
MEMBER-I     X(I,1)        X(I,2)        Y(I,1)         Y(I,2)        Z(I,1)        Z(I,2)

    1     -32.250000    -18.089996     0.0            6.270000     16.000000     18.089996
    2     -36.000000    -18.969986     0.0            8.919999      0.0           0.0
    3     -32.250000    -18.089996     0.0            6.270000    -16.000000    -18.089996
    4     -16.000000    -18.089996     0.0            6.270000     32.250000     18.089996
    5     -18.089996    -18.969986     6.270000       8.919999     18.089996      0.0
    6     -18.969986    -18.089996     8.919999       6.270000      0.0         -18.089996
    7     -16.000000    -18.089996     0.0            6.270000    -32.250000    -18.089996
    8     -18.089996      0.0          6.270000       8.919999     18.089996     18.969986
    9     -18.969986      0.0          8.919999      12.000000      0.0           0.0
   10     -18.089996      0.0          6.270000       8.919999    -18.089996    -18.969986
   11       0.0           0.0          0.0            8.919999     36.000000     18.969986
   12       0.0           0.0          8.919999      12.000000     18.969986      0.0
   13       0.0           0.0         12.000000       8.919999      0.0         -18.969986
   14       0.0           0.0          0.0            8.919999    -36.000000    -18.969986
   15       0.0          18.089996     8.919999       6.270000     18.969986     18.089996
   16       0.0          18.969986    12.000000       8.919999      0.0           0.0
   17       0.0          18.089996     8.919999       6.270000    -18.969986    -18.089996
   18      16.000000     18.089996     0.0            6.270000     32.250000     18.089996
   19      18.089996     18.969986     6.270000       8.919999     18.089996      0.0
   20      18.969986     18.089996     8.919999       6.270000      0.0         -18.089996
   21      16.000000     18.089996     0.0            6.270000    -32.250000    -18.089996
   22      32.250000     18.089996     0.0            6.270000     16.000000     18.089996
   23      36.000000     18.969986     0.0            8.919999      0.0           0.0
   24      32.250000     18.089996     0.0            6.270000    -16.000000    -18.089996


                                            MEMBER PROPERTIES
MEMBER-I      IX            IY            IZ           AREA         RADIUS          PHI           ALPHA

    1      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550      0.679980
    2      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
    3      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550     -0.679980
    4      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550     -0.679980
    5      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135     -0.355170
    6      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135     -0.355170
    7      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550      0.679980
    8      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135      0.355170
    9      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   10      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135     -0.355170
   11      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   12      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   13      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   14      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   15      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135      0.355170
   16      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   17      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135     -0.355170
   18      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550      0.679980
   19      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135      0.355170
   20      0.000550      0.000326      0.000326      0.062500     60.000000      0.153135      0.355170
   21      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550     -0.679980
   22      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550     -0.679980
   23      0.000550      0.000326      0.000326      0.062500     60.000000      0.160877      0.0
   24      0.000550      0.000326      0.000326      0.062500     60.000000      0.130550      0.679980


MEMB   NODE(I,1)   NODE(I,2)

  1        0           1
  2        0           2
  3        0           3
  4        0           1
  5        1           2
  6        2           3
  7        0           3
  8        1           4
  9        2           5
 10        3           6
 11        0           4
 12        4           5
 13        5           6
 14        0           6
 15        4           7
 16        5           8
 17        6           9
 18        0           7
 19        7           8
 20        8           9
 21        0           9
 22        0           7
 23        0           8
 24        0           9


NODE   NBRN              LINK
                  1      2      3      4      5      6

  1      4       -1     -4      5      8
  2      4       -2     -5      6      9
  3      4       -3     -6     -7     10
  4      4       -8    -11     12     15
  5      4       -9    -12     13     16
  6      4      -10    -13    -14     17
  7      4      -15    -18     19    -22
  8      4      -16    -19     20    -23
  9      4      -17    -20    -21    -24
```

```
                                             APPLIED NODAL LOADS
 NODE        PX          PY            PZ          MX          MY          MZ

   1         0.0         0.0           0.0         0.0         0.0         0.0
   2         0.0         0.0           0.0         0.0         0.0         0.0
   3         0.0       -40.000000      0.0         0.0         0.0         0.0
   4         0.0         0.0           0.0         0.0         0.0         0.0
   5         0.0         0.0           0.0         0.0         0.0         0.0
   6         0.0         0.0           0.0         0.0         0.0         0.0
   7         0.0         0.0           0.0         0.0         0.0         0.0
   8         0.0         0.0           0.0         0.0         0.0         0.0
   9         0.0         0.0           0.0         0.0         0.0         0.0
```

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 DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.0
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```
                                   NODAL DISPLACEMENTS
 NODE      DELTA-X      DELTA-Y      DELTA-Z      THETA-X      THETA-Y      THETA-Z

   1     -0.043077     0.084818     0.042683     0.006593     0.001564     0.001892
   2     -0.032136     0.062454     0.049762    -0.010722    -0.004098    -0.000083
   3      0.085048    -0.171622     0.085048     0.003756    -0.000000    -0.003756
   4     -0.026281    -0.032331    -0.016425    -0.001516     0.002731    -0.005685
   5     -0.018377    -0.028110    -0.018377     0.002815     0.000001    -0.002816
   6      0.049761     0.062453    -0.032137     0.000085     0.004097     0.010722
   7     -0.024293    -0.049283    -0.024293    -0.003572    -0.000000     0.003572
   8     -0.016424    -0.032330    -0.026281     0.005685    -0.002730     0.001516
   9      0.042683     0.084817    -0.043076    -0.001891    -0.001564    -0.006593
```

```
                               MEMBER END FORCES AND MOMENTS
                            PPX          PPY          PPZ          MPX          MPY          MPZ
 MEMB.  END      PX          PY           PZ           MX           MY           MZ

         1'             -2.444512    -3.945823    -1.625709    -3.390611     7.864228   -20.132660
         1   -4.015769  -2.768638     0.629530    -2.609644    -4.646996   -21.219345
   1     2'              2.444512     3.945823     1.625709     1.443732    10.045988   -20.407288
         2    4.015769   2.768638    -0.629530     2.609702    -5.187362   -22.039597

         1'             -3.699088    -3.252299    -0.895260    -0.758547     8.552631    -8.684322
         1   -4.785834  -1.164695    -0.895260     3.296360     7.928238    -8.684322
   2     2'              3.699088     3.252299     0.895260    -7.227168     6.693660   -13.707257
         2    4.785834   1.164695     0.895260    -3.296357     9.282841   -13.707257

         1'             33.887909    20.520157    -7.623210    -1.801078    11.242842    30.262466
         1   39.960815   5.439025     1.063071    -1.168472    -8.716777    31.114532
   3     2'            -33.887909   -20.520157     7.623210    -3.110323    25.874847    47.814438
         2  -39.960815  -5.439025    -1.063071     1.168599    -7.889267    53.868301

         1'             -2.259562     8.028668   -21.492416   -20.899155   -12.130882    -3.143442
         1   22.999084  -1.586038    -0.121348     0.776227     2.148938   -24.260910
   4     2'              2.259562    -8.028668    21.492416    -0.168851    -0.792101     0.530863
         2  -22.999084   1.586038     0.121348    -0.776285    -0.254238    -0.520091

         1'             -0.972456     3.103307   -23.545868    -4.371877    -2.323667     0.560908
         1   23.766327  -0.379839     0.043348    -0.680571    -0.580476    -4.901756
   5     2'              0.972440    -3.103322    23.545593    -1.885569    -0.804529    -0.714758
         2  -23.766052   0.379788    -0.043368     0.680567    -0.212858    -2.050617

         1'             -0.423727    -0.517383   -25.835571    10.625197     8.845891     0.864419
         1   25.587723   3.603690    -0.453646    -1.624153     4.454154    13.015935
   6     2'              0.423724     0.517383    25.835587    48.480087    21.554306    -2.442521
         2  -25.587738  -3.603691     0.453644     1.624122     3.849292    52.947296

         1'             -7.622706    20.518707    33.884537   -30.264282   -11.243473     1.801233
         1   39.957108   5.439045    -1.063102     1.168602     8.717318    31.116364
   7     2'              7.622706   -20.518707   -33.884537   -47.814072   -25.873825     3.109929
         2  -39.957108  -5.439045     1.063102    -1.168595     7.889935    53.867371

         1'             -3.731860     0.979253     0.431044     3.097985    -6.929807    19.315811
         1   -3.525689   1.624354     0.050116     2.987086    -0.319480    20.535202
   8     2'              3.731865    -0.979253    -0.431031    -2.817456    -4.151538     8.287776
         2    3.525695  -1.624351    -0.050104    -2.987080    -0.597825     9.196767

         1'             -4.246271     0.369142     1.390156    -1.514117   -14.735621    13.556859
         1   -4.132227   1.044891     1.390156    -3.856092   -14.302307    13.556859
   9     2'              4.246210    -0.369173    -1.390156     5.795790   -11.635812     6.525080
         2    4.132162  -1.044911    -1.390156     3.856086   -17.414269     6.525080
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       1'                25.837341     0.517596     0.423813     2.442166   -21.554947   -48.480377
 10    1     25.589493   -3.603790     0.453792     1.623693    -3.849731   -52.947784
       2'               -25.837387    -0.517583    -0.423786    -0.863574    -8.848263   -10.624490
       2    -25.589539    3.603800    -0.453762    -1.623695    -4.456722   -13.016091

       1'                 0.392652    -1.012810     2.700112     5.664502    -4.124129    -0.023860
 11    1     -2.861804    0.355627     0.392652    -1.892407    -3.664398     5.664502
       2'                -0.392652     1.012810    -2.700112     1.172794    -2.562739    -3.478595
       2      2.861804   -0.355627    -0.392652     1.892407    -3.884206     1.172794

       1'                -0.301367    -0.369205     3.157532     0.806022     4.117459    -0.258188
 12    1     -3.175800    0.141604    -0.301367     0.914728     4.022862     0.806022
       2'                 0.301367     0.369221    -3.157569     1.914948     1.599458     1.186398
       2      3.175928   -0.141593     0.301367    -0.914728     1.768919     1.914948

       1'                -1.390332    -0.369305     4.246817    -6.524196    11.633545    -5.795672
 13    1     -4.132740   -1.045139    -1.390332     3.856333    12.412013    -6.524196
       2'                 1.390332     0.369306    -4.246806   -13.561557    14.741059     1.513452
       2      4.132729    1.045138     1.390332    -3.856339    14.307980   -13.561557

       1'                -0.895388    -3.252616    -3.699192     8.685723    -8.553239     0.759118
 14    1     -4.786073   -1.164927     0.895388    -3.296136    -7.929041    -8.685723
       2'                 0.895388     3.252616     3.699192    13.710475    -6.695219     7.227733
       2      4.786073    1.164927    -0.895388     3.296134    -9.284484   -13.710475

       1'                -3.033691     0.335554    -0.026070     0.838656     2.597199    -4.552170
 15    1     -3.045512   -0.160149    -0.125585     0.671680     0.986200    -5.171779
       2'                 3.033691    -0.335554     0.026072    -0.474318     0.544094     2.582128
       2      3.045512    0.160150     0.125587    -0.671677     1.312283     2.239455

       1'                -3.156701     0.369057     0.301294    -1.186542    -1.597185    -1.915973
 16    1     -3.175046   -0.141616     0.301294    -0.915235    -1.766700    -1.915973
       2'                 3.156713    -0.369059    -0.301294     0.258558    -4.118353    -0.805676
       2      3.175057    0.141616    -0.301294     0.915236    -4.023685    -0.805676

       1'                23.548645    -3.103660     0.972688     0.715090     0.802632     1.884491
 17    1     23.769119    0.379855    -0.043238     0.681118     0.211516     2.048955
       2'               -23.548630     3.103660    -0.972684    -0.561527     2.323421     4.372601
       2    -23.769104   -0.379855     0.043241    -0.681113     0.579906     4.902349

       1'                 0.057870    -0.335724     3.003764     9.940258    -4.440490    -2.145207
 18    1     -2.848842    0.997153    -0.168649     1.491659     1.708559    10.862059
       2'                -0.057870     0.335724    -3.003764     4.136353    -2.656528     1.080385
       2      2.848842   -0.997153     0.168649    -1.491680     0.925085     4.717296

       1'                 0.026032    -0.335534     3.033951    -2.592102    -0.543943     0.474387
 19    1     -3.045769    0.160194     0.125541    -0.671721    -1.312123    -2.239482
       2'                -0.026037     0.335534    -3.033936     4.551731    -2.596893    -0.939658
       2      3.045753   -0.160194    -0.125547     0.671718    -0.985982     5.171229

       1'                -0.431113    -0.979301     3.730601    -8.287552     4.151939     2.917376
 20    1     -3.524435   -1.624230    -0.050170    -2.987056     0.598192    -9.196660
       2'                 0.431111     0.979301    -3.730605   -19.315491     6.930925    -3.098035
       2      3.524439    1.624229     0.050168     2.987060     0.319795   -20.534988

       1'                -1.625732    -3.945951    -2.444767    20.132660    -7.864102     3.390469
 21    1     -4.016055   -2.768641    -0.629549     2.609566     4.647142   -21.219254
       2'                 1.625732     3.945951     2.444767    20.407837   -10.045939    -1.443747
       2      4.016055    2.768641     0.629549    -2.609621     5.187717   -22.039993

       1'                 3.002913    -0.335320     0.058003     2.145107     4.440226    -0.939974
 22    1     -2.847800    0.997177     0.168658    -1.491631    -1.708595    10.861674
       2'                -3.002913     0.335320    -0.058003    -1.080358     2.656598    -4.136535
       2      2.847899   -0.997177    -0.168658     1.491659    -0.925130     4.717486

       1'                 2.699589    -1.012533     0.392669     0.024011     4.124169    -5.664001
 23    1     -2.861211    0.355629    -0.392669     1.892293     3.664503     5.664001
       2'                -2.699588     1.012533    -0.392669     3.478593     2.562987    -1.172916
       2      2.861211   -0.355629     0.392669    -1.892290     3.884424     1.172916

       1'               -21.491318     8.028116    -2.259430     3.143342    12.130899    20.809758
 24    1     22.997849   -1.586067     0.121410    -0.776112    -2.148803   -24.260544
       2'                21.491318    -8.028116     2.259430    -0.530604     0.792422     0.169001
       2    -22.997849    1.586067    -0.121410     0.776161     0.254490    -0.520424

IHC217I
TRACEBACK FOLLOWS-    ROUTINE    ISN   REG. 14
                      IBCOM            8200FDC0
                      MAIN             00002848

ENTRY POINT=  50005020
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                                              APPLIED NODAL LOADS
  NODE        PX            PY              PZ            MX            MY            MZ

    1         0.0           0.0             0.0           0.0           0.0           0.0
    2         0.0         -20.000000        0.0           0.0           0.0           0.0
    3         0.0           0.0             0.0           0.0           0.0           0.0
    4         0.0         -20.000000        0.0           0.0           0.0           0.0
    5         0.0           0.0             0.0           0.0           0.0           0.0
    6         0.0         -20.000000        0.0           0.0           0.0           0.0
    7         0.0           0.0             0.0           0.0           0.0           0.0
    8         0.0         -20.000000        0.0           0.0           0.0           0.0
    9         0.0           0.0             0.0           0.0           0.0           0.0



DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.0



                                     NODAL DISPLACEMENTS
  NODE      DELTA-X        DELTA-Y        DELTA-Z        THETA-X        THETA-Y        THETA-Z

    1      -0.016924       0.030124       0.016924      -0.001354       0.000000      -0.001354
    2       0.036008      -0.071643       0.000000       0.000000       0.000000       0.002922
    3      -0.016923       0.030123      -0.016923       0.001354      -0.000000      -0.001354
    4       0.000000      -0.071650      -0.036008       0.002922      -0.000000       0.000000
    5       0.000001       0.127074      -0.000001       0.000003      -0.000000       0.000003
    6      -0.000000      -0.071644       0.036007      -0.002926      -0.000000      -0.000000
    7       0.016924       0.030124       0.016924      -0.001354       0.000000       0.001354
    8      -0.036036      -0.071645       0.000001      -0.000000       0.000000      -0.002926
    9       0.016922       0.030120      -0.016922       0.001354      -0.000000       0.001354



                                  MEMBER END FORCES AND MOMENTS
                              PPY            PPY            PPZ            MPX            MPY            MPZ
 MEMB.  END       PX          PY             PZ             MX             MY             MZ

         1'                 11.194366      3.495017       0.922810      -0.595716       7.384768     -12.799625
         1    11.666666    -1.463911       0.252663       0.711356      -1.833402     -14.651900
   1     2'                -11.194366     -3.495017      -0.922810      -0.922196       2.944355      -3.039120
         2   -11.666666     1.463911      -0.252663      -0.711330      -2.175223      -8.298774

         1'                 21.950446     13.929799       0.000001      -0.000022      -0.000018       2.837831
         1    24.603334     1.775217       0.000001      -0.000078      -0.000016       2.837831
   2     2'                -21.950446    -13.929799      -0.000001       0.000035      -0.000006      31.299817
         2   -24.603334    -1.775217      -0.000001       0.000120      -0.000021      31.299817

         1'                 11.193020      3.494420      -0.922633       0.595794      -7.384250     -12.798835
         1    11.664131    -1.462250      -0.250642      -0.711264       1.829219     -14.652259
   3     2'                -11.193020     -3.494420       0.922633       0.922127      -2.944365      -3.038921
         2   -11.664131     1.462250       0.250642       0.711247       2.175[illegible]     -8.298610

         1'                 [illegible]    3.434974     -11.193601      [illegible]     -7.384702      -0.595693
         1    11.[illegible]177    -1.4[illegible]     -0.252659      -0.711366       1.830286     -14.651760
   4     2'                 [illegible]   -3.434364      11.193601      [illegible]     -2.944419      -3.302214
         2   -11.[illegible]177     1.4[illegible]      0.252659       0.711345       2.175[illegible]     -8.298275

         1'                 -1.617104      3.495510     -11.969204      [illegible]      7.219152      -0.791124
         1    12.[illegible]    1.[illegible]     -0.347052       1.330236      [illegible]     11.549415
   5     2'                 1.[illegible]     -3.495510      11.36[illegible]     [illegible]     11.264154       1.[illegible]
         2   -12.[illegible]   -1.[illegible]      0.347049      -1.33[illegible]     [illegible]     24.434974

         1'                 1.[illegible]     -3.495517     -11.960230     -21.503747     -11.255654       1.229951
         1    12.[illegible]   -1.[illegible]71      0.347022      -1.330130      [illegible]    -24.435[illegible]
   6     2'                -1.[illegible]      3.495517      11.960233      [illegible]     -7.219261      -0.791[illegible]
         2    1[illegible]     1.[illegible]71     -0.347022       1.33[illegible]     [illegible]    -11.54[illegible]

         1'                 [illegible]    3.495151      11.1[illegible]     [illegible]      7.384[illegible]     -[illegible]777
         1    11.[illegible]   -1.4[illegible]      0.252665       0.711[illegible]     -1.[illegible]    -14.651[illegible]
   7     2'                 [illegible]   -3.495151     -11.1[illegible]14     [illegible]      2.944326      -3.[illegible]
         2   -11.[illegible]    1.463760      -0.252655      -0.711267      -2.17[illegible]     -8.297976

         1'                 11.[illegible]     3.495523       1.597109      [illegible]     -7.[illegible]     [illegible]
         1    12.[illegible]    1.[illegible]72      0.347053      -1.330185      [illegible]     11.549[illegible]
   8     2'                -11.[illegible]    -3.495523      -1.597106      [illegible]    -11.[illegible]     21.[illegible]
         2   -12.[illegible]   -1.[illegible]     -0.347061       1.33[illegible]     [illegible]     24.417[illegible]

         1'                 12.[illegible]     [illegible]     [illegible]     [illegible]     [illegible]     [illegible]
         1    12.[illegible]   -2.[illegible]      [illegible]     [illegible]     [illegible]     [illegible]     -12.[illegible]
   9     2'                -12.[illegible]     [illegible]     [illegible]     [illegible]     [illegible]
         2   -12.[illegible]    [illegible]     [illegible]     [illegible]
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```
          1'                   11.858961     3.485193    -1.587151     0.792241     7.019598     9.731461
 10       1     12.301044       1.965859    -0.347116     1.331385     3.075422    11.548720
          2'                  -11.858963    -3.485193     1.587148    -1.931242    11.256245    21.889786
          2    -12.301045      -1.965858     0.347113    -1.331382     3.278195    24.435135

          1'                   -0.000004    13.029823   -21.050446     2.837913     0.000040    -0.000018
 11       1     24.693039       1.775229    -0.000004     0.000034     0.000027     2.837913
          2'                    0.000004   -13.029823    21.050446    31.290863     0.000024     0.000051
          2    -24.693039      -1.775229     0.000004    -0.000034     0.000045    31.290863

          1'                   -0.000054     0.000103   -17.873749   -35.149750     0.000417    -0.000891
 12       1     17.642731      -2.864401    -0.000054     0.000946     0.000769   -35.149750
          2'                    0.000054    -0.000075    17.873764   -19.900879     0.000612     0.001058
          2    -17.642731       2.864431     0.000054    -0.000946     0.000774   -19.900879

          1'                    0.000067     0.000386   -17.873169    19.898972    -0.000711     0.001108
 13       1     17.642090       2.864791     0.000067    -0.000979    -0.000880    19.898972
          2'                   -0.000067    -0.000386    17.873169    35.158737    -0.000558    -0.000902
          2    -17.642090      -2.864791    -0.000067     0.000979    -0.000406    35.158737

          1'                    0.000005    13.030338    21.050400    -2.840647     0.000051    -0.000024
 14       1     24.693222       1.775706    -0.000005     0.000003     0.000056     2.840647
          2'                   -0.000005   -13.030338   -21.050400   -31.297562     0.000041    -0.000024
          2    -24.693222      -1.775706     0.000005    -0.000003     0.000048    31.297562

          1'                   11.860391    -3.485593    -1.587187     1.929852    11.255795   -21.891113
 15       1     12.302517      -1.966026    -0.347018     1.330136     3.277115   -24.436218
          2'                  -11.860391     3.485592     1.587198    -0.791048     7.019375    -9.732294
          2    -12.302517       1.966026     0.347019    -1.330133     3.075113   -11.549433

          1'                   17.873383     0.000366    -0.000075     0.001142     0.000792    19.898895
 16       1     17.642303       2.864806    -0.000075     0.001000     0.000965    19.898895
          2'                  -17.873383    -0.000366     0.000075    -0.000910     0.000640    35.158966
          2    -17.642303      -2.864806     0.000075    -0.001000     0.000486    35.158966

          1'                   11.859166    -3.485241     1.587136    -1.931197   -11.255818   -21.888992
 17       1     12.301364      -1.965869     0.347086    -1.331361    -3.278364   -24.434235
          2'                  -11.859166     3.485240    -1.587137     0.792225    -7.019498    -9.731353
          2    -12.301364       1.965869    -0.347087     1.331359    -3.075369   -11.548586

          1'                    0.022634     3.494479   -11.193101   -12.799119     7.384395     0.595721
 18       1     11.664[illegible]      -1.469780     0.259661     0.711260    -1.380372   -14.651275
          2'                   -0.022634    -3.494479    11.193101    -8.033202     2.944457     0.202140
          2    -11.664[illegible]       1.469780    -0.259661    -0.711259    -2.175[illegible]    -8.2988[illegible]

          1'                    1.587167     3.485198   -11.858994     9.731645    -7.019631     0.792228
 19       1     12.301[illegible]       1.965965     0.347128    -1.331377    -3.075448    11.548926
          2'                   -1.587163    -3.485213    11.858009    21.88996[illegible]   -11.256357    -1.931244
          2    -12.301[illegible]      -1.965978    -0.347120     1.331376    -3.278239    24.435333

          1'                   -1.587154    -3.485279   -11.859371   -21.889236    11.255[illegible]    -1.931187
 20       1     12.301564      -1.965979    -0.347090     1.331349     3.278164   -24.434494
          2'                    1.587156     3.485279    11.859371    -9.731253     7.019533     0.792219
          2    -12.301[illegible]       1.965970     0.347092    -1.331360     3.075403   -11.548598

          1'                    0.022206     3.494649    11.193100    12.799[illegible]    -7.383936     0.595701
 21       1     11.664[illegible]      -1.469[illegible]    -0.259633    -0.711209     1.380147   -14.650268
          2'                   -0.022216    -3.494649   -11.193100     8.037[illegible]    -2.943892     0.202011
          2    -11.664[illegible]       1.469[illegible]     0.259633     0.711200     2.175736    -8.297500

          1'                  -11.193170     3.495073     0.022912    -0.595764    -7.394649    12.799402
 22       1     11.664441      -1.469[illegible]    -0.259605    -0.711294     1.380438   -14.651655
          2'                   11.193170    -3.495078    -0.022912    -0.202113    -2.944142     8.033627
          2    -11.664441       1.469[illegible]     0.259605     0.711280     2.175881    -8.298226

          1'                  -21.050[illegible]    13.031226    -0.000006    -1.[illegible]    -0.000073    -2.840[illegible]
 23       1     24.692917       1.775747     0.000009    -0.000000    -0.000074     2.840[illegible]
          2'                   21.050[illegible]   -13.031226     0.000008    -0.000042    -0.000062   -31.297531
          2    -24.692917      -1.775747    -0.000009     0.000000    -0.000074    31.297531

          1'                  -11.193730     3.494569    -0.022690     0.595579     7.383780    12.797[illegible]
 24       1     11.663027      -1.469532     0.259578     0.711219    -1.380148   -14.649[illegible]
          2'                   11.193730    -3.494569     0.022690     0.202329     2.943834     8.037[illegible]
          2    -11.663027       1.469532    -0.259578    -0.711219    -2.175674    -8.297473

IHC212I
TRACEBACK FOLLOWS-   ROUTINE     ISN   REG. 14
                     IBCOM             82006C[illegible]
                     MAIN              00002849
ENTRY POINT=  61006020
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NUMBER OF NODES 15
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                                         MEMBER COORDINANTS
  MEMBER I        X(I,1)          X(I,2)          Y(I,1)          Y(I,2)          Z(I,1)          Z(I,2)

     1          -36.000000      -20.784988       0.0             20.784988       0.0             20.784988
     2          -36.000000      -25.455994       0.0             25.455994       0.0             0.0
     3          -36.000000      -20.784988       0.0             20.784988       0.0            -20.784988
     4           0.0            -20.784988       0.0             20.784988       36.000000       20.784988
     5          -20.784988      -25.455994       20.784988       25.455994       20.784988       0.0
     6          -25.455994      -20.784988       25.455994       20.784988       0.0            -20.784988
     7           0.0             20.784988       0.0             20.784988      -36.000000      -20.784988
     8          -20.784988       0.0             20.784988       25.455994       20.784988       25.455994
     9          -25.455994       0.0             25.455994       36.000000       0.0             0.0
    10          -20.784988       0.0             20.784988       25.455994      -20.784988      -25.455994
    11           0.0             0.0             0.0             25.455994       36.000000       25.455994
    12           0.0             0.0             25.455994       36.000000       25.455994       0.0
    13           0.0             0.0             36.000000       25.455994       0.0            -25.455994
    14           0.0             0.0             0.0             25.455994      -36.000000      -25.455994
    15           0.0             20.784988       25.455994       20.784988       25.455994       20.784988
    16           0.0             25.455994       36.000000       25.455994       0.0             0.0
    17           0.0             20.784988       25.455994       20.784988      -25.455994      -20.784988
    18           0.0             20.784988       0.0             20.784988       36.000000       20.784988
    19           20.784988       25.455994       20.784988       25.455994       20.784988       0.0
    20           25.455994       20.784988       25.455994       20.784988       0.0            -20.784988
    21           0.0             20.784988       0.0             20.784988      -36.000000      -20.784988
    22           20.779999       36.000000       20.779999       0.0             20.779999       0.0
    23           25.449997       36.000000       25.449997       0.0             0.0             0.0
    24           20.779999       36.000000       20.779999       0.0            -20.779999       0.0
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                                                         MEMBER PROPERTIES
  MEMBER I        IX              IY              IZ              AREA            RADIUS          PHI             ALPHA

     1           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670        1.287000
     2           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
     3           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670       -1.287000
     4           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670       -1.287000
     5           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742       -0.831423
     6           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742       -0.831423
     7           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670        1.287000
     8           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742        0.831423
     9           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    10           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742       -0.831423
    11           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    12           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    13           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    14           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    15           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742        0.831423
    16           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    17           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742       -0.831423
    18           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670        1.287000
    19           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742        0.831423
    20           0.000550        0.000326        0.000326        0.062500        36.000000       0.307742        0.831423
    21           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670       -1.287000
    22           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670        1.287000
    23           0.000550        0.000326        0.000326        0.062500        36.000000       0.392700        0.0
    24           0.000550        0.000326        0.000326        0.062500        36.000000       0.477670       -1.287000
```

```
 MEMB   NODE(I,1)   NODE(I,2)

    1        1           4
    2        2           5
    3        3           6
    4        0           4
    5        4           5
    6        5           6
    7        0           6
    8        4           7
    9        5           8
   10        6           9
   11        0           7
   12        7           8
   13        8           9
   14        0           9
   15        7          10
   16        8          11
   17        9          12
   18        0          10
   19       10          11
   20       11          12
   21        0          12
   22       10          13
   23       11          14
   24       12          15
```

```
 NODE   NRDN              LINK
                   1      2      3      4      5      6

   1      1        1      0      0      0
   2      1        2      0      0      0
   3      1        3      0      0      0
   4      4       -1     -4      5      8
   5      4       -2     -5      6      9
   6      4       -3     -6     -7     10
   7      4       -8    -11     12     15
   8      4       -9    -12     13     16
   9      4      -10    -13    -14     17
  10      4      -15    -18     19     22
  11      4      -16    -19     20     23
  12      4      -17    -20    -21     24
  13      1      -22      0      0      0
  14      1      -23      0      0      0
  15      1      -24      0      0      0
```

```
                                                   APPLIED NODAL LOADS
 NODE          PX             PY             PZ             MX             MY             MZ

    1          0.0            0.0            0.0            0.0            0.0            0.0
    2          0.0            0.0            0.0            0.0            0.0            0.0
    3          0.0            0.0            0.0            0.0            0.0            0.0
    4          0.0            0.0            0.0            0.0            0.0            0.0
    5          0.0            0.0            0.0            0.0            0.0            0.0
    6          0.0            0.0            0.0            0.0            0.0            0.0
    7          0.0            0.0            0.0            0.0            0.0            0.0
    8          0.0            0.0            0.0            0.0            0.0            0.0
    9          0.0            0.0            0.0            0.0            0.0            0.0
   10          0.0          -40.000000       0.0            0.0            0.0            0.0
   11          0.0            0.0            0.0            0.0            0.0            0.0
   12          0.0            0.0            0.0            0.0            0.0            0.0
   13          0.0            0.0            0.0            0.0            0.0            0.0
   14          0.0            0.0            0.0            0.0            0.0            0.0
   15          0.0            0.0            0.0            0.0            0.0            0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.6754088E 39


                                         NODAL DISPLACEMENTS
 NODE        DELTA-X        DELTA-Y        DELTA-Z        THETA-X        THETA-Y        THETA-Z

    1        0.0            0.0            0.0           -0.005634       0.009215      -0.010434
    2        0.0            0.0            0.0           -0.000655       0.005948      -0.003976
    3        0.0            0.0            0.0           -0.002004      -0.004152      -0.001392
    4        0.159222       0.055776      -0.093064      -0.003843       0.000026      -0.002467
    5        0.010728       0.013363      -0.075798      -0.000222       0.005882       0.003423
    6       -0.040652       0.002423      -0.078181      -0.002650       0.001957       0.004048
    7        0.192465      -0.087487      -0.143823      -0.007058       0.003064      -0.015069
    8       -0.016549       0.051464      -0.101322       0.004063       0.001118      -0.002985
    9       -0.053564       0.034495      -0.073972      -0.003862      -0.003264       0.000010
   10        0.198900      -0.428630       0.046474      -0.020330      -0.004191       0.021766
   11       -0.040893      -0.053085       0.054137       0.012072       0.001784       0.007130
   12       -0.078560       0.035988       0.048537      -0.000079      -0.002487       0.000717
   13        0.0            0.0            0.0            0.018424       0.059561      -0.026546
   14        0.0            0.0            0.0           -0.002435      -0.000408      -0.006370
   15        0.0            0.0            0.0            0.004436       0.003921       0.005409


                                     MEMBER END FORCES AND MOMENTS
                            PPX          PPY          PPZ          MPX          MPY          MPZ
 MEMB.  END       PX        PY           PZ           MX           MY           MZ

         1'              -1.232122    -2.142327    -2.204646     0.000039    -0.000245     0.000178
         1   -3.296151   -0.321760     0.003122    -0.000024    -0.000012     0.000304
   1     2'               1.232121     2.142323     2.204642    -1.295363     7.934389    -6.296135
         2    3.296145    0.321759    -0.003122     0.000013    -0.103323   -10.650253

         1'              -0.567262    -1.409019     0.010423    -0.000019     0.000047    -0.000032
         1   -1.518845   -0.015116     0.010423     0.000036     0.000036    -0.000092
   2     2'               0.567261     1.409015    -0.010423     0.265350    -0.109947    -0.416521
         2    1.518841    0.015115    -0.010423    -0.000034    -0.287226    -0.416529

         1'              -0.744847    -1.259261     1.305142     0.000013     0.000065     0.000049
         1   -1.952761   -0.174962     0.006876     0.000016    -0.000018     0.000078
   3     2'               0.744846     1.259261    -1.305141     0.953638    -4.376123    -3.678012
         2    1.952759    0.174962    -0.006875    -0.000007    -0.227588    -5.791027

         1'              -2.172884     1.562993    -1.127028    -3.047172    -1.593038     6.537444
         1    2.864091    0.274338    -0.395321    -2.089717     6.697121    -2.326223
   4     2'               2.172884    -1.562993     1.127029     3.402864    11.228116     6.144071
         2   -2.864091   -0.274339     0.395321     2.089677     6.397449    11.406383

         1'               0.473238     0.536191    -2.403889    -3.517875   -14.908717    -5.279231
         1    2.304452   -0.701203     0.698533     2.583114    -8.283018   -13.230135
   5     2'              -0.473239    -0.536205     2.403869     3.433440    -6.156617     0.555255
         2   -2.304436    0.701188    -0.698544    -2.583107    -6.250641    -2.063440

         1'               0.324376    -0.470716    -2.143113    -0.568745     1.605123    -0.419563
         1    2.212624    0.115891    -0.100602    -0.066683     1.575238     0.767632
   6     2'              -0.324407     0.470245     2.143106     0.806800     1.664222    -0.262507
         2   -2.212629   -0.115848     0.100602     0.066673     0.618643     1.761139

         1'              -1.259095     1.297213     1.183397     6.666121     6.730664    -2.078082
         1    2.149271   -0.221609     0.005594    -0.914732     0.458049    -9.644215
   7     2'               1.259095    -1.297213    -1.183397    -1.806348    -1.290929     1.285722
         2   -2.149271    0.221609    -0.005584     0.914726    -0.642868     2.309251

         1'              -3.879219    -1.115711    -0.227680     1.410549    -4.253512     6.113074
         1   -4.134641   -0.199089     0.137367     1.742543     0.986741     7.310322
   8     2'               3.879238     1.115742     0.927711    -0.532238     5.416380   -11.183922
         2    4.134672    0.199125    -0.137367    -1.742507    -3.982593   -11.653530

         1'              -0.418147    -0.402718    -0.251366    -3.131734     4.660124     0.279758
         1   -0.540430   -0.212049    -0.251366    -1.110032     5.503847     0.279758
   9     2'               0.413152     0.402720     0.251366     0.481331     1.738651    -6.122457
         2    0.540435    0.212048     0.251366     1.110034     1.422114    -6.122457
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         1'                -1.679472   -0.432081    0.346083    0.046415    4.003270    2.654762
         1    -1.767243    -0.014368   -0.061140    0.333039    0.790980    4.726430
  10     2'                 1.679449    0.432070   -0.346071   -0.448097   -3.351555   -3.790497
         2     1.767217     0.014359    0.061141   -0.333041    0.542393   -5.039484

         1'                -0.194318    6.252525   -2.189238   -4.512263    0.357020    7.411133
         1     6.614367     0.370099   -0.194318   -2.506224    6.983638   -4.512263
  11     2'                 0.194318   -6.252525    2.189238   14.709961    1.691861   -2.464594
         2    -6.614367    -0.370099    0.194318    2.506223   -1.629559   14.709961

         1'                 1.450416    0.324870   -3.385584  -23.487045  -16.929474  -13.838737
         1     3.252201    -0.995442    1.450416    6.306846  -20.936600  -23.487045
  12     2'                -1.450416   -0.324890    3.385592   -3.940898  -19.992310   -1.454459
         2    -3.252216     0.995427   -1.450416   -6.306846  -19.027115   -3.940898

         1'                 0.266009   -0.705444   -2.107691    0.833989   -2.108016   -0.097741
         1     2.217215     0.154817    0.266009    0.896991   -1.910154    0.833989
  13     2'                -0.266009    0.705413    2.107685    3.431840   -4.663514    2.902540
         2    -2.217197    -0.154844   -0.266009   -0.896987   -5.419272    3.431840

         1'                 0.150464    1.584593    0.820566    6.665943    1.282538   -2.172465
         1     1.777988    -0.151720   -0.150464    0.353562    2.497899   -6.665943
  14     2'                -0.150464   -1.584593   -0.820566   -2.485449    0.303053   -1.657744
         2    -1.777988     0.151720    0.150464   -0.353563    1.647877    2.485449

         1'                -5.522141    4.812387    0.268787    9.308955    9.824526   27.484390
         1    -6.351003     1.680551   -3.250528    0.881104   28.229385   11.869898
  15     2'                 5.522217   -4.812346   -0.268746   11.914280   10.387884   46.742691
         2     6.351059    -1.680471    3.250526   -0.881226   42.663239   24.775131

         1'                 0.766305    0.627431   -1.528727    2.626074   20.361725    7.674747
         1     0.467872     0.872919   -1.528727   -5.365779   19.816757    7.674747
  16     2'                -0.766299   -0.627427    1.528727   13.492826   18.553513   16.377029
         2    -0.467869    -0.872914    1.528727    5.365783   22.304642   16.377029

         1'                -1.263977    0.447056   -0.941391   -0.498669    7.712433    2.547993
         1    -1.501972     0.560369   -0.337314   -1.581523    3.169612    7.326010
  17     2'                 1.263950   -0.447072    0.941406    2.807785    5.949600    0.832875
         2     1.501953    -0.560398    0.337313    1.581527    4.187304    4.994090

         1'                14.777126   16.999359  -12.215216  -41.069351   62.199356   29.305252
         1    25.560778    -0.743957   -1.478292   -0.202210   21.836975  -77.054214
  18     2'               -14.777126  -16.999359   12.215216   45.822235  -33.140640   16.884186
         2   -25.560778     0.743957    1.478292    0.202243   27.093018   52.430710

         1'                 1.453578   -4.417094    1.584736  -52.740540  -21.095917  -16.118027
         1    -2.145001    -1.425500    4.183529   -0.452896  -55.118225  -21.169922
  19     2'                -1.453573    4.417111   -1.584640  -31.665329  -16.520081  -11.303876
         2     2.144914     1.425544   -4.183537    0.452862  -36.122192   -9.917859

         1'                 0.735400    0.457269    0.405451    9.282898   -5.719547    1.256635
         1    -0.641844     0.685031    0.181657   -2.627900    2.041363   10.566021
  20     2'                -0.735428   -0.457299   -0.405481   -1.672421   -7.671998   -0.657462
         2     0.641884    -0.685111   -0.181654    2.627904   -6.003284    4.375328

         1'                 0.055140   -0.158724   -0.139066   -0.816839    2.455376   -2.733136
         1    -0.128974     0.111024   -0.136427   -0.227461    2.588849    2.722603
  21     2'                -0.055140    0.158724    0.139066    0.341357    1.274013   -1.711039
         2     0.128974    -0.111024    0.136427    0.227448    1.926678    0.952127

         1'                 7.800955  -13.772197  -13.531759   -4.996105   43.850632  -47.502288
         1    20.731567    -1.905908    0.454573   -0.000031  -15.043879  -63.077011
  22     2'                -7.800969   13.772193   13.531742   -0.000179   -0.001265    0.001137
         2   -20.731552     1.905887   -0.454579   -0.000002    0.000051    0.001709

         1'                 1.484360   -4.247066   -0.349324    8.990245    3.685341   -7.029814
         1     4.491747    -0.255157   -0.349324    0.000007    0.623836   -7.029816
  23     2'                -1.484360    4.247059    0.349324    0.000031    0.000023   -0.000145
         2    -4.491740     0.255155    0.349324   -0.000010    0.000038   -0.000145

         1'                -0.472502    0.745572   -0.674516   -1.476487    0.447468    1.528910
         1    -1.108963    -0.034402    0.055897    0.000007   -1.849809    1.138424
  24     2'                 0.472501   -0.745569    0.674514   -0.000007    0.000032    0.000022
         2     1.108960    -0.034402   -0.055896   -0.000009   -0.000008    0.000037


IHC217I
TRACEBACK FOLLOWS-   ROUTINE    ISN   REG. 14
                     IBCOM            8200EDC0
                     MAIN             0000284B

ENTRY POINT=  500D5020
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                                       APPLIED NODAL LOADS
  NODE        PX            PY            PZ            MX            MY            MZ

    1        0.0           0.0           0.0           0.0           0.0           0.0
    2        0.0           0.0           0.0           0.0           0.0           0.0
    3        0.0           0.0           0.0           0.0           0.0           0.0
    4        0.0           0.0           0.0           0.0           0.0           0.0
    5        0.0           0.0           0.0           0.0           0.0           0.0
    6        0.0        -40.000000       0.0           0.0           0.0           0.0
    7        0.0           0.0           0.0           0.0           0.0           0.0
    8        0.0           0.0           0.0           0.0           0.0           0.0
    9        0.0           0.0           0.0           0.0           0.0           0.0
   10        0.0           0.0           0.0           0.0           0.0           0.0
   11        0.0           0.0           0.0           0.0           0.0           0.0
   12        0.0           0.0           0.0           0.0           0.0           0.0
   13        0.0           0.0           0.0           0.0           0.0           0.0
   14        0.0           0.0           0.0           0.0           0.0           0.0
   15        0.0           0.0           0.0           0.0           0.0           0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.6754088E 39


                                     NODAL DISPLACEMENTS
  NODE      DELTA-X       DELTA-Y       DELTA-Z       THETA-X       THETA-Y       THETA-Z

    1        0.0           0.0           0.0         -0.004438      0.003920     -0.005411
    2        0.0           0.0           0.0          0.002439     -0.000400      0.006372
    3        0.0           0.0           0.0         -0.018429      0.059558      0.026565
    4        0.078613      0.036010     -0.048579      0.000078     -0.002487     -0.000718
    5        0.040880     -0.053064     -0.054171     -0.012077      0.001787     -0.007130
    6       -0.198981     -0.428638     -0.046506      0.020323     -0.004193     -0.021765
    7        0.053607      0.034506      0.073997      0.003863     -0.003267     -0.000010
    8        0.016542      0.051468      0.101349     -0.004064      0.001118      0.002984
    9       -0.192527     -0.087505      0.143858      0.007059      0.003062      0.015070
   10        0.040697      0.002422      0.078237      0.002651      0.001957     -0.004050
   11       -0.010733      0.013364      0.075848      0.000221      0.005885     -0.003423
   12       -0.159281      0.055780      0.093172      0.003844      0.000025      0.002469
   13        0.0           0.0           0.0          0.002006     -0.004151      0.001389
   14        0.0           0.0           0.0          0.000655      0.005951      0.003977
   15        0.0           0.0           0.0          0.005639      0.009221      0.010439


                                  MEMBER END FORCES AND MOMENTS
                          PPX           PPY           PPZ           MPX           MPY           MPZ
 MEMB.  END     PX        PY            PZ            MX            MY            MZ

         1'              -0.472051     -0.745210     -0.674093      0.000014     -0.000074      0.000056
         1   -1.108273   -0.034295      0.055917     -0.000005     -0.000004      0.000094
   1     2'               0.472051      0.745209      0.674090      1.478179      0.444796     -1.526844
         2    1.108270    0.034294     -0.055918      0.000004     -1.850805     -1.135176

         1'               1.483054      4.246929     -0.349334     -0.000055      0.000025      0.000158
         1    4.491192    0.255034     -0.349334      0.000002      0.000060      0.000168
   2     2'              -1.483057     -4.246922      0.349334     -8.892600      3.683355      7.027069
         2   -4.491185   -0.255033      0.349334     -0.000006      9.625251      7.027069

         1'               7.796214     13.773074    -13.531968      0.000163     -0.001465     -0.001130
         1   20.730515    1.905673      0.454680     -0.000098      0.000044     -0.001891
   3     2'              -7.796208    -13.773055     13.531965      5.011091     43.846269     47.514374
         2  -20.730499   -1.905673     -0.454669      0.000061    -15.049174     63.077271

         1'              -0.054928     -0.159117      0.139395      0.818727      2.458030      2.735763
         1   -0.129505    0.111138     -0.136539     -0.728122      2.500897      2.726195
   4     2'               0.054928      0.159117     -0.139395     -0.342366      1.274912      1.713104
         2    0.129505   -0.111138      0.136539      0.228115      1.028327      0.952298

         1'               0.735975     -0.457291      0.406527      1.673833     -7.676162      0.655235
         1   -0.642997   -0.685166      0.182046     -2.626976     -6.007672     -4.377371
   5     2'              -0.735975      0.457276     -0.406530     -9.280033     -5.722392     -1.2566[illegible]
         2    0.642996    0.685156     -0.182056      2.626982      2.037427    -11.566085

         1'               1.453811      4.417096      1.586323     31.668198    -16.571835     11.304440
         1   -2.146464    1.424960      4.183681     -0.452409    -36.125488      0.918588
   6     2'              -1.453838     -4.417067     -1.586385     52.731476    -21.104752     16.118333
         2    2.146511   -1.424804     -4.183678      0.452498    -55.117889     21.157272

         1'             -14.775113     16.997787     12.213729     41.063248     62.193161    -20.302193
         1   25.566833   -0.743848     -1.478622     -0.204081     21.841675    -77.046127
   7     2'              14.775113    -16.997787    -12.213729    -45.823334    -33.134970    -16.882435
         2  -25.566833    0.743848      1.478622      0.204072     27.099335     52.426514

         1'              -1.263768     -0.446968     -0.941808     -2.810047      5.955952     -0.940626
         1   -1.501842   -0.560662     -0.337665     -1.582548      4.191443     -4.900416
   8     2'               1.263782      0.446998      0.941836      0.498691      7.716904     -2.546031
         2    1.501869    0.560696      0.337663      1.582535      3.172655     -7.329127

         1'               0.765459     -0.627717     -1.529229    -13.495960     18.560425    -16.374557
         1    0.466981   -0.872860     -1.529228     -5.366035     22.312225    -16.374557
   9     2'              -0.765472      0.627708      1.529228     -2.628229     20.367569     -7.675522
         2   -0.466997    0.872857      1.529228      5.366024     19.822983     -7.675522
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10	1'		-5.526794	-4.813293	0.268973	-11.919114	10.396805	-46.741486
	1	-6.355673	-1.679865	-3.251022	0.878271	42.669739	-24.767822	
	2'		5.526932	4.813259	-0.268941	-9.307311	9.826946	-27.487778
	2	6.355789	1.679779	3.251019	-0.878293	28.232819	-11.870497	
11	1'		-0.150593	1.585025	-0.820841	-6.668329	1.283508	2.174337
	1	1.778493	-0.151808	-0.150593	0.353741	2.500000	-6.668329	
	2'		0.150593	-1.585025	0.820841	2.485435	0.304341	1.659144
	2	-1.778493	0.151808	0.150593	-0.353741	1.649318	2.485435	
12	1'		0.266383	0.705784	-2.108379	-3.431993	-4.668794	-2.905354
	1	2.717980	-0.154767	0.266383	0.897566	-5.425227	-3.431993	
	2'		-0.266383	-0.705773	2.108375	-0.832590	-2.112240	0.096617
	2	-2.717972	0.154775	-0.266383	-0.897568	-1.914487	-0.832590	
13	1'		1.450819	-0.325080	-3.386505	3.940749	-19.996994	1.455318
	1	3.253132	0.995601	1.450819	6.307845	-19.031784	3.940749	
	2'		-1.450819	0.325096	3.386495	23.490524	-16.935028	13.942131
	2	-3.253128	-0.995582	-1.450819	-6.307857	-20.943024	23.490524	
14	1'		0.194513	6.253847	2.189587	4.512067	0.358154	-7.414121
	1	6.615723	0.370281	-0.194513	-2.506320	6.986833	-4.512067	
	2'		-0.194513	-6.253847	-2.189587	-14.714828	1.692798	2.462593
	2	-6.615723	-0.370281	0.194513	2.506319	-1.627341	14.714829	
15	1'		-1.679699	0.432182	0.345951	0.448082	-3.350984	3.791693
	1	-1.767453	0.014275	-0.061302	0.332645	0.543594	5.039907	
	2'		1.679664	-0.432166	-0.345951	-0.045365	4.006431	-2.655100
	2	1.767416	-0.014275	0.061291	-0.332654	0.793180	-4.728990	
16	1'		-0.419004	0.403023	-0.251645	-0.480533	1.741712	6.123472
	1	-0.541338	0.212002	-0.251645	-1.110468	1.425247	6.123472	
	2'		0.419018	-0.403026	0.251645	3.133876	4.664155	-0.282123
	2	0.541357	-0.212000	0.251645	1.110469	5.508391	-0.282123	
17	1'		-3.881577	1.116187	-0.928168	0.532098	5.416811	11.184505
	1	-4.137095	0.199025	0.137357	1.742393	-3.282709	11.654199	
	2'		3.881604	-1.116228	0.928225	-1.410290	-4.255327	-6.115310
	2	4.137142	-0.199082	-0.137347	-1.742405	0.987226	-7.313227	
18	1'		1.259159	1.297402	-1.183649	-6.668314	6.733206	2.079874
	1	2.149546	-0.221762	0.005517	-0.915338	0.459244	-9.647777	
	2'		-1.259159	-1.297402	1.183649	1.806157	-1.289203	-1.285031
	2	-2.149546	0.221762	-0.005517	0.915326	-0.641878	2.307734	
19	1'		0.324642	0.470257	-2.143541	-0.805772	1.660836	0.261612
	1	2.213098	-0.115810	-0.100444	-0.066191	0.616970	-1.758136	
	2'		-0.324643	-0.470242	2.143541	0.568529	1.603016	.418554
	2	-2.213094	0.115820	0.100433	0.066192	1.573701	-0.766261	
20	1'		0.473485	-0.536381	-2.404829	-3.435434	-6.158470	-0.555154
	1	2.305335	0.701533	0.698835	2.583836	-6.253266	2.063399	
	2'		-0.473531	0.536336	2.404806	3.519097	-14.915108	5.272202
	2	-2.305295	-0.701589	-0.698834	-2.583826	-8.987860	13.235666	
21	1'		2.173569	1.563548	1.127316	3.047155	-1.592538	-4.533860
	1	2.865003	0.274496	-0.395391	-2.090064	6.588466	-2.325656	
	2'		-2.173569	-1.563548	-1.127316	-3.405279	11.232065	-6.145375
	2	-2.865003	-0.274496	0.395391	2.090040	6.398429	11.411078	
22	1'		-0.745419	1.259472	1.305398	-0.255371	-4.378305	2.678631
	1	-1.953245	0.175053	0.006900	0.000010	-0.228367	5.793331	
	2'		0.745420	-1.259423	-1.305397	-0.000010	0.000012	-0.000057
	2	1.953245	-0.175052	-0.006899	-0.000013	-0.000017	-0.000089	
23	1'		-0.567912	1.409674	0.010430	-0.265480	-0.113393	0.418734
	1	-1.519695	0.015198	0.010430	0.000035	-0.287401	0.418734	
	2'		0.567910	-1.409670	-0.010430	0.000038	0.000055	-0.000006
	2	1.519691	-0.015198	-0.010430	-0.000036	0.000056	-0.000013	
24	1'		-1.233493	2.143239	-2.205620	1.296339	7.937520	4.283860
	1	-3.297803	0.321925	0.003157	-0.000028	-0.104395	10.654011	
	2'		1.233492	-2.143237	2.205619	-0.000029	-0.000037	-0.000043
	2	3.297800	-0.321925	-0.003157	0.000014	-0.000026	-0.000026	

```
                                              APPLIED NODAL LOADS
 NODE      PX           PY              PZ             MX             MY             MZ
   1      0.0          0.0             0.0            0.0            0.0            0.0
   2      0.0          0.0             0.0            0.0            0.0            0.0
   3      0.0          0.0             0.0            0.0            0.0            0.0
   4      0.0          0.0             0.0            0.0            0.0            0.0
   5      0.0        -20.000000        0.0            0.0            0.0            0.0
   6      0.0          0.0             0.0            0.0            0.0            0.0
   7      0.0        -20.000000        0.0            0.0            0.0            0.0
   8      0.0          0.0             0.0            0.0            0.0            0.0
   9      0.0        -20.000000        0.0            0.0            0.0            0.0
  10      0.0          0.0             0.0            0.0            0.0            0.0
  11      0.0        -20.000000        0.0            0.0            0.0            0.0
  12      0.0          0.0             0.0            0.0            0.0            0.0
  13      0.0          0.0             0.0            0.0            0.0            0.0
  14      0.0          0.0             0.0            0.0            0.0            0.0
  15      0.0          0.0             0.0            0.0            0.0            0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.6754088E 39


                                       NODAL DISPLACEMENTS
 NODE     DELTA-X              DELTA-Y          DELTA-Z        THETA-X        THETA-Y        THETA-Z
   1     0.0                  0.0              0.0            0.002206      -0.005723      -0.001905
   2     0.0                  0.0              0.0            0.000000      -0.000000       0.022809
   3     0.0                  0.0              0.0           -0.002206       0.005723      -0.001905
   4    -0.[illegible]7321   -0.046350         0.045081      -0.006311      -0.000265      -0.004671
   5    -0.[illegible]3911   -0.130664         0.000001       0.000000      -0.000000      -0.011617
   6    -0.[illegible]7321   -0.046350        -0.045079       0.006311       0.000265      -0.004671
   7    -0.000004            -0.089125        -0.063291      -0.008245      -0.000001       0.000001
   8    -0.000057             0.069316         0.000001      -0.000000       0.000000      -0.000001
   9    -0.000004            -0.089125         0.063292       0.008245       0.000001       0.000001
  10     0.[illegible]7216   -0.046357         0.045128      -0.006315       0.000269       0.004672
  11    -0.[illegible]3965   -0.139730         0.000000       0.000000       0.000000       0.011617
  12     0.[illegible]7217   -0.046357        -0.045128       0.006315      -0.000269       0.004672
  13     0.0                  0.0              0.0            0.002202       0.005724       0.001912
  14     0.0                  0.0              0.0            0.000000      -0.000000      -0.022789
  15     0.0                  0.0              0.0           -0.002202      -0.005724       0.001912



                                MEMBER END FORCES AND MOMENTS
                             PPX            PPY            PPZ            MPX            MPY            MPZ
 MEMB.  END      PX          PY             PZ             MY             MY             MZ

         1*                  0.062993      -0.030001      -0.233951      -0.000030       0.000078      -0.000072
         1   -0.1[illegible] -0.143719     -0.124433      -0.000000       0.000013      -0.000109
   1     2*                 -0.062993       0.030002       0.233952      -4.237163       4.451146      -1.349453
         2    0.14[illegible] 0.143711      0.124433       0.000005       4.119520      -4.756579

         1*                  6.273901      16.413086      -0.000001      -0.000034      -0.000001       0.000198
         1   12.1[illegible]  1.433443     -0.000001      -0.000003       0.000013       0.000198
   2     2*                 -6.273905     -16.413055       0.000001      -0.000015       0.000030      33.997175
         2  -12.1[illegible] -1.433427      0.000001       0.000003       0.000017      33.997175

         1*                  0.062962      -0.030007       0.233263       0.000026      -0.000159      -0.000137
         1   -0.14[illegible] -0.143722     0.124431      -0.000001       0.000031      -0.000211
   3     2*                 -0.062953       0.030003      -0.233864       4.237002      -4.450217      -1.349180
         2    0.14[illegible] 0.143722     -0.124431      -0.000003      -4.119593      -4.756146

         1*                 -1.363[illegible] 1.661216    -1.502176      -4.373242      -0.725207      -3.286566
         1    0.6[illegible] -0.302236      0.163317      -0.594195      -2.226771     -11.947011
   4     2*                  1.363[illegible] -1.661216    1.502176       0.411714      -3.029926      -3.111612
         2   -0.6[illegible]  0.302236     -0.163317       0.594195      -2.1[illegible] -0.925216

         1*                 -1.301763       1.237063      -2.674722       1.204992       5.725310       2.923383
         1    0.11[illegible] 0.[illegible] -0.001707     -1.730000       2.223512       6.247247
   5     2*                  1.3[illegible] -1.237061      2.674721      11.023331      10.811121      -2.274449
         2   -0.11[illegible] -0.[illegible] 0.001714      1.73079       -1.733777      15.041512

         1*                  1.326[illegible] -1.237107    -2.674921     -11.023466     -10.811310      -2.174431
         1    0.11[illegible] -0.067016     0.001601       1.730797       1.232730     -16.041749
   6     2*                 -1.3[illegible]  1.237107      2.674939      -1.204759      -5.726246       2.923394
         2   -0.11[illegible] 0.067357     -0.001600      -1.730794      -3.730560      -5.947832

         1*                 -1.36[illegible] 1.660173      1.502137       4.373052       0.725133      -3.286557
         1    0.6[illegible] -0.302[illegible] -0.163329    0.594199       2.226205     -11.847636
   7     2*                  1.362343      -1.660173      -1.502137      -0.411659       0.229920      -3.111674
         2   -0.6[illegible]  0.30[illegible] 0.163329     -0.594200       2.109958      -1.925332

         1*                  0.[illegible]7414 0.303004    0.038514       2.531514      -9.256628       1.640674
         1     .2[illegible]  0.[illegible]11 0.366601      0.721453      -5.720273       7.933303
   8     2*                 -0.[illegible] -0.330001      -0.329523       0.017135      -3.941731       6.116662
         2   -[illegible]581 -0.570023     -0.366601      -0.791446      -2.266953      11.336974

         1*                  0.461334      -1.112875      -0.000002       0.000014       0.000012     -34.658157
         1    1.[illegible]  -1.[illegible] -0.000002      0.000019       0.000005     -34.658157
   9     2*                 -0.461337       1.112861       0.000002      -0.000037       0.000042     -10.922739
         2   -1.[illegible]   1.677991      0.000003      -0.000019       0.000053     -10.922739
```

10	1'		0.087255	0.392844	-0.938466	-2.531481	9.256627	1.640639
	1	0.368289	0.878999	-0.366585	-0.781427	5.728345	7.833314	
	2'		-0.087246	-0.392850	0.938474	-0.017185	9.841491	6.116443
	2	-0.368282	-0.879010	0.366586	0.781428	2.266905	11.336523	
11	1'		0.000018	20.327377	-8.541472	-38.874161	0.000138	-0.000407
	1	22.048706	-0.112499	0.000018	0.000283	-0.000324	-38.874161	
	2'		-0.000018	-20.327377	8.541472	35.775085	-0.000330	-0.000057
	2	-22.048706	0.112499	-0.000018	-0.000283	-0.000179	35.775085	
12	1'		0.000315	1.113007	-6.663794	-35.811737	-0.003959	-0.002092
	1	6.582482	-1.521792	0.000315	0.000418	-0.004458	-35.811737	
	2'		-0.000315	-1.113018	6.663803	-6.118742	-0.004069	-0.001233
	2	-6.582496	1.521795	-0.000315	-0.000418	-0.004231	-6.118742	
13	1'		-0.000315	-1.113036	-6.663864	6.118708	0.004066	-0.001235
	1	6.582559	1.521792	-0.000315	-0.000415	0.004229	6.118708	
	2'		0.000315	1.113036	6.663852	35.811874	0.003950	-0.002085
	2	-6.582547	-1.521739	0.000315	0.000415	0.004447	35.811874	
14	1'		0.000019	20.327332	8.541446	38.874023	-0.000137	-0.000420
	1	22.048663	-0.112493	-0.000019	-0.000287	0.000336	-38.874023	
	2'		-0.000019	-20.327332	-8.541446	-35.775009	0.000336	-0.000060
	2	-22.048663	0.112493	0.000019	0.000287	0.000194	35.775009	
15	1'		0.086963	-0.392626	-0.939043	0.019273	9.845930	-6.114370
	1	0.368087	-0.879341	-0.367139	-0.780833	2.271887	-11.338306	
	2'		-0.086017	0.392626	0.939043	2.533080	9.265639	-1.639719
	2	-0.368043	0.879355	0.367138	0.780821	5.735404	-7.839184	
16	1'		2.490062	1.112859	0.000003	-0.000043	-0.000059	19.825027
	1	1.866260	1.077556	0.000003	-0.000021	-0.000063	19.825027	
	2'		-2.490042	-1.112859	-0.000003	0.000009	-0.000033	34.663193
	2	-1.866239	-1.077552	-0.000003	0.000021	-0.000027	34.663193	
17	1'		0.087269	-0.392684	0.939099	-0.019279	-9.846084	-6.114523
	1	0.368303	-0.879327	0.367137	0.780829	-2.271886	-11.338524	
	2'		-0.087214	0.392684	-0.939098	-2.533265	-9.265269	-1.639350
	2	-0.368269	0.879341	-0.367137	-0.780830	-5.735432	-7.839670	
18	1'		[illegible]	1.661939	-1.503774	-6.391210	9.734462	[illegible]
	1	[illegible]	[illegible]	-0.163312	0.594297	2.226630	-11.860133	
	2'		[illegible]	-1.661933	1.503774	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	-0.594290	[illegible]	[illegible]	
19	1'		[illegible]	[illegible]	-2.677294	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	1.739172	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	2.677201	[illegible]	-11.822344	[illegible]
	2	[illegible]	[illegible]	[illegible]	-1.739150	[illegible]	[illegible]	
20	1'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
21	1'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
22	1'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	-0.234617	[illegible]	[illegible]	
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
23	1'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
24	1'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	-0.147371	[illegible]	[illegible]	-0.000009	[illegible]	[illegible]	
	2'		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

```
NUMBER OF NODES 15
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  2
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                                        MEMBER COORDINANTS
MEMBER-I        X(I,1)           X(I,2)            Y(I,1)          Y(I,2)          Z(I,1)          Z(I,2)

    1       -33.369995      -18.369995        0.0             9.740000       13.500000       18.369995
    2       -36.000000      -20.129990        0.0            13.250000        0.0             0.0
    3       -33.369995      -18.369995        0.0             9.740000      -13.500000      -18.369995
    4       -13.500000      -18.369995        0.0             9.740000       33.369995       18.369995
    5       -18.369995      -20.129990        9.740000       13.250000       18.369995        0.0
    6       -20.129990      -18.369995       13.250000        9.740000        0.0            -18.369995
    7       -13.500000      -18.369995        0.0             9.740000      -33.369995      -18.369995
    8       -18.369995        0.0             9.740000       13.250000       18.369995       20.129990
    9       -20.129990        0.0            13.250000       18.000000        0.0             0.0
   10       -18.369995        0.0             9.740000       13.250000      -18.369995      -20.129990
   11         0.0             0.0             0.0            13.250000       36.000000       20.129990
   12         0.0             0.0            13.250000       18.000000       20.129990        0.0
   13         0.0             0.0            18.000000       13.250000        0.0            -20.129990
   14         0.0             0.0             0.0            13.250000      -36.000000      -20.129990
   15         0.0            18.369995       13.250000        9.740000       20.129990       18.369995
   16         0.0            20.129990       18.000000       13.250000        0.0             0.0
   17         0.0            18.369995       13.250000        9.740000      -20.129990      -18.369995
   18        13.500000       18.369995        0.0             9.740000       33.369995       18.369995
   19        18.369995       20.129990        9.740000       13.250000       18.369995        0.0
   20        20.129990       18.369995       13.250000        9.740000        0.0            -18.369995
   21        13.500000       18.369995        0.0             9.740000      -33.369995      -18.369995
   22        18.369995       33.369995        9.740000        0.0            18.369995       13.500000
   23        20.129990       36.000000       13.250000        0.0             0.0             0.0
   24        18.369995       33.369995        9.740000        0.0           -18.369995      -13.500000
```

```
                                                        MEMBER PROPERTIES
MEMBER-I          IX              IY              IZ             AREA           RADIUS           PHI           ALPHA

    1          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430       0.761490
    2          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
    3          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430      -0.761490
    4          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430      -0.761490
    5          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200      -0.505970
    6          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200      -0.505970
    7          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430       0.761490
    8          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200       0.505970
    9          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   10          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200      -0.505970
   11          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   12          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   13          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   14          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   15          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200       0.505970
   16          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   17          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200      -0.505970
   18          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430       0.761490
   19          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200       0.505970
   20          0.000550        0.000326        0.000326        0.062500       45.000000       0.210200       0.505970
   21          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430      -0.761490
   22          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430       0.761490
   23          0.000550        0.000326        0.000326        0.062500       45.000000       0.231870       0.0
   24          0.000550        0.000326        0.000326        0.062500       45.000000       0.207430      -0.761490
```

```
MEMB   NODE(I,1)   NODE(I,2)

  1        1           4
  2        2           5
  3        3           6
  4        0           4
  5        4           5
  6        5           6
  7        0           6
  8        4           7
  9        5           8
 10        6           9
 11        0           7
 12        7           8
 13        8           9
 14        0           9
 15        7          10
 16        8          11
 17        9          12
 18        0          10
 19       10          11
 20       11          12
 21        0          12
 22       10          13
 23       11          14
 24       12          15
```

```
NODE    NMBN                    LINK
                     1       2       3       4       5       6

  1       1          1       0       0       0
  2       1          2       0       0       0
  3       1          3       0       0       0
  4       4         -1      -4       5       8
  5       4         -2      -5       6       9
  6       4         -3      -6      -7      10
  7       4         -8     -11      12      15
  8       4         -9     -12      13      16
  9       4        -10     -13     -14      17
 10       4        -15     -18      19      22
 11       4        -16     -19      20      23
 12       4        -17     -20     -21      24
 13       1        -22       0       0       0
 14       1        -23       0       0       0
 15       1        -24       0       0       0
```

```
                                             APPLIED NODAL LOADS
  NODE        PX             PY             PZ             MX             MY             MZ

     1        0.0            0.0            0.0            0.0            0.0            0.0
     2        0.0            0.0            0.0            0.0            0.0            0.0
     3        0.0            0.0            0.0            0.0            0.0            0.0
     4        0.0            0.0            0.0            0.0            0.0            0.0
     5        0.0            0.0            0.0            0.0            0.0            0.0
     6        0.0          -40.000000       0.0            0.0            0.0            0.0
     7        0.0            0.0            0.0            0.0            0.0            0.0
     8        0.0            0.0            0.0            0.0            0.0            0.0
     9        0.0            0.0            0.0            0.0            0.0            0.0
    10        0.0            0.0            0.0            0.0            0.0            0.0
    11        0.0            0.0            0.0            0.0            0.0            0.0
    12        0.0            0.0            0.0            0.0            0.0            0.0
    13        0.0            0.0            0.0            0.0            0.0            0.0
    14        0.0            0.0            0.0            0.0            0.0            0.0
    15        0.0            0.0            0.0            0.0            0.0            0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =    0.5073614E 67


                                        NODAL DISPLACEMENTS
  NODE       DELTA-X        DELTA-Y        DELTA-Z        THETA-X        THETA-Y        THETA-Z

     1        0.0            0.0            0.0            0.006576      -0.002586       0.010161
     2        0.0            0.0            0.0           -0.004542      -0.012898       0.003400
     3        0.0            0.0            0.0            0.005852      -0.000714      -0.007455
     4       -0.088426       0.084096       0.080606       0.005951       0.003334       0.000784
     5       -0.043170       0.048367       0.085477      -0.011205      -0.006980      -0.000602
     6        0.136753      -0.152276       0.131245       0.005813       0.000851      -0.004698
     7       -0.060974      -0.025105      -0.019541      -0.001174       0.004289      -0.005080
     8       -0.026624      -0.021367      -0.020879       0.001576      -0.000157      -0.001588
     9        0.091051       0.042268      -0.034825       0.000026       0.006010       0.009155
    10       -0.065801      -0.062582      -0.058780      -0.003962       0.001319       0.002546
    11       -0.025399      -0.027227      -0.056831       0.006730      -0.005321       0.000861
    12        0.092233       0.084689      -0.082958      -0.002072      -0.000325      -0.003369
    13        0.0            0.0            0.0           -0.004837      -0.002784       0.008081
    14        0.0            0.0            0.0            0.003401      -0.008278       0.002889
    15        0.0            0.0            0.0           -0.004065      -0.007016      -0.011159


                                   MEMBER END FORCES AND MOMENTS
                             PPX            PPY            PPZ            MPX            MPY            MPZ
  MEMB.  END        PX             PY             PZ             MX             MY             MZ

          1'               -3.769684      -3.473620      -1.902687       0.000253      -0.000486      -0.000275
          1    -5.375718   -0.997498       0.058928      -0.000123      -0.000593       0.000096
    1     2'                3.769684       3.473618       1.902686      -1.616362      10.184112     -15.389237
          2     5.375716    0.997496      -0.058927       0.000126      -1.091418     -18.492325

          1'               -2.537621      -2.729042      -0.396336       0.000055      -0.000059      -0.000356
          1    -3.696982   -0.468531      -0.396336       0.000005      -0.000081      -0.000356
    2     2'                2.537613       2.729035       0.396336      -5.251519       6.789916      -9.686096
          2     3.696973    0.468531       0.396336      -0.000013       8.193995      -9.686096

          1'               26.313858      19.634888     -10.377169       0.000486      -0.000850      -0.000549
          1    34.337906    2.557581       0.028209       0.000091      -0.000507      -0.000998
    3     2'              -26.313858     -19.634888      10.377168      -5.453407      27.511169      38.225876
          2   -34.337906   -2.557581      -0.028210      -0.000115      -0.520401      47.408325

          1'               -2.300817       6.026206     -11.227514     -19.265274     -16.572144      -5.052598
          1    12.856752   -1.502920       0.333874       0.442278      -2.729198     -25.761810
    4     2'                2.300817      -6.026206      11.227514       0.303367      -3.593675      -1.885448
          2   -12.856752    1.502920      -0.333874      -0.442277      -3.460343      -2.095682

          1'               -1.486395       2.291820     -13.485654      -1.720194       2.774769       1.349021
          1    13.755268   -0.154090      -0.306566      -0.630783       3.467402      -0.182524
    5     2'                1.486393      -2.291821      13.485670      -3.516204       0.795439      -1.156127
          2   -13.755283    0.154094       0.306565       0.630815       2.292459      -2.714314

          1'               -0.920541      -0.362033     -15.696216       6.530437      13.473164       0.325517
          1    15.330907    3.397881      -0.976307      -2.214621       8.417733      12.131426
    6     2'                0.920541       0.362094      15.696214      41.914474      31.112778      -4.193666
          2   -15.330916   -3.397827       0.876336       2.214595       9.043213      51.699295

          1'              -11.322347      20.756302      26.841446      -9.502992      -6.947486       3.702203
          1    35.602448    3.454202       0.133982       1.847703      -1.290071      12.134844
    7     2'               11.322347     -20.756302     -26.841446     -40.406097     -32.170929       5.487871
          2   -35.602448   -3.454202      -0.133982      -1.847712      -1.194248      51.893127

          1'               -4.581454       0.262292       0.354015       3.032467      -9.364960      15.933122
          1    -4.398077    1.347807       0.155615       7.708426      -1.242376      19.490097
    8     2'                4.581455      -0.262288      -0.354018      -2.251474      -5.201298       4.965055
          2     4.398079   -1.347805      -0.155619      -2.708429      -1.681124       6.827350

          1'               -3.104267      -0.075094       1.813293       2.237558     -20.508881       9.516465
          1    -3.038539    0.639846       1.813293      -2.532304     -20.474579       9.516465
    9     2'                3.104254       0.075085      -1.813293       6.375579     -15.992719       3.717672
          2     3.038526   -0.639843      -1.813293       2.532294     -17.029465       3.717672
```

10	1'		14.065642	0.025189	0.763056	3.941886	-26.452484	-39.518356
	1	13.688166	-3.273151	0.588408	2.614664	-5.104645	-47.371719	
	2'		-14.065641	-0.025193	-0.763059	-1.219215	-12.320159	-9.388641
	2	-13.688165	3.273149	-0.588413	-2.614690	-5.948832	-14.113627	
11	1'		0.691235	0.523497	-0.226753	2.792375	-6.381434	-3.527855
	1	0.509570	0.256524	0.691235	-1.381771	-7.159554	2.792375	
	2'		-0.691235	-0.523497	0.226753	2.511161	-4.588459	-5.630998
	2	-0.509570	-0.256524	-0.691235	1.381772	-7.131119	2.511161	
12	1'		-0.715335	0.046862	-0.151646	-1.304646	8.943169	1.445222
	1	0.158355	0.010782	-0.715335	0.647288	9.036042	-1.304646	
	2'		0.715335	-0.046856	0.151628	1.527449	5.456499	1.952611
	2	-0.158336	-0.010781	0.715335	-0.647285	5.759091	1.527449	
13	1'		-1.884956	-0.456676	0.825265	-5.269773	16.966095	-5.829310
	1	-0.698327	-0.633999	-1.884956	1.777081	17.851364	-5.269773	
	2'		1.884956	0.456692	-0.825275	-7.842919	20.978027	-3.124224
	2	0.698334	0.634017	1.884956	-1.777081	21.134811	-7.842919	
14	1'		-1.193804	-1.387649	-0.541168	6.364200	-10.428412	5.848132
	1	-1.304755	-0.718363	1.193804	-2.194364	-11.753184	-6.364200	
	2'		1.193804	1.387649	0.541168	8.487003	-8.517257	9.969761
	2	1.304755	0.718363	-1.193804	2.194365	-12.927673	-8.487003	
15	1'		-3.172806	0.738409	0.278634	1.045334	0.847259	-0.780014
	1	-3.266800	0.101744	-0.085219	0.937013	0.582281	-1.096334	
	2'		3.172791	-0.738365	-0.278633	-0.723710	-0.381359	3.207902
	2	3.266777	-0.101709	0.085199	-0.937021	1.018740	3.007320	
16	1'		-1.934738	0.428409	0.836201	-2.632951	-6.429882	0.158514
	1	-1.991414	-0.027373	0.836201	-1.085894	-6.862704	0.158514	
	2'		1.934759	-0.428440	-0.836201	-1.338994	-10.402830	-0.724331
	2	1.991441	0.027347	-0.836201	1.085902	-10.432294	-0.724331	
17	1'		10.984177	-1.819012	1.046360	0.575659	-0.139565	2.545390
	1	11.179286	0.244058	0.128385	0.927503	-1.187997	2.175712	
	2'		-10.984146	1.817962	-1.046358	-1.049676	2.249158	2.610199
	2	-11.179246	-0.244103	-0.128412	-0.827515	-1.223576	2.406959	
18	1'		0.609625	0.269629	1.304331	10.762491	-8.860394	-3.496600
	1	-0.754189	1.243669	0.171972	1.001410	-1.657234	14.249145	
	2'		-0.609625	-0.269629	-1.304331	5.971143	-6.636247	-1.133051
	2	0.754189	-1.243669	-0.171972	-1.001293	-1.529653	8.812662	
19	1'		-0.271948	-0.279819	0.990803	-5.739758	4.741783	0.961557
	1	-1.046578	-0.152900	-0.111606	-0.591097	1.595636	-7.311392	
	2'		0.271847	0.279819	-0.990805	4.078369	-1.510693	-0.502349
	2	1.046589	0.152899	0.111605	0.591103	0.591013	4.309938	
20	1'		-1.103673	-0.798845	2.027981	-5.359961	8.771959	0.705787
	1	-1.730514	-1.675388	-0.576534	-1.915083	4.260148	-8.884466	
	2'		1.103673	0.798800	-2.027980	-16.435029	15.072946	-3.263712
	2	1.730521	1.625349	0.576558	1.915082	5.261114	-21.659659	
21	1'		-2.067590	-2.591052	-0.521667	16.510031	-13.413834	[illegible]
	1	-2.322069	-2.404210	0.202344	1.394288	-2.197992	-21.774797	
	2'		2.067590	2.591052	0.521667	17.038437	-15.069692	2.522910
	2	2.322069	2.404210	-0.202344	-1.394281	-1.553181	-22.709774	
22	1'		-2.293859	1.287129	0.593038	0.492230	[illegible]	[illegible]
	1	-2.698416	-0.206360	-0.002623	0.000075	0.240966	-3.823429	
	2'		2.293660	-1.286966	-0.592977	-0.000070	0.000738	-1.221419
	2	2.698157	0.206373	0.002606	-0.000019	-0.000457	[illegible]	
23	1'		-1.102350	0.947495	-0.107891	2.622992	[illegible]	[illegible]
	1	-1.453441	0.020822	-0.107891	-0.000002	4.091269	[illegible]	
	2'		1.102379	-0.947510	0.107891	-0.000032	-0.000041	[illegible]
	2	1.453472	-0.020822	0.107891	0.000001	-0.000052	-0.000135	
24	1'		7.815637	-5.200246	2.554481	0.444595	[illegible]	[illegible]
	1	-0.728373	-0.086377	-0.059943	-0.000022	1.111114	-1.599454	
	2'		-7.815377	5.200047	-2.554388	-0.000104	[illegible]	[illegible]
	2	-0.728034	0.086200	0.059933	0.000048	-0.100773	0.002489	

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                                           APPLIED NODAL LOADS
NODE      PX            PY            PZ            MX            MY            MZ

  1       0.0           0.0           0.0           0.0           0.0           0.0
  2       0.0           0.0           0.0           0.0           0.0           0.0
  3       0.0           0.0           0.0           0.0           0.0           0.0
  4       0.0           0.0           0.0           0.0           0.0           0.0
  5       0.0         -20.000000      0.0           0.0           0.0           0.0
  6       0.0           0.0           0.0           0.0           0.0           0.0
  7       0.0         -20.000000      0.0           0.0           0.0           0.0
  8       0.0           0.0           0.0           0.0           0.0           0.0
  9       0.0         -20.000000      0.0           0.0           0.0           0.0
 10       0.0           0.0           0.0           0.0           0.0           0.0
 11       0.0         -20.000000      0.0           0.0           0.0           0.0
 12       0.0           0.0           0.0           0.0           0.0           0.0
 13       0.0           0.0           0.0           0.0           0.0           0.0
 14       0.0           0.0           0.0           0.0           0.0           0.0
 15       0.0           0.0           0.0           0.0           0.0           0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.5073614E 67


                                   NODAL DISPLACEMENTS

NODE      DELTA-X       DELTA-Y       DELTA-Z       THETA-X       THETA-Y       THETA-Z

  1       0.0           0.0           0.0          -0.001365     -0.005138      0.003649
  2       0.0           0.0           0.0           0.000003      0.000003      0.001003
  3       0.0           0.0           0.0           0.001362      0.005136      0.003651
  4      -0.028499      0.019147      0.025360     -0.002729      0.000525     -0.003647
  5       0.054304     -0.073555     -0.000003      0.000003      0.000002      0.000992
  6      -0.028502      0.019151     -0.025361      0.002727     -0.000528     -0.003647
  7       0.000003     -0.078959     -0.057823      0.001403     -0.000002      0.000003
  8      -0.000005      0.142360      0.000003     -0.000000      0.000000      0.000001
  9       0.000004     -0.078969      0.057831     -0.001403      0.000002      0.000003
 10       0.028499      0.019152      0.025364     -0.002729     -0.000523      0.003644
 11      -0.054222     -0.073559     -0.000004      0.000003     -0.000002     -0.000996
 12       0.028503      0.019157     -0.025366      0.002726      0.000525      0.003644
 13       0.0           0.0           0.0          -0.001365      0.005137     -0.003648
 14       0.0           0.0           0.0           0.000003     -0.000003     -0.000994
 15       0.0           0.0           0.0           0.001362     -0.005135     -0.003650


                              MEMBER END FORCES AND MOMENTS
                           PPX           PPY           PPZ           MPX           MPY           MPZ
MEMB.  END     PX            PY            PZ            MX            MY            MZ

        1'                 1.845886      0.829156      0.303601      0.000338     -0.000077     -0.000322
        1      0.390406   -0.389332     -0.019080     -0.000095     -0.000243     -0.000208
  1     2'                -1.845886     -0.828156     -0.303601     -1.076106      4.440465     -5.566171
        2     -0.390406    0.389331      0.013081      0.003071      0.353906     -7.192550

        1'                13.511349     13.193346      0.000030     -0.011997      0.000008      0.000387
        1     13.520467    1.463497      0.000030      0.000000      0.000119      0.000337
  2     2'               -13.511351    -13.193368     -0.000030      0.000408     -0.000490     30.194382
        2    -13.520467   -1.463497     -0.000031     -0.000000     -0.000638     30.194382

        1'                 1.845330      0.827371     -0.303169     -0.000066      0.000196      0.000090
        1      2.000176   -0.320177      0.019292      0.000038      0.000109      0.000136
  3     2'                -1.845990     -0.827379      0.303162      1.076363     -4.442033     -5.568631
        2     -2.000176    0.383176     -0.013091     -0.000024     -0.352574     -7.195453

        1'                -1.557220      3.058813     -7.711761    -11.171337    -10.227622     -1.463149
        1      5.721893   -1.150021      0.143154     -1.279328     -1.169633    -15.049636
  4     2'                 1.557220     -3.058813      7.701761     -4.562674     -3.921566     -2.649911
        2     -5.721893    1.150021     -0.143154      1.279330     -1.404015     -6.269322

        1'                -2.273153      3.142266     -8.048164      5.412024     10.031897      0.188776
        1      0.621066    1.806115     -0.610577      1.121296      0.126664      9.550763
  5     2'                 2.273267     -3.142266      8.148162     10.351433     15.970514      2.435922
        2     [illegible] -1.806115      0.610677     -1.181230      0.246303     24.377533

        1'                 2.273153     -3.042132     -8.048241    -10.352307    -15.982265      2.436516
        1      0.621075   -1.806241      0.610582     -1.181424     -5.247256    -24.370572
  6     2'                -2.273154      3.042099      8.048297     -5.422372    -10.024945      2.187845
        2     -0.621069    1.806999     -0.610584      1.181433     -6.122117     -9.542486

        1'                -1.557373      2.958373      7.701053     11.176696     10.225302     -1.462662
        1      5.721073   -1.149661     -0.143161      1.279464      1.110643    -15.046414
  7     2'                 1.557374     -3.059873     -7.701053      4.541625      3.917792     -2.649223
        2     -5.721073    1.149559      0.143161     -1.279448      1.433994     -6.262024

        1'                 2.563104      1.744471      1.549751      0.231614    -10.550713      9.126229
        1      2.077644    1.682062      0.143437     -1.022261     -5.361231     12.082726
  8     2'                -2.563103     -1.744470     -1.549752      0.167725    -13.417315     15.223527
        2     -2.077643   -1.682062     -1.549437      1.022251     -4.559919     12.609170

        1'                 8.965644     -0.732453     -0.000224      0.000233      0.003079    -35.065513
        1      8.557794   -2.771917     -0.000224      0.000931      0.002044    -35.066513
  9     2'                -8.965632      0.732467      0.000224     -0.001295      0.001437    -22.264359
        2     -8.557773    2.771031      0.000224     -0.000931      0.001697    -22.264359
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     1'                 2.563194    1.744685   -1.549685   -0.202108   10.548908    8.028318
10   1     2.977766     1.687197   -0.549277    1.021251    5.358814   12.083651
     2'                -2.563193   -1.744684    1.549686   -2.166577   13.407743   15.025677
     2    -2.977765    -1.687197    0.549278   -1.021240    4.959042   19.611160

     1'                -0.000042   17.243790  -18.370392   -5.713165    0.000920   -0.000705
11   1    25.153107     1.463253   -0.000042    0.001130    0.000254   -5.713165
     2'                 0.000042  -17.243790   18.370392   35.964478   -0.000253    0.001262
     2   -25.153107    -1.463253    0.000042   -0.001130    0.000615   35.964478

     1'                 0.000224    0.732236  -15.271321  -40.299973   -0.003074   -0.000092
12   1    15.031312    -2.794537    0.000224   -0.000616   -0.003012  -40.299973
     2'                -0.000224   -0.732222   15.271311  -17.498795   -0.001440   -0.000973
     2   -15.031299     2.794546   -0.000224    0.000616   -0.001625  -17.498795

     1'                -0.000232   -0.732198  -15.271647   17.501511    0.001511   -0.000995
13   1    15.031621     2.794647   -0.000232    0.000622    0.001699   17.501511
     2'                 0.000232    0.732198   15.271754   40.298798    0.003168   -0.000109
     2   -15.031725    -2.794672    0.000232   -0.000622    0.003108   40.298798

     1'                -0.000047   17.243820   18.370193    5.711428   -0.000965   -0.000681
14   1    25.152969     1.463403    0.000047   -0.001141   -0.000305   -5.711428
     2'                 0.000047  -17.243820  -18.370193  -35.965820    0.000222    0.001301
     2   -25.152969    -1.463403   -0.000047    0.001141   -0.000664   35.965820

     1'                 2.563405   -1.744465   -1.549714    2.168245   13.410933  -15.025157
15   1   [illegible]   -1.686958   -0.549409    1.022227    4.962375  -19.612228
     2'                -2.563540    1.744462    1.549719    0.201071   10.545690   -8.022341
     2    -2.978966     1.686940    0.549415   -1.022222    5.358613  -12.076849

     1'                 8.966069    0.732100    0.000234   -0.001313   -0.001519   22.266296
16   1     8.559269     2.771668    0.000234   -0.000933   -0.001791   22.266296
     2'                -8.966155   -0.732100   -0.000234    0.000207   -0.003199   35.058838
     2   [illegible]   -2.771632   -0.000234    0.000933   -0.003056   35.058838

     1'                 2.561061   -1.744411    1.549505   -2.167095  -13.410897  -15.026303
17   1   [illegible]   -1.687135    0.549241   -1.021216   -4.961568  -19.613220
     2'                -2.562022    1.744407   -1.549510   -0.201594  -10.544530   -9.025287
     2   [illegible]    1.687120   -0.549247    1.021219   -5.356359  -12.078826

     1'                 1.556969    3.959423   -7.701446  -11.991674   10.227633    1.464444
18   1   [illegible]   -1.150291   -0.143174    1.277954    1.169792  -15.050815
     2'                -1.556968   -3.958423    7.701446   -4.555291    3.923982    2.648171
     2   [illegible]    1.150291    0.143174   -1.277956    1.494123   -6.270931

     1'                 2.273444    3.042600   -8.048600    5.423251  -10.031623   -0.198443
19   1   [illegible]    1.906233    0.610739   -1.191470   -6.124953    9.551765
     2'                -2.273444   -3.042501    8.048599   10.352924  -15.982183   -2.436492
     2   [illegible]   -1.906234   -0.610739    1.191456   -5.347537   24.379990

     1'                -2.273195   -3.042246   -8.948051  -19.053375   15.984887   -2.437196
20   1   [illegible]   -1.906056   -0.610628    1.191612    5.349733  -24.381775
     2'                 2.273100    3.042243    8.949997   -5.424106   10.025024   -0.187526
     2   [illegible]    1.906046    0.610633   -1.191617  [illegible]   -9.544086

     1'                 1.557274    3.959706    7.701396  [illegible]  -10.226375    1.464093
21   1     0.721612  [illegible]    0.143165   -1.278133   -1.169793  -15.048450
     2'                -1.557274   -3.958706   -7.701306    4.555212   -3.929122    2.647538
     2    -0.721612  [illegible]   -0.143165    1.278006   -1.494181   -6.264582

     1'               [illegible]   -0.224263   -0.303632   -1.375519   -4.437794    5.562837
22   1   [illegible] [illegible]    0.012097    0.000035   -0.353729    7.188217
     2'                -1.346677    0.828202    0.303678    0.000019   -0.000223    0.000632
     2    -0.000471    -0.398842   -0.012072   -0.000036    0.000217    0.000643

     1'                13.512633  -13.133760   -0.000032    0.001425    0.000519  -30.185974
23   1   [illegible]   -1.460070   -0.000032    0.000001    0.001663  -30.185974
     2'               -13.512444   13.133722    0.000032    0.000001    0.000002   -0.000224
     2   [illegible]    1.460096    0.000032   -0.000001    0.000001   -0.000224

     1'                 1.645766   -0.827766    0.303443    1.376621    4.430259    5.565214
24   1     0.000747     0.398001   -0.019055   -0.000031    0.353433    7.191025
     2'                -1.645199    0.827706   -0.303412   -0.000031    0.000187    0.001695
     2   [illegible]   -0.398019    0.019052    0.000056   -0.000272    0.000656
```

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NUMBER OF NODES 15
NUMBER OF MEMBERS 24
NUMBER OF LOADING CONDITION  2
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                                      MEMBER COORDINANTS
MEMBER-I      X(I,1)          X(I,2)          Y(I,1)          Y(I,2)          Z(I,1)          Z(I,2)

    1       -32.250000      -18.089996       0.0             6.270000        16.000000       18.089996
    2       -36.000000      -18.969986       0.0             8.919999         0.0             0.0
    3       -32.250000      -18.089996       0.0             6.270000       -16.000000      -18.089996
    4       -16.000000      -18.089996       0.0             6.270000        32.250000       18.089996
    5       -18.089996      -18.969986       6.270000        8.919999        18.089996        0.0
    6       -18.969986      -18.089996       8.919999        6.270000         0.0           -18.089996
    7       -16.000000      -18.089996       0.0             6.270000       -32.250000      -18.089996
    8       -18.089996        0.0            6.270000        8.919999        18.089996       18.969986
    9       -18.969986        0.0            8.919999       12.000000         0.0             0.0
   10       -18.089996        0.0            6.270000        8.919999       -18.089996      -18.969986
   11         0.0             0.0            0.0             8.919999        36.000000       18.969986
   12         0.0             0.0            8.919999       12.000000        18.969986        0.0
   13         0.0             0.0           12.000000        8.919999         0.0           -18.969986
   14         0.0             0.0            0.0             8.919999       -36.000000      -18.969986
   15         0.0            18.089996       8.919999        6.270000        18.969986       18.089996
   16         0.0            18.969986      12.000000        8.919999         0.0             0.0
   17         0.0            18.089996       8.919999        6.270000       -18.969986      -18.089996
   18        16.000000       18.089996       0.0             6.270000        32.250000       18.089996
   19        18.089996       18.969986       6.270000        8.919999        18.089996        0.0
   20        18.969986       18.089996       8.919999        6.270000         0.0           -18.089996
   21        16.000000       18.089996       0.0             6.270000       -32.250000      -18.089996
   22        18.089996       32.250000       6.270000        0.0             18.089996       16.000000
   23        18.969986       36.000000       8.919999        0.0              0.0             0.0
   24        18.089996       32.250000       6.270000        0.0            -18.089996      -16.000000


                                                      MEMBER PROPERTIES
MEMBER-I      IX              IY              IZ              AREA            RADIUS          PHI             ALPHA

    1       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550        0.679980
    2       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
    3       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550       -0.679980
    4       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550       -0.679980
    5       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135       -0.355170
    6       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135       -0.355170
    7       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550        0.679980
    8       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135        0.355170
    9       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   10       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135       -0.355170
   11       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   12       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   13       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   14       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   15       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135        0.355170
   16       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   17       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135       -0.355170
   18       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550        0.679980
   19       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135        0.355170
   20       0.000550        0.000326        0.000326        0.062500        60.000000       0.153135        0.355170
   21       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550       -0.679980
   22       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550        0.679980
   23       0.000550        0.000326        0.000326        0.062500        60.000000       0.160877        0.0
   24       0.000550        0.000326        0.000326        0.062500        60.000000       0.130550       -0.679980


MEMB   NODE(I,1)   NODE(I,2)

  1        1           4
  2        2           5
  3        3           6
  4        0           4
  5        4           5
  6        5           6
  7        0           6
  8        4           7
  9        5           8
 10        6           9
 11        0           7
 12        7           8
 13        8           9
 14        0           9
 15        7          10
 16        8          11
 17        9          12
 18        0          10
 19       10          11
 20       11          12
 21        0          12
 22       10          13
 23       11          14
 24       12          15


                                   LINK
NODE    NMBN        1       2       3       4       5       6

  1       1         1       0       0       0
  2       1         2       0       0       0
  3       1         3       0       0       0
  4       4        -1      -4       5       8
  5       4        -2      -5       6       9
  6       4        -3      -6      -7      10
  7       4        -8     -11      12      15
  8       4        -9     -12      13      16
  9       4       -10     -13     -14      17
 10       4       -15     -18      19      22
 11       4       -16     -19      20      23
 12       4       -17     -20     -21      24
 13       1       -22       0       0       0
 14       1       -23       0       0       0
 15       1       -24       0       0       0
```

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                                              APPLIED NODAL LOADS
NODE        PX              PY            PZ             MX              MY             MZ

   1        0.0             0.0           0.0            0.0             0.0            0.0
   2        0.0             0.0           0.0            0.0             0.0            0.0
   3        0.0             0.0           0.0            0.0             0.0            0.0
   4        0.0             0.0           0.0            0.0             0.0            0.0
   5        0.0          -20.000000       0.0            0.0             0.0            0.0
   6        0.0             0.0           0.0            0.0             0.0            0.0
   7        0.0          -20.000000       0.0            0.0             0.0            0.0
   8        0.0             0.0           0.0            0.0             0.0            0.0
   9        0.0          -20.000000       0.0            0.0             0.0            0.0
  10        0.0             0.0           0.0            0.0             0.0            0.0
  11        0.0          -20.000000       0.0            0.0             0.0            0.0
  12        0.0             0.0           0.0            0.0             0.0            0.0
  13        0.0             0.0           0.0            0.0             0.0            0.0
  14        0.0             0.0           0.0            0.0             0.0            0.0
  15        0.0             0.0           0.0            0.0             0.0            0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =    0.0


                                          NODAL DISPLACEMENTS
NODE      DELTA-X         DELTA-Y         DELTA-Z         THETA-X         THETA-Y         THETA-Z

   1      0.0             0.0             0.0            -0.001178       -0.003630        0.005247
   2      0.0             0.0             0.0             0.000000        0.000000       -0.002066
   3      0.0             0.0             0.0             0.001178        0.003630        0.005247
   4     -0.019556        0.029857        0.017311       -0.001646        0.000524       -0.003012
   5      0.038413       -0.073163        0.000000        0.000000        0.000000        0.003433
   6     -0.019555        0.029855       -0.017310        0.001646       -0.000524       -0.003012
   7     -0.000000       -0.079756       -0.039954        0.003260       -0.000000        0.000000
   8      0.000003        0.140372       -0.000001        0.000003        0.000000        0.000003
   9      0.000000       -0.079750        0.039953       -0.003264        0.000000        0.000000
  10      0.019554        0.029852        0.017309       -0.001646       -0.000523        0.003010
  11     -0.038408       -0.073154        0.000000        0.000000       -0.000000       -0.003436
  12      0.019552        0.029851       -0.017308        0.001646        0.000523        0.003009
  13      0.0             0.0             0.0            -0.001177        0.003631       -0.005249
  14      0.0             0.0             0.0             0.000000       -0.000000        0.002065
  15      0.0             0.0             0.0             0.001177       -0.003631       -0.005249


                                      MEMBER END FORCES AND MOMENTS
                              PPX            PPY            PPZ            MPX            MPY            MPZ
MEMB.  END        PX          PY             PZ             MX             MY             MZ

        1'                  6.414230       2.376843       0.775358       0.000120      -0.000577       0.000656
        1      6.869677    -0.428816       0.128724      -0.000035      -0.000081       0.000877
  1     2'                 -6.414230      -2.376848      -0.775360      -0.106511       2.427423      -6.560425
        2     -6.869678     0.428811      -0.128723       0.000030      -2.010383      -6.700838

        1'                 20.396713      12.456002       0.000001       0.000001      -0.000003      -0.001247
        1     23.847687     1.570237       0.000001      -0.000000      -0.000003      -0.001247
  2     2'                -20.396713     -12.455998      -0.000001       0.000009      -0.000016      30.189926
        2    -23.847687    -1.570233      -0.000001       0.000000      -0.000018      30.189926

        1'                  6.413498       2.376454      -0.775234      -0.000111       0.000554       0.000595
        1      6.868839    -0.428870      -0.128749       0.000042       0.000096       0.000814
  3     2'                 -6.413498      -2.376459       0.775236       0.106511      -2.427374      -6.560230
        2     -6.868842     0.428867       0.128748      -0.000037       2.010305      -6.700654

        1'                 -0.962855       3.908360     -12.213599     -13.168047      -8.553738      -0.279451
        1     12.764388    -1.552371      -0.186787      -1.417705       1.386847     -15.579110
  4     2'                  0.962855      -3.908360      12.213599      -8.066319      -3.338361      -1.852151
        2    -12.764388     1.552371       0.186787       1.417691       1.530615      -8.676862

        1'                 -1.764144       3.614352     -12.788038       9.120300       8.270918      -1.312344
        1     13.246457     2.004331      -0.473251       2.055943       4.365232      11.402997
  5     2'                  1.764140      -3.614367      12.788030      22.375985      12.389114       2.906690
        2    -13.246450    -2.004345       0.473243      -2.055943       4.297020      25.285477

        1'                  1.764136      -3.614450     -12.788459     -22.375153     -12.388640       2.906570
        1     13.246887    -2.004354       0.473212      -2.055858      -4.296812     -25.284637
  6     2'                 -1.764137       3.614449      12.788459      -9.120294      -8.270826      -1.312268
        2    -13.246887     2.004354      -0.473213       2.055856      -4.365160     -11.402950

        1'                 -0.962899       3.908433      12.213453      13.167350       8.553323      -0.279505
        1     12.764291    -1.552236       0.186761       1.417583      -1.386720     -15.578317
  7     2'                  0.962899      -3.908433     -12.213453       8.065355       3.337947      -1.851976
        2    -12.764291     1.552236      -0.186761      -1.417571      -1.530425      -8.675824

        1'                  7.218300       2.672415       1.347979      -0.948276      -7.359927       2.724030
        1      7.585526     1.837928       0.380260      -1.535222      -3.369890      11.659109
  8     2'                 -7.218308      -2.672415      -1.347975       2.168694     -10.672935      12.491828
        2     -7.585533    -1.837925      -0.380257       1.535224      -3.590325      21.994116

        1'                 16.863495      -0.316916       0.000071      -0.000973      -0.000579     -35.800720
        1     16.594727    -3.015415       0.000071      -0.001053      -0.000416     -35.800720
  9     2'                -16.863449       0.316958      -0.000071       0.001192      -0.000772     -22.151749
        2    -16.594681     3.015451      -0.000071       0.001053      -0.000953     -22.151749
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        1'                 7.216971    2.672085   -1.347951    0.949527    7.360441    9.723665
10      1     7.584164     1.837814   -0.380341    1.536551    3.370300   11.657937
        2'                -7.216996   -2.672085    1.347947   -2.170156   10.673151   19.490005
        2    -7.584188    -1.837810    0.380338   -1.536547    3.591393   21.982407

        1'                -0.000000   14.973040  -24.327194    2.635213    0.000051   -0.000124
11      1    28.497345     1.976242   -0.000000    0.000134   -0.000012    2.635213
        2'                 0.000000  -14.973040   24.327194   35.358109   -0.000045    0.000127
        2   -28.497345    -1.976242    0.000000   -0.000134    0.000019   35.358109

        1'                -0.000088    0.316885  -21.627853  -39.693695    0.000667   -0.000847
12      1    21.399094    -3.153358   -0.000088    0.000943    0.000523  -39.693695
        2'                 0.000088   -0.316843   21.627869  -20.909607    0.000993    0.001116
        2   -21.399094     3.153402    0.000088   -0.000943    0.001159  -20.909607

        1'                 0.000087   -0.316319  -21.627167   20.907593   -0.000988    0.001113
13      1    21.398315     3.153807    0.000087   -0.000940   -0.001154   20.907593
        2'                -0.000087    0.316319   21.627167   39.703842   -0.000661   -0.000845
        2   -21.398315    -3.153807   -0.000087    0.000940   -0.000517   39.703842

        1'                -0.000001   14.973688   24.327225   -2.638282   -0.000056   -0.000125
14      1    28.497681     1.976802    0.000001   -0.000136    0.000008    2.638282
        2'                 0.000001  -14.973688  -24.327225  -35.365646    0.000041    0.000132
        2   -28.497681    -1.976802   -0.000001    0.000136   -0.000025   35.365646

        1'                 7.219108   -2.672731   -1.348034    2.168503   10.672476  -19.491516
15      1     7.586371    -1.838118   -0.380207    1.535083    3.589998  -21.983597
        2'                -7.219108    2.672730    1.348035   -0.948152    7.360659   -9.726625
        2    -7.586371     1.838117    0.380208   -1.535081    3.369702  -11.660798

        1'                16.862793    0.317490   -0.000071    0.001188    0.000769   22.149872
16      1    16.593948     3.015870   -0.000071    0.001049    0.000950   22.149872
        2'               -16.862793   -0.317490    0.000071   -0.000970    0.000573   35.810684
        2   -16.593948    -3.015870    0.000071   -0.001049    0.000411   35.810684

        1'                 7.217083   -2.672293    1.347979   -2.169954  -10.672629  -19.489349
17      1     7.584306    -1.837999    0.380296   -1.536390   -3.591101  -21.981613
        2'                -7.217084    2.672293   -1.347980    0.949385   -7.361288   -9.726664
        2    -7.584307     1.838000   -0.380298    1.536389   -3.370087  -11.661044

        1'                 0.962949    3.908484  -12.213516  -13.166635    8.552585    0.280192
18      1    12.764375    -1.552195    0.186780    1.416759   -1.386557  -15.577410
        2'                -0.962949   -3.908484   12.213516   -8.064511    3.337667    1.851063
        2   -12.764375     1.552195   -0.186780   -1.416741   -1.530503   -8.674858

        1'                 1.764014    3.614139  -12.788005    9.118540   -8.269420    1.312907
19      1    13.246387     2.004093    0.473203   -2.056368   -4.364355   11.400818
        2'                -1.764011   -3.614139   12.787995   22.373596  -12.388311   -2.807117
        2   -13.246377    -2.004093   -0.473200    2.056370   -4.297120   25.283051

        1'                -1.763966   -3.614096  -12.787572  -22.372467   12.387708   -2.806980
20      1    13.245951    -2.004104   -0.473170    2.056269    4.296924  -25.281799
        2'                 1.763967    3.614096   12.787572   -9.118999    8.269450    1.312823
        2   -13.245951     2.004104    0.473171   -2.056268    4.364240  -11.401259

        1'                 0.963056    3.908768   12.213729   13.166097   -8.552268    0.280293
21      1    12.764696    -1.552018   -0.186732   -1.416614    1.386433  -15.576806
        2'                -0.963056   -3.908768  -12.213729    8.063417   -3.337195    1.850864
        2   -12.764696     1.552018    0.186732    1.416605    1.530289   -8.673678

        1'                 6.415092   -2.376989   -0.775359   -0.106752   -2.429104    6.563810
22      1     6.870515     0.429056   -0.128757    0.000034    2.011040    6.704569
        2'                -6.415198    2.377052    0.775373    0.000107    0.000484   -0.000607
        2    -6.870640    -0.429046    0.128747   -0.000016    0.000038   -0.000783

        1'                20.396286  -12.456316   -0.000001    0.000009    0.000018  -30.199341
23      1    23.847458    -1.570713   -0.000001   -0.000001    0.000020  -30.199341
        2'               -20.396271   12.456341    0.000001   -0.000001   -0.000004    0.001414
        2   -23.847443     1.570742    0.000001    0.000001   -0.000004    0.001414

        1'                 6.414659   -2.376788    0.775298    0.106725    2.428953    6.563495
24      1     6.870033     0.429061    0.128766   -0.000040   -2.010976    6.704225
        2'                -6.414765    2.376851   -0.775312   -0.000048   -0.000307   -0.000290
        2    -6.870157    -0.429050   -0.128755    0.000041   -0.000071   -0.000417


IHC217I
TRACEBACK FOLLOWS-   ROUTINE    ISN   REG.  14
                     IBCOM            8200FDC0
                     MAIN             00002848

ENTRY POINT=  50005020
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                                                    APPLIED NODAL LOADS
   NODE        PX              PY              PZ             MX              MY              MZ

      1        0.0             0.0             0.0            0.0             0.0             0.0
      2        0.0             0.0             0.0            0.0             0.0             0.0
      3        0.0             0.0             0.0            0.0             0.0             0.0
      4        0.0             0.0             0.0            0.0             0.0             0.0
      5        0.0             0.0             0.0            0.0             0.0             0.0
      6        0.0          -40.000000         0.0            0.0             0.0             0.0
      7        0.0             0.0             0.0            0.0             0.0             0.0
      8        0.0             0.0             0.0            0.0             0.0             0.0
      9        0.0             0.0             0.0            0.0             0.0             0.0
     10        0.0             0.0             0.0            0.0             0.0             0.0
     11        0.0             0.0             0.0            0.0             0.0             0.0
     12        0.0             0.0             0.0            0.0             0.0             0.0
     13        0.0             0.0             0.0            0.0             0.0             0.0
     14        0.0             0.0             0.0            0.0             0.0             0.0
     15        0.0             0.0             0.0            0.0             0.0             0.0


   DETERMINANT OF SYSTEM STIFFNESS MATRIX =      0.0


                                          NODAL DISPLACEMENTS

   NODE        DELTA-X         DELTA-Y         DELTA-Z        THETA-X         THETA-Y         THETA-Z

      1        0.0             0.0             0.0            0.008642       -0.001862        0.014020
      2        0.0             0.0             0.0           -0.010961       -0.012649        0.005225
      3        0.0             0.0             0.0            0.005178       -0.005230       -0.018977
      4       -0.066522        0.118756        0.060233       0.008793        0.003384        0.000048
      5       -0.039103        0.069169        0.066235      -0.015488       -0.005841       -0.000987
      6        0.114802       -0.212704        0.107008       0.005287        0.001728       -0.000886
      7       -0.042379       -0.038829       -0.019660      -0.001638        0.003528       -0.007318
      8       -0.023584       -0.029071       -0.020897       0.003202       -0.000090       -0.002909
      9        0.070531        0.068911       -0.035547       0.000012        0.004805        0.012411
     10       -0.043993       -0.080460       -0.040197      -0.005447        0.001149        0.003215
     11       -0.022822       -0.039540       -0.041035       0.009604       -0.004433        0.000970
     12        0.068947        0.122964       -0.063257      -0.003071       -0.000183       -0.005043
     13        0.0             0.0             0.0           -0.005695       -0.001477        0.008665
     14        0.0             0.0             0.0            0.007394       -0.007757        0.003883
     15        0.0             0.0             0.0           -0.004306       -0.006046       -0.013970


                                     MEMBER END FORCES AND MOMENTS
                           PPX             PPY             PPZ            MPX             MPY             MPZ
 MEMB.  END     PX         PY              PZ              MX             MY              MZ

        1'                -4.773315       -3.579529       -1.318680       0.000348       -0.001587        0.002029
        1   -5.937989     -1.399140        0.349231       -0.000050      -0.000100        0.002597
   1    2'                 4.773346        3.579529        1.318676      -0.788355        8.696983      -21.740084
        2    5.938016      1.398126       -0.349230        0.000093      -5.451345      -21.841843

        1'                -4.769577       -3.214030       -0.426699       0.000013       -0.000031        0.001312
        1   -5.716362     -0.634100       -0.426699       -0.000002      -0.000033        0.001312
   2    2'                 4.769567        3.214019        0.426699      -3.806175        7.266719      -12.192650
        2    5.716344      0.634098        0.426699       -0.000009       8.203176      -12.192650

        1'                36.046036       19.160843       -7.060614       0.000417       -0.002106       -0.002655
        1   41.295746      3.282272        0.440081       -0.000112      -0.000136       -0.003419
   3    2'               -36.046066      -19.160843        7.060607      -4.225394       24.640045       45.294434
        2  -41.295776     -3.282256       -0.440081        0.000122      -6.968835       51.278000

        1'                -1.852825        7.718354      -22.239838     -27.009209      -16.848114       -3.372517
        1   23.497452     -2.340852       -0.073890       -0.091881       2.210124      -31.933305
   4    2'                 1.852825       -7.718354       22.239838      -3.137664       -3.306043       -1.141062
        2  -23.497452      2.340852        0.073890        0.091813      -1.067335       -4.640525

        1'                -1.233211        3.257465      -23.931244       0.050918        1.648178        0.644331
        1   24.182053     -0.206734       -0.150261       -0.400593       1.609921        0.617971
   5    2'                 1.233196       -3.257481       23.931213      -4.541520       -0.398585       -0.242796
        2  -24.182022      0.206720        0.150243        0.400577       1.140705       -4.402455

        1'                -1.008451       -0.174896      -26.179565      10.666497       12.533992       -0.835307
        1   25.850006      4.173110       -0.883187       -0.476281       8.120737       14.331773
   6    2'                 1.008448        0.174895       26.179581      55.547150       28.746567       -1.999992
        2  -25.850021     -4.173112        0.883183        0.476279       8.044713       62.055374

        1'                -8.450715       21.535355       33.751022     -38.817139      -17.987335        2.118874
        1   40.354797      6.693944       -0.999346       -0.105568       8.717378       41.938312
   7    2'                 8.450715      -21.535355      -33.751022     -54.493561      -31.134523        5.852546
        2  -40.354797     -6.693944        0.999346        0.105508       6.892439       62.655534

        1'                -5.388247        0.884357        0.376128       3.876095       -6.947221       21.245179
        1   -5.179070      1.770164        0.023370        3.846212       0.202426       22.356682
   8    2'                 5.388225       -0.884371       -0.376114      -3.657512       -4.598171        2.031655
        2    5.179047     -1.770169       -0.023352       -3.846203      -0.630610       10.044921

        1'                -4.990771        0.219953        1.813953      -2.321373      -12.402749       13.269067
        1   -4.891014      1.016947        1.813953       -5.400914     -18.779907       13.269057
   9    2'                 4.990714       -0.219998       -1.813953       7.909345      -15.007956        6.276211
        2    4.890950     -1.016981       -1.813953        5.400907     -16.081390        6.276211
```

10	1'		26.584991	0.516701	0.507666	3.169601	-22.253540	-49.162628
	1	26.324234	-3.747191	0.528679	2.274275	-4.376266	-53.832199	
	2'		-26.585022	-0.516671	-0.507638	-1.369552	-10.325038	-11.940347
	2	-26.324265	3.747214	-0.528642	-2.274291	-5.301225	-14.757328	
11	1'		0.642986	-0.578029	2.085026	6.299972	-6.442738	-0.728144
	1	-2.115202	0.455383	0.642986	-2.344328	-6.045097	6.299972	
	2'		-0.642986	0.578029	-2.085026	2.455194	-4.507311	-5.007281
	2	2.115202	-0.455383	-0.642986	2.344326	-6.316081	2.455194	
12	1'		-0.526411	-0.305105	2.452864	-0.293638	6.632126	-0.272168
	1	-2.470057	0.091942	-0.526411	1.331535	6.502786	-0.293638	
	2'		0.526411	0.305122	-2.452915	2.060197	3.353888	1.893513
	2	2.470110	-0.091934	0.526411	-1.331533	3.613998	2.060197	
13	1'		-1.849249	-0.541700	3.639183	-7.314548	15.672317	-6.788939
	1	-3.505331	-1.117926	-1.848248	4.189494	16.557755	-7.314548	
	2'		1.848248	0.541702	-3.639171	-14.170905	19.388931	1.096333
	2	3.505318	1.117926	1.848248	-4.189494	18.962616	-14.170905	
14	1'		-1.238339	-3.099888	-3.174291	10.039996	-11.585178	1.906051
	1	-4.250229	-1.273182	1.238339	-3.686916	-11.147024	-10.039996	
	2'		1.238339	3.099888	3.174291	14.437375	-0.503777	0.139935
	2	4.250229	1.273182	-1.238339	3.686911	-12.659657	-14.437375	
15	1'		-4.212677	0.611032	0.008518	1.496015	2.473985	-3.754028
	1	-4.252246	-0.072566	-0.182320	1.300811	1.244094	-4.383097	
	2'		4.212662	-0.611032	-0.008515	-0.980898	1.078641	3.644971
	2	4.252231	0.072565	0.182323	-1.300813	2.093102	3.055953	
16	1'		-3.669437	0.456247	0.628317	-2.653904	-4.018280	-1.380281
	1	-3.695128	-0.137725	0.628317	-1.975617	-4.301673	-1.380281	
	2'		3.669449	-0.456249	-0.628317	0.718691	-7.900875	-1.266580
	2	3.695147	0.137725	-0.628317	1.975670	-7.683576	-1.266580	
17	1'		23.487091	-3.123865	0.974602	1.103935	0.449964	1.708813
	1	23.711304	0.351072	-0.049684	1.109232	-0.004900	1.761475	
	2'		-23.487091	3.123865	-0.974598	-0.337415	2.597580	4.020637
	2	-23.711304	-0.351074	0.048688	-1.109215	0.896871	4.664440	
18	1'		0.467701	0.286367	3.092228	15.744151	-8.073024	-2.628720
	1	-2.624579	1.711922	-0.208612	1.248525	2.273593	17.698410	
	2'		-0.467701	-0.286367	-3.092228	7.695743	-5.012175	0.264333
	2	2.624579	-1.711922	0.208612	-1.248576	0.984439	9.050134	
19	1'		-0.000171	-0.390294	2.680505	-6.779153	2.225617	0.759404
	1	-2.709973	0.015907	0.036950	-0.745412	-0.130796	-7.134498	
	2'		0.000155	0.390309	-2.680497	6.822943	-2.953721	-0.855027
	2	2.709956	-0.015925	-0.036969	0.745411	-0.545792	7.426621	
20	1'		-0.956318	-1.421861	3.521440	-9.399330	7.305257	1.796011
	1	-3.228407	-2.181867	-0.392010	-2.380728	3.399536	-11.339464	
	2'		0.956316	1.421861	-3.521445	-25.654449	13.002515	-3.079874
	2	3.228406	2.181866	0.392008	2.380725	3.873923	-28.607132	
21	1'		-2.171917	-4.556594	-1.385788	29.735779	-13.691168	3.934519
	1	-3.374522	-3.042522	-0.685042	1.924523	5.279541	-31.579622	
	2'		2.171917	4.556594	1.385788	27.020958	-14.165594	1.260393
	2	3.374522	3.042522	0.685042	-1.924533	5.423754	-20.931709	
22	1'		-3.657150	1.288014	0.419273	0.064123	1.707834	-4.088567
	1	-3.886812	-0.305513	0.093655	-0.000055	-1.463814	-4.771229	
	2'		3.657640	-1.288243	-0.419254	-0.000279	-0.000347	0.000434
	2	3.887359	0.305529	-0.093616	0.000019	-0.000043	0.000577	
23	1'		-2.802530	1.497093	-0.208403	1.959955	3.549111	3.325349
	1	-3.172591	0.016992	-0.208403	-0.000002	4.206484	2.325349	
	2'		2.802497	-1.497076	0.208403	-0.000001	-0.000012	0.000647
	2	3.172554	-0.016992	0.208403	0.000005	-0.000011	0.000642	
24	1'		20.360886	-9.100273	3.113073	-0.497937	-1.525192	-1.303636
	1	22.517868	-0.122384	0.038232	-0.000082	-0.592440	-1.915575	
	2'		-20.361374	9.100486	-3.113136	-0.000251	-0.001232	-0.001324
	2	-22.518402	0.122376	-0.038225	0.000010	-0.000072	-0.001695	

APPENDIX B

COMPUTER SOLUTIONS FOR THE EXPERIMENTAL MODEL

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NUMBER OF NODES  4
NUMBER OF MEMBERS 12
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                              MEMBER COORDINANTS
MEMBER-I      X(I,1)          X(I,2)          Y(I,1)          Y(I,2)         Z(I,1)          Z(I,2)

    1       -20.969986       -7.290000       0.0             6.250000        5.870000        7.219999
    2       -20.969986       -7.230000       0.0             6.250000       -6.620000       -7.330000
    3        -6.059999       -7.290000       0.0             6.250000       20.969986        7.219999
    4        -7.290000       -7.230000       6.250000        6.250000        7.219999       -7.330000
    5        -6.250000       -7.230000       0.0             6.250000      -20.969986       -7.330000
    6        -7.290000        7.219999       6.250000        6.250000        7.219999        7.290000
    7        -7.230000        7.190000       6.250000        6.250000       -7.330000       -7.190000
    8         6.059999        7.219999       0.0             6.250000       20.969986        7.290000
    9         7.219999        7.190000       6.250000        6.250000        7.290000       -7.190000
   10         6.120000        7.190000       0.0             6.250000      -20.969986       -7.190000
   11        20.969986        7.219999       0.0             6.250000        6.309999        7.290000
   12        20.969986        7.190000       0.0             6.250000       -6.309999       -7.190000


                                              MEMBER PROPERTIES
MEMBER-I      IX              IY              IZ              AREA           RADIUS          PHI             ALPHA

    1        0.000550        0.000326        0.000326        0.062500       35.000000        0.217400        0.471900
    2        0.000550        0.000326        0.000326        0.062500       35.000000        0.217600       -0.470900
    3        0.000550        0.000326        0.000326        0.062500       35.000000        0.218100       -0.472900
    4        0.000550        0.000326        0.000326        0.062500       35.000000        0.209400       -0.208100
    5        0.000550        0.000326        0.000326        0.062500       35.000000        0.216500       -0.470900
    6        0.000550        0.000326        0.000326        0.062500       35.000000        0.208800        0.208900
    7        0.000550        0.000326        0.000326        0.062500       35.000000        0.207500       -0.208900
    8        0.000550        0.000326        0.000326        0.062500       35.000000        0.217100        0.471300
    9        0.000550        0.000326        0.000326        0.062500       35.000000        0.208400        0.208100
   10        0.000550        0.000326        0.000326        0.062500       35.000000        0.218400        0.471900
   11        0.000550        0.000326        0.000326        0.062500       35.000000        0.218000        0.472200
   12        0.000550        0.000326        0.000326        0.062500       35.000000        0.218300       -0.471300


MEMB   NODE(I,1)   NODE(I,2)

  1        1           4
  2        2           5
  3        3           4
  4        4           5
  5        5           6
  6        4           8
  7        5           9
  8        7           8
  9        8           9
 10        9          10
 11        8          11
 12        9          12


NODE   NBRM                  LINK
                  1     2     3     4     5     6

  1      1        1     0     0     0
  2      1        2     0     0     0
  3      1        3     0     0     0
  4      4       -1    -3     4     6
  5      4       -2    -4     5     7
  6      1       -5     0     0     0
  7      1        8     0     0     0
  8      4       -6    -8     9    11
  9      4       -7    -9    10    12
 10      1      -10     0     0     0
 11      1      -11     0     0     0
 12      1      -12     0     0     0


                                              APPLIED NODAL LOADS
NODE          PX              PY              PZ              MX              MY              MZ

  1          0.0             0.0             0.0             0.0             0.0             0.0
  2          0.0             0.0             0.0             0.0             0.0             0.0
  3          0.0             0.0             0.0             0.0             0.0             0.0
  4          0.0           -30.000000        0.0             0.0             0.0             0.0
  5          0.0           -30.000000        0.0             0.0             0.0             0.0
  6          0.0             0.0             0.0             0.0             0.0             0.0
  7          0.0             0.0             0.0             0.0             0.0             0.0
  8          0.0           -30.000000        0.0             0.0             0.0             0.0
  9          0.0           -30.000000        0.0             0.0             0.0             0.0
 10          0.0             0.0             0.0             0.0             0.0             0.0
 11          0.0             0.0             0.0             0.0             0.0             0.0
 12          0.0             0.0             0.0             0.0             0.0             0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =      0.1251125E 25


                                              NODAL DISPLACEMENTS
NODE        DELTA-X         DELTA-Y         DELTA-Z         THETA-X         THETA-Y         THETA-Z

  1          0.0             0.0             0.0            -0.003161       -0.005792        0.006113
  2          0.0             0.0             0.0             0.002644        0.005773        0.006314
  3          0.0             0.0             0.0             0.006473        0.006056       -0.003032
  4         -0.001715       -0.021328        0.002114       -0.004948       -0.000337       -0.004247
  5         -0.000966       -0.022345       -0.000476        0.004809       -0.000359       -0.004360
  6          0.0             0.0             0.0            -0.005352       -0.005719       -0.003885
  7          0.0             0.0             0.0             0.006223       -0.005960        0.002021
  8          0.000002       -0.022559        0.001123       -0.004034        0.000334        0.004809
  9          0.001691       -0.022295       -0.001537        0.004977        0.000344        0.004987
 10          0.0             0.0             0.0            -0.006202        0.005077        0.003036
 11          0.0             0.0             0.0            -0.002943        0.005916       -0.006074
 12          0.0             0.0             0.0             0.002940       -0.005980       -0.006432
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                                        MEMBER END FORCES AND MOMENTS
                                  PPX            PPY            PPZ            MPX            MPY            MPZ
 MEMB.  END          PX           PY             PZ             MX             MY             MZ

        1'                     29.547409      14.820759       3.426393      -0.000006      -0.000122       0.000153
   1    1      33.208252        1.283886      -0.084843      -0.000042      -0.000033       0.000188
        2'                    -29.547394     -14.820743      -3.426389       1.406838      -6.983936      19.077484
        2     -33.208221       -1.283883       0.084844       0.000034       1.281693      19.388306

        1'                     30.225372      15.090419      -2.110114       0.000051       0.000097       0.000046
   2    1      33.822800        1.326509       0.060938       0.000085       0.000039       0.000074
        2'                    -30.225357     -15.090420       2.110113      -2.473983       7.532850      18.435089
        2     -33.822784       -1.325514      -0.060943      -0.000072      -0.921525      20.046516

        1'                     -3.262359      15.211133     -30.453659       0.000063       0.000065      -0.000025
   3    1      34.170944        1.336428       0.081670       0.000044       0.000016       0.000082
        2'                      3.262358     -15.211149      30.453690      18.818359       7.399334       1.679987
        2     -34.170975       -1.336429      -0.081674      -0.000036      -1.237991      20.252655

        1'                      0.109624       0.008730     -27.192734     -20.314774      -2.844772      -0.113202
   4    1      27.192932        0.003060      -0.000654       0.029429       1.413719     -20.464478
        2'                     -0.109623      -0.008730      27.192749      20.441742       2.881330       0.113775
        2     -27.192947       -0.003060       0.000655      -0.029428      -1.404182      20.596268

        1'                      2.654429     -14.892336     -29.609863     -18.070663      -7.188804       1.995709
   5    1      33.224701       -1.298245      -0.071053      -0.000043       1.068718     -19.520950
        2'                     -2.654429      14.892351      29.609848       0.000040      -0.000036      -0.000033
        2     -33.224685        1.298265       0.071061       0.000047      -0.000033       0.000025

        1'                     26.175522       0.023201       0.165042       0.089537       2.429336     -19.644257
   6    1      26.175995        0.032735       0.033109      -0.005233      -1.697475     -19.721191
        2'                    -26.175461      -0.023200      -0.165042      -0.091161      -2.991779      19.980927
        2     -26.175934       -0.032734      -0.033109       0.005233       1.217031      20.167175

        1'                     27.689634      -0.008531       0.307172       0.192865      -3.225393     -20.544510
   7    1      27.692207       -0.016314       0.035821      -0.096592       1.105335     -20.766769
        2'                    -27.689619       0.008532      -0.307172      -0.101669       2.671268      20.421478
        2     -27.692291        0.016315      -0.035821       0.096595      -1.621869      20.531494

        1'                      3.126793      15.287081     -30.458954       0.000094      -0.000140       0.000031
   8    1      34.196701        1.341101      -0.075043      -0.000079      -0.000062       0.000139
        2'                     -3.126779     -15.287067      30.459008      18.759795      -7.441078      -1.800360
        2     -34.196640       -1.341102       0.075044       0.000066       1.132497      20.231247

        1'                     -0.101870      -0.004136     -27.673219     -20.659035       3.211113      -0.018884
   9    1      27.673355       -0.013248      -0.042721       0.061683      -1.126122     -20.875656
        2'                      0.101870       0.004136      27.673218      20.598145      -2.566222       0.019022
        2     -27.673355        0.013249       0.042721      -0.061684       1.744726      20.683838

        1'                     -2.949722     -14.866494     -29.947610     -19.313156       7.212411      -1.897878
  10    1      33.441019       -1.304167       0.071047       0.000051      -1.077375     -19.783437
        2'                      2.949709      14.866485      29.947580       0.000021       0.000055       0.000030
        2     -33.440973        1.304178      -0.071053      -0.000051       0.000042      -0.000000

        1'                     29.404053     -14.695574      -2.620989       1.389295       7.222728     -18.152695
  11    1      32.046152       -1.295309       0.073227       0.000033       1.199970     -19.606506
        2'                    -29.403976      14.695573       2.620988      -0.000045       0.000019       0.000032
        2     -32.046091        1.295328      -0.073237      -0.000047       0.000004       0.000030

        1'                     30.427505     -15.146171       2.481909      -2.183373      -7.474574     -18.542775
  12    1      34.053492       -1.323731      -0.071095      -0.000040       1.077753     -20.063919
        2'                    -30.427475      15.146165      -2.481908       0.000047       0.000018       0.000065
        2     -34.053452        1.323730       0.071096       0.000039       0.000025       0.000072
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NUMBER OF NODES  4
NUMBER OF MEMBERS 12
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                            MEMBER COORDINANTS
  MEMBER-I      X(I,1)         X(I,2)         Y(I,1)         Y(I,2)         Z(I,1)         Z(I,2)

      1       -20.969986      -7.290000      0.0            6.250000       5.870000       7.219999
      2       -20.969986      -7.230000      0.0            6.250000      -6.620000      -7.330000
      3        -6.059999      -7.290000      0.0            6.250000      20.969986       7.219999
      4        -7.290000      -7.230000      6.250000       6.250000       7.219999      -7.330000
      5        -6.250000      -7.230000      0.0            6.250000     -20.969986      -7.330000
      6        -7.290000       7.219999      6.250000       6.250000       7.219999       7.290000
      7        -7.230000       7.190000      6.250000       6.250000      -7.330000      -7.190000
      8         6.059999       7.219999      0.0            6.250000      20.969986       7.290000
      9         7.219999       7.190000      6.250000       6.250000       7.290000      -7.190000
     10         6.120000       7.190000      0.0            6.250000     -20.969986      -7.190000
     11        20.969986       7.219999      0.0            6.250000       6.309999       7.290000
     12        20.969986       7.190000      0.0            6.250000      -6.309999      -7.190000


                                                  MEMBER PROPERTIES
  MEMBER-I      IX             IY             IZ             AREA           RADIUS         PHI            ALPHA

      1       0.000550       0.000326       0.000326       0.062500      35.000000       0.217400       0.471900
      2       0.000550       0.000326       0.000326       0.062500      35.000000       0.217600      -0.470900
      3       0.000550       0.000326       0.000326       0.062500      35.000000       0.218100      -0.472900
      4       0.000550       0.000326       0.000326       0.062500      35.000000       0.209400      -0.208100
      5       0.000550       0.000326       0.000326       0.062500      35.000000       0.216500       0.470900
      6       0.000550       0.000326       0.000326       0.062500      35.000000       0.208800       0.208900
      7       0.000550       0.000326       0.000326       0.062500      35.000000       0.207500      -0.208900
      8       0.000550       0.000326       0.000326       0.062500      35.000000       0.217100       0.471300
      9       0.000550       0.000326       0.000326       0.062500      35.000000       0.208400       0.208100
     10       0.000550       0.000326       0.000326       0.062500      35.000000       0.218400      -0.471900
     11       0.000550       0.000326       0.000326       0.062500      35.000000       0.218000      -0.472200
     12       0.000550       0.000326       0.000326       0.062500      35.000000       0.218300       0.471300


  MEMB   NODE(I,1)  NODE(I,2)

    1       0          1
    2       0          2
    3       0          1
    4       1          2
    5       0          2
    6       1          3
    7       2          4
    8       2          3
    9       1          4
   10       0          4
   11       0          3
   12       0          4


  NODE   NBON                 LINK
                    1      2      3      4      5      6

    1      4       -1     -3      4      6
    2      4       -2     -4     -5      7
    3      4       -6     -8      9    -11
    4      4       -7     -9    -10    -12


                                             APPLIED NODAL LOADS
  NODE        PX             PY             PZ             MX             MY             MZ

    1         0.0            0.0            0.0            0.0            0.0            0.0
    2         0.0            0.0            0.0            0.0            0.0            0.0
    3         0.0            0.0            0.0            0.0            0.0            0.0
    4         0.0          -31.079987       0.0            0.0            0.0            0.0


DETERMINANT OF SYSTEM STIFFNESS MATRIX =     0.5138254E 45

                                             NODAL DISPLACEMENTS
  NODE       DELTA-X        DELTA-Y        DELTA-Z        THETA-X        THETA-Y        THETA-Z

    1        0.011238      -0.010221      -0.011062       0.000719      -0.000000       0.000720
    2       -0.014952       0.024225      -0.011620       0.000715      -0.003599      -0.001570
    3        0.011612       0.024132       0.015374      -0.001548       0.000542       0.000752
    4       -0.016060      -0.040532       0.016203       0.000276       0.000001       0.000225
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                                   MEMBER END FORCES AND MOMENTS
                          PPX          PPY          PPZ          MPX          MPY          MPZ
MEMB.  END       PX       PY           PZ           MX           MY           MZ

        1'               -5.515539    -1.434613    -0.042577     0.814041    -4.625140     9.732392
  1     1   -5.594247     1.088785     0.004890    -0.306765    -0.034807    10.801790
        2'                5.515539     1.434613     0.042577     0.856616    -2.238565     5.114753
        2    5.594247    -1.088785    -0.004890     0.306769    -0.038971     5.640038

        1'               20.553268     7.807212    -0.404281     2.804404    -9.064332   -20.389435
  2     1   21.936005    -1.536638    -0.045157    -0.241083     0.397881   -22.484192
        2'              -20.553268    -7.807212     0.404281     0.211919     0.076400    -0.797744
        2  -21.936005     1.536638     0.045157     0.241087     0.284724    -0.736757

        1'               -0.037906    -1.244091     5.097093     9.472454     4.509384     0.860342
  3     1   -5.134943     1.077912    -0.001060     0.310339     0.019323    10.521663
        2'                0.037906     1.244091    -5.097093     5.278820     2.281328     0.906780
        2    5.134943    -1.077912     0.001060    -0.310342    -0.003494     5.813459

        1'                1.112828    -1.337521     6.226297    -6.621561    -7.217366     0.431269
  4     1   -6.221640    -1.543877     0.837598    -0.458571    -5.694010    -7.968023
        2'               -1.112828     1.337522    -6.226295   -12.839427    -9.347838    -0.511522
        2    6.221652     1.543878    -0.837598     0.458571    -6.493108   -14.495652

        1'                1.027711    -4.245849    -6.543375     4.235605     2.295510     0.092007
  5     1   -7.767964    -1.248722     0.011646     0.761589     0.019309    -4.757917
        2'               -1.027711     4.245849     6.543375    12.782243     5.310082    -2.354277
        2    7.767964     1.248722    -0.011646    -0.761580    -0.194581   -14.018109

        1'               -6.666533    -1.341434    -1.171264     0.486334     7.174612    -6.452661
  6     1   -6.672105    -1.549498    -0.836133     0.455199     5.679981    -7.802499
        2'                6.666567     1.341452     1.171268    -0.392433     7.353803   -13.011706
        2    6.672133     1.549516     0.836133    -0.455200     6.452450   -14.666658

        1'               22.693909     2.223970    -0.721108    -0.154595     4.011444     3.563585
  7     1   22.685922     2.370850    -0.459711    -0.119021     3.164188     4.417145
        2'              -22.693924    -2.223977     0.721107    -0.156765     9.564094    28.406250
        2  -22.685937    -2.370956     0.459710     0.119019     3.465131    29.772293

        1'                1.051600     7.753870   -20.370590   -20.355301     9.179082     2.144754
  8     1   21.767044    -1.543877     0.031059     0.272710    -0.300131   -22.407990
        2'               -1.051600    -7.753870    20.370590    -0.888747     0.114656     0.277729
        2  -21.767044     1.543877    -0.031059    -0.272704    -0.168570    -0.881682

        1'                0.883060     2.222319   -22.574646     3.660682    -3.903535    -0.078200
  9     1   22.572756     2.366476     0.450634     0.070616    -3.151041     4.406922
        2'               -0.883060    -2.222319    22.574646    28.518539    -9.470377     0.011531
        2  -22.572754    -2.366475    -0.450634    -0.070615    -3.374110    29.859756

        1'                2.565798    13.174665    25.545502     3.283307    -7.579364     0.893763
 10     1   28.815842     1.536932     0.131516     0.001368    -1.016471    -4.116302
        2'               -2.566799   -13.174665   -25.545502   -25.170959    10.566409    -2.839448
        2  -28.815842    -1.536932    -0.131516    -0.001367    -0.078308    27.428650

        1'                6.408544    -4.190294    -1.032918     0.030142    -2.359070     4.188618
 11     1   -7.700939    -1.246441     0.001535    -0.730319    -0.110651    -4.750267
        2'               -6.408544     4.190294     1.032918    -2.379398    -5.475005    12.812797
        2    7.700939     1.246441    -0.001535     0.730331     0.087420   -14.115636

        1'              -26.144653    13.459445    -2.248552     0.982389     2.682357     3.511650
 12     1   20.450577     1.548600    -0.140720     0.009049     1.055916    -4.401653
        2'               26.144653   -13.459445     2.248552    -3.191485   -10.660041   -25.578917
        2  -20.450577    -1.548600     0.140720    -0.009057     1.076099    27.873627


IHC217I
TRACEBACK FOLLOWS-   ROUTINE    ISN   REG. 14
                     IBCOM            8200FDCC
                     MAIN             00002868

ENTRY POINT=  50005020
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                                 MEMBER END FORCES AND MOMENTS
MEMB.  END                PPX          PPY          PPZ          MPX          MPY          MPZ
                 PX           PY           PZ           MX           MY           MZ

        1'                33.945358    15.415774     3.181581    -1.762552     9.444395   -18.029602
  1     1    37.416824    -0.145364    -0.113842     0.700360     0.879639   -20.398636
        2'               -33.945358   -15.415774    -3.181581     0.836111    -7.142142    16.759033
        2   -37.416824     0.145364     0.113842    -0.700353     0.839569    18.203812

        1'                34.626465    15.674585    -1.645257     2.624065    -9.408550   -18.148865
  2     1    38.044250    -0.124330     0.098112    -0.652696    -0.783352   -20.585129
        2'               -34.626465   -15.674585     1.645257    -1.777940     7.429569    17.102615
        2   -38.044250     0.124330    -0.098112     0.652692    -0.699449    18.706772

        1'                -2.938115    15.692607   -34.726151   -18.535324    -9.696741    -1.981327
  3     1    38.219894    -0.145473     0.113871    -0.697050    -0.866794   -20.982666
        2'                 2.938115   -15.692607    34.726151    17.270355     7.382614     1.042606
        2   -38.219894     0.145473    -0.113871     0.697051    -0.858893    18.778473

        1'                 0.135034     0.012717   -31.710052   -18.198761    -3.353313    -0.084546
  4     1    31.710327     0.011561     0.006806     0.009499     0.478958   -18.499100
        2'                -0.135034    -0.012717    31.710068    18.383774     3.291184     0.085308
        2   -31.710342    -0.011561    -0.006805    -0.009498    -0.577972    18.667282

        1'                -2.277507    15.389171    33.687546    17.393784     9.124817    -2.167693
  5     1    37.105392    -0.099639    -0.109169     0.692812     0.857931   -19.730377
        2'                 2.277507   -15.388171   -33.687546   -16.741440    -7.176315     1.321733
        2   -37.105392     0.099639     0.109169    -0.692815     0.783559    18.232590

        1'                30.972116     0.015663     0.165470     0.092337     3.112819   -17.717056
  6     1    30.972543     0.018751     0.012926     0.006864    -0.629138   -17.977661
        2'               -30.972101    -0.015661    -0.165469    -0.093433    -3.352708    17.944290
        2   -30.972528    -0.018749    -0.012925    -0.006864     0.441590    18.249695

        1'                32.483810    -0.004544     0.332147     0.135516    -3.544415   -18.509583
  7     1    32.485489    -0.007923     0.015462    -0.044187     0.371323   -18.842651
        2'               -32.483810     0.004544    -0.332148    -0.134879     3.302598    18.444061
        2   -32.485489     0.007923    -0.015462     0.044188    -0.594295    18.728394

        1'                 2.789707    15.799638   -34.738861   -18.227951     9.508473     2.043368
  8     1    38.264481    -0.123742    -0.111391     0.684816     0.862318   -20.630814
        2'                -2.789707   -15.799638    34.738861    17.249115    -7.374622    -1.151478
        2   -38.264481     0.123742     0.111391    -0.684813     0.818002    18.764435

        1'                -0.084655     0.004050   -32.318985   -19.492529     3.483249     0.016003
  9     1    32.319077     0.000306    -0.018151     0.022310    -0.412493   -18.813248
        2'                 0.084655    -0.004050    32.318985    18.551239    -3.227002    -0.016124
        2   -32.319077    -0.000306     0.018151    -0.022310     0.675326    18.817688

        1'                 2.487633    15.356285    34.048370    19.108139    -9.473238     2.103353
 10     1    37.432456    -0.136603     0.105104    -0.715139    -0.839566   -20.514709
        2'                -2.487633   -15.356285   -34.048370   -16.915436     7.321138    -1.219863
        2   -37.433456     0.136603    -0.105104     0.715142    -0.754738    18.442825

        1'               -33.746567    15.268773     2.254434    -2.210115    -9.317251    17.779022
 11     1    37.108245    -0.121718     0.106713    -0.688466    -0.937911   -20.164642
        2'                33.746567   -15.268773    -2.254434     1.336920     7.244097   -16.808853
        2   -37.108246     0.121718    -0.106713     0.688461    -0.777366    18.322754

        1'               -34.886871    15.724177    -2.061607     2.453246     9.688285    18.571733
 12     1    38.321762    -0.151800    -0.108905     0.686358     0.854047   -21.061615
        2'                34.986871   -15.724177     2.061607    -1.500995    -7.396753   -17.208115
        2   -38.321762     0.151800     0.108905    -0.686355     0.796713    18.761078

IHC217I
TRACEBACK FOLLOWS-   ROUTINE    ISN   REG. 14
                     IBCOM            8200EDC0
                     MAIN             00002848

ENTRY POINT=  50005020
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NUMBER OF NODES  4
NUMBER OF MEMBERS 12
NUMBER OF LOADING CONDITION  1
MAXIMUM NUMBER OF MEMBERS PER NODE  4

                                                   MEMBER COORDINANTS
 MEMBER-I      X(I,1)         X(I,2)         Y(I,1)          Y(I,2)          Z(I,1)          Z(I,2)

     1       -20.969986     -7.290000      0.0            6.250000        5.870000        7.219999
     2       -20.969986     -7.230000      0.0            6.250000       -6.620000       -7.330000
     3        -6.059999     -7.290000      0.0            6.250000       20.969986        7.219999
     4        -7.290000     -7.230000      6.250000       6.250000        7.219999       -7.330000
     5        -6.250000     -7.230000      0.0            6.250000      -20.969986       -7.330000
     6        -7.290000      7.219999      6.250000       6.250000        7.219999        7.290000
     7        -7.230000      7.190000      6.250000       6.250000       -7.330000       -7.190000
     8         6.059999      7.219999      0.0            6.250000       20.969986        7.290000
     9         7.219999      7.190000      6.250000       6.250000        7.290000       -7.190000
    10         6.120000      7.190000      0.0            6.250000      -20.969986       -7.190000
    11        20.969986      7.219999      0.0            6.250000        6.309999        7.290000
    12        20.969986      7.190000      0.0            6.250000       -6.309999       -7.190000


                                                   MEMBER PROPERTIES
 MEMBER-I        IX             IY             IZ              AREA            RADIUS          PHI          ALPHA

     1        0.000550       0.000326       0.000326        0.062500        35.000000       0.217600      0.471900
     2        0.000550       0.000326       0.000326        0.062500        35.000000       0.217600     -0.470900
     3        0.000550       0.000326       0.000326        0.062500        35.000000       0.218100     -0.472900
     4        0.000550       0.000326       0.000326        0.062500        35.000000       0.209400     -0.208100
     5        0.000550       0.000326       0.000326        0.062500        35.000000       0.216500      0.470900
     6        0.000550       0.000326       0.000326        0.062500        35.000000       0.208800      0.208900
     7        0.000550       0.000326       0.000326        0.062500        35.000000       0.207500     -0.208900
     8        0.000550       0.000326       0.000326        0.062500        35.000000       0.217100      0.471300
     9        0.000550       0.000326       0.000326        0.062500        35.000000       0.208400      0.208100
    10        0.000550       0.000326       0.000326        0.062500        35.000000       0.218400     -0.471900
    11        0.000550       0.000326       0.000326        0.062500        35.000000       0.218000     -0.472200
    12        0.000550       0.000326       0.000326        0.062500        35.000000       0.218300      0.471300


 MEMB   NODE(I,1)   NODE(I,2)

   1        0           1
   2        0           2
   3        0           1
   4        1           2
   5        0           2
   6        1           3
   7        2           4
   8        0           3
   9        3           4
  10        0           4
  11        0           3
  12        0           4


 NODE   NBRN                    LINK
                  1       2       3       4       5       6

   1      4      -1      -3       4       6
   2      4      -2      -4      -5       7
   3      4      -6      -8       9     -11
   4      4      -7      -9     -10     -12


                                                   APPLIED NODAL LOADS
 NODE        PX             PY             PZ              MX              MY              MZ
   1        0.0          -31.079987      0.0             0.0             0.0             0.0
   2        0.0          -31.079987      0.0             0.0             0.0             0.0
   3        0.0          -31.079987      0.0             0.0             0.0             0.0
   4        0.0          -31.079987      0.0             0.0             0.0             0.0


 DETERMINANT OF SYSTEM STIFFNESS MATRIX =      0.5139254E 45

                                                   NODAL DISPLACEMENTS
 NODE       DELTA-X        DELTA-Y        DELTA-Z         THETA-X         THETA-Y         THETA-Z
   1        0.000261      -0.011782      -0.000083       -0.001801       -0.000013       -0.001928
   2        0.000510      -0.012529       0.000792        0.001757       -0.000039       -0.001992
   3       -0.000470      -0.012338      -0.000466       -0.001814        0.000227        0.001787
   4       -0.000251      -0.012306       0.000340        0.001461        0.000337        0.001856
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