Lawrence Berkeley National Laboratory

PROGRAM ROCMAS: INTRODUCTION AND USER'S GUIDE

Author
Noorishad, J.

Publication Date
1980-09-01

Peer reviewed

LBL-12987

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

EARTH SCIENCES DIVISION

PROGRAM ROCMAS: INTRODUCTION AND USER'S GUIDE

J. Noorishad and M.S. Ayatollahi

September 1980

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

LEGAL NOTICE

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price Code: A05

LBL-12987

PROGRAM ROCMAS: INTRODUCTION AND USER'S GUIDE

J. Noorishad and M. S. Ayatollahi

Earth Sciences Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

September 1980

This work was supported by the Assistant Secretary for Nuclear Energy, Office of Waste Isolation of the U. S. Department of Energy under contract W-7405-ENG-48. Funding for this project is administered by the Office of Nuclear Waste Isolation at Battelle Memorial Institute.

TABLE OF CONTENTS

INTRODUCTION

ROCMAS (ROCk MASS) is a finite-element program for coupled flow and stress in deformable, saturated, fractured rock medium. The two-dimensional code combines the capability of isothermal transient pressure analysis and stress-strain analysis in formations with discrete fractures and porous blocks. Coupling of the pressure field and the mechanical deformation is founded on the extension of Biot's consolidation theory for porous elastic medium to nonlinear fracture behavior. The current version of the model is described by Noorishad [18]. Summary of early developments and related information are in Ayatollahi [1]. The early version of this code is known as PORFRC.

I. GOVERNING EQUATIONS

In this model, the fluid movement and the solid deformation are coupled. Each point in space, either inside a discrete fracture or within a rock block, has a pressure variable P and a solid displacement vector $\bar{u}$. The pressure field determines the fluid flow. The coupling between P and $\bar{u}$ can be described in the following loop. As the pressure changes, the effective stress acting on the rock solid changes accordingly and affects the displacement or strain of the solid. The displacement of solid changes the flow path of fluid and results in changes in the pressure field. The last coupling step is especially important for fractures. The fracture flow is very sensitive to the aperture 2b. The fracture-specific permeability $k^f = (2b)^2/12$ for parallel-plate laminar flow is used in this model.

Pressure-Strain Equation

The mathematical form of the coupling between the fluid flow and solid displacement can be written down as a set of three equations for the pressure-strain, strain-stress, and stress-load balance relations. The first fluid flow equation is

$$\frac{1}{M^i}\frac{\partial P}{\partial t} - \alpha^i \frac{\partial \varepsilon}{\partial t} = \nabla \cdot \frac{k^i}{\mu} \nabla P$$

where α^i and M^i (i = fractures or rock medium blocks) are material properties (Biot constants) representing the responses of fluid mass content to changes in pressure and changes in volumetric strain ε. Depending on the boundary conditions, the derivative $\partial\varepsilon/\partial t$ in some cases can be approximated in terms of the pressure derivative $\partial P/\partial t$. The fluid flow equation will be reduced to a simple transient pressure equation with the storage coefficient in front of $\partial P/\partial t$ determined by the porosity and compressibilities of fluid and void structures.

Stress-Strain Relation

In more general cases, the volumetric strain $\varepsilon = \varepsilon_{xx} + \varepsilon_{zz}$ depends on the effective stress field. The pressure counteracts normal to the fluid-solid interfaces. The effective stress-strain relation can be formally written in the form of Hook's Law [2-5]:

$$\overline{\overline{\tau}} - \alpha^i P \overline{\overline{I}} = \overline{\overline{\overline{\overline{C}}}}^i : \overline{\overline{\varepsilon}} .$$

For isotropic elastic porous rock medium, the components of the tensor $\overline{\overline{\overline{\overline{C}}}}^i$ can be expressed in terms of two elastic constants, e.g., Young's modulus and Poisson's ratio. For anisotropic, inelastic deformable fractures, the stress-strain-strain relation is very nonlinear. In this model, a nonlinear normal stress-normal displacement relation and a nonlinear shear stress-shear displacement relation are used [12]. The normal and shear stiffness (change of stress per unit change of displacement) as functions of stresses characterize the fracture behavior. The displacement $\bar{u}$ is simply related to the strain $\bar{\bar{\varepsilon}}$ by the component definition:

$$\varepsilon_{i,j} = 0.5\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

<u>Load Balance</u>

The third equation for the unknowns P, $\bar{\bar{\tau}}$ and $\bar{\bar{\varepsilon}}$ is Newton's first law of static equilibrium applied to an infinitesimal volume element of the fluid-filled medium

$$\nabla \cdot \bar{\bar{\tau}} + \rho_s \bar{f} = 0$$

where ρ_s is the bulk mass density and $\bar{f}$ is the body force. One body force or volumetric force is the gravity. Both the gravity effects on the fluid and rock can be taken into account. Gravitational drainage of fluid can be modeled.

II. NUMERICAL METHOD

Having established the governing and constitutive relations for fractures and solids from structural and fluid flow analysis points of view, the media under consideration could be thought to be composed of two materials with known behaviors. Analysis of such media for coupled stress and fluid flow behavior is made feasible by application of a numerical method. The method starts with adoption of a variational principle [8,9]. The variational form, written for general initial and boundary conditions, includes all the terms of the static-structural analysis variational and those of the transient fluid flow analysis in porous media. A coupling term links the two functions [1,18]. A finite-element discretization is used to discretize the space domain. The two-dimensional space is decomposed into finite element quadrilateral domains with four-corner nodes[22]. Each node has the values of three variables: the pressure P and the two components of solid displacement $\bar{u}$. Isoparametric bilinear polynomial basis functions are used to interpolate from the nodal values to the space within an element representing the porous rock medium. For a fracture, it is assumed that the aperture is small and fluid flow is along the fracture surfaces. The pressure difference between adjacent nodes across the aperture is negligible and a one-dimensional element can be used for interpolating between two end point pressures [21]. For the fracture displacements, it is convenient to take the same spatial (global) coordinates for each pair of points across the small aperture for the four-corner element. However, the relative movements of the surfaces in the direction vertical to the fracture plane and along the fracture are important for the structure analysis. The fracture element in terms of these relative displacements is used [12].

Taking variation of the discretized variational principle with respect to u and p results in the following matrix equations:

$$[K]\ \{\bar{u}\} + [C]\ \{P\} = \{F\}$$

$$[C]^T\{\bar{u}\} + ([E] + 1 * [H])\{P\} = 1 * \{Q\}$$

where the matrix [K] contains the coefficients of the stiffness of stress displacement of both inelastic fractures and elastic medium, [C] the Biot coupling coefficients, [E] fluid storage coefficients, [H] fluid hydraulic conductivities, and {Q} the fluid boundary fluxes. The column vector $\{\bar{u}\}$ contains the 2N nodal values of $\bar{u}$ for the m porous nodes and N − m fracture nodes, {P} the N values of P, and {F} the body force and boundary loads.

Time Discretion: The notation 1* in the matrix equation represents the time integration from 0 to t. To step from t to t+Δt, this model uses a predictor-corrector scheme. The solution is first predicted at t+θΔt with $2 \geq \theta \geq 1$

$$1 * P_\theta = A(t+\theta\Delta t) = \int_0^{t+\theta\Delta t} P(\tau)\,d\tau = A(t) + \frac{1}{2}\theta\Delta t(P_t + P_{t+\theta\Delta t})$$

and then it is corrected by linear interpolation

$$1 * P_t = A(t + \Delta t) = A(t) + \frac{1}{2}\Delta t(P_t + P_{t+\theta\Delta t})$$

the unknown at t+Δt is given by

$$P_{t+\Delta t} = P_t + \frac{1}{\theta} (P_{t+\theta\Delta t} + P_t)$$

It is noted that $\theta = 1$ is the central differencing Crank-Nicholson scheme. The coefficient $\theta > 1$ is used to damp out the numerical oscillation while slightly slowing down the convergence rate [20].

Solution Scheme

The nonlinear behavior of fracture stress-displacement is dealt with by the stiffness perturbation technique [12] during each time step. The stiffness matrix depends on the displacement when the displacement are out of the linear range. Iterations proceed until the stiffness matrix stabilizes within convergent criteria.

Within one iteration the matrix equation of $\{\tilde{u}\}$ and $\{P\}$ is solved by a direct procedure. The matrix is decomposed into lower and upper triangular matrices by the Gaussian LU decomposition method [2]. This reduces the matrix equation into two triangular systems which can be solved by backward and forward substitution procedures.

III. COMPUTER CODE

Documentation and Availability

The code is written in FORTRAN IV and presently being used on the CDC 7600 at LBL. Set-up of the data follows the organization of other finite-element programs at the University of California, Berkeley. Familiar options of two-dimensional finite-element (2-D FE) stress and strain analysis codes and two-dimensional finite-element (2-D FE) fluid flow codes are included in this code.

Spatial Grid

The two-dimensional grid consists of four-corner quadrilateral elements for the porous rock medium and two-node elements for the discrete fractures. The fractures can extend from one boundary to another, intersect each other, or can be isolated in the porous rock medium. An axisymmetric grid is also used.

Material Properties

The constant permeability of the porous rock medium and the initial aperture of the fracture are input parameters. For coupled calculations, the pressure- and stress-induced changes in displacement will be used to update the aperture and the fracture permeability.

The parameters M^i in the fluid flow equation for the porous rock medium and fracture can be estimated in general from the porosity and the compressibility of fluid as $1/(nC_f)$. The coupling constants a^i are dimensionless.

$\alpha^i = 0$ decouples the pressure calculations from the stress-strain analysis. For material with highly incompressible solid grains, $\alpha \cong 1$.

The mechanical properties required are Young's modulus and Poisson's ratio for the elastic porous rock medium and the initial normal stiffness, tangential stiffness, cohesion, and angle of friction for the fracture.

Fluid Properties

The fluid density and viscosity are input parameters.

Initial Conditions

Distribution of stresses, pressure and displacement can be specified at initial or program restarting time.

Boundary Conditions

Pressure and flux boundary conditions can be specified for the fluid flow. Static load and displacement boundary conditions can be specified for the stress-strain analysis.

Time Stepping and Solution Control

The time step can be increased logarithmically. A convergent criterion is specified on the stiffness difference in the iteration-perturbation procedure to handle the nonlinear fracture behavior.

Output

At the end of each time step, the pressure, displacement and the flow flux and the stress components on the elements can be printed. Graphic output of the mesh with the plot of the principal components of stress, and displacement are generated in the program.

IV. VALIDATION

The code is developed from an early iterative finite element program with steady state flow and static force-displacement analysis in jointed formation with impermeable rock [17]. Most of the efforts to validate this code are on the transient fluid flow behavior in fractures embedded in porous rock medium. Validation of the capability to handle coupling between transient fluid flow and stress-strain analysis is limited due to absence of both the analytic solutions and other numerical results. The documented tests [1] on the transient fluid flow in porous media and in fractures will be listed below.

1. Continuous Finite-Radius Well Source: The early time transient pressure responses of an axisymmetric flow to a producing well are compared with the analytic solution of Mueller and Witherspoon [15].

2. Finite Axisymmetric Aquifer: The late time pressure responses with no flow as well as constant outer boundaries are compared with the analytic solutions of Muskat [16].

3. Vertical Fractures: The pressure responses for a single vertical fracture and two perpendicular vertical fractures intersecting a well at the center of a rectangular porous medium are compared with the analytic solutions of Raghavan [19]. Geometry, mesh, input data, and the results for the latter problem are given at the end.

4. Vertical Fracture Near a Well: The pressure responses for an observation well is a system with a fracture not intersecting, but aligned with a producing

and an observation well, are compared with the analytic solution of Heber-Cinco et al. [13].

5. Horizontal Fracture: The pressure responses for a horizontal fracture located at the center of an aquifer and intersecting a well in an axisymmetric region are compared with the analytic solution of Gringarten and Ramey [11].

V. APPLICATION

The importance of the coupling between the fluid flow and the mechanical deformation in fractures has been analyzed by the iterative steady state version of this code. The flow through a jointed dam foundation has been simulated [17]. It is noted that a deformable fracture system has lower flow through the foundation and higher uplift pressure than a rigid network of fractures. The code has also been used in the analyses of laboratory experiments of large rock samples with tension fractures and of field tests in shallow fractured formations [7]. It is well known that high pressure at a wellbore can open up the fractures and will result in a high injection rate while low pressure at a wellbore during withdrawal can close the fracture and decrease the hydraulic conductivity of flow.

This recently developed transient code is well suited for a thorough study of the mentioned effects due to the fact that it can provide additional insight to the very important transient processes of the coupling phenomena.

VI. SUMMARY

This model is for the study of coupled fluid flow and stress in deformable fractured rock masses. The effective mass theory of Biot is used to relate the pressure changes with the displacements of the rock matrix. The deformation of the fracture surfaces in turn affects the fracture flow through the sensitive dependence of permeability on aperture.

The code combines techniques of fluid flow modeling and stress-strain analysis. The two-dimensional finite-element code incorporates the flow element of Wilson and Witherspoon [21] for the fracture flow, the joint element of Goodman et al. [12] for the representation of mechanical behavior, and a predictor-corrector scheme to damp out numerical oscillation.

The model is based on general theory which is of fundamental interest and practical importance. The code has the capability of handling a range of complex problems in fluid flow, induced rock mass deformation and soil consolidation [8]. Further developments to couple the fluid flow with heat transfer, or to incorporate dynamic stress analysis, can increase the range of applicability. More extensive application of the code is called for.

VII. REFERENCES

1. Ayatollahi, M. S., Noorishad, J., Witherspoon, P. A., "A finite element method for stress and fl w analysis in fractured rock masses." submitted for publication in J. of Engineering Mechanics Division. Proceedings ASCE 1981.

2. Bathe, K. J. and Wilson, E. L. Numerical Methods in Finite Element Analysis. Prentice Hall, Englewood Cliff, New Jersey, 1976.

3. Biot, M. A. "General theory of three-dimensional consolidation." J. Applied Physics, V. 12, pp. 155-164, 1941.

4. Biot, M. A. "Theory of elasticity and consolidation for a porous anisotropic media." J. Applied Physics, V. 26, pp. 182-185, 1955.

5. Biot, M. A. "Theory of deformation of a porous viscoelastic anisotropic solid." J. Applied Physics, V. 27, 1956.

6. Biot, M. A. "Mechanics of deformation and acoustic propagation in porous media." J. Applied Physics, V. 34-A, pp. 1483-1498, 1961.

7. Gale, J. E. A Numerical, Field and Laboratory Study of Flow in Rocks with Deformable Fractures. Ph.D. thesis, University of California, Berkeley, 1975.

8. Ghaboussi, J. and Wilson, E. L. "Flow of compressible fluids in porous media." SESM Report No. 72-12, University of California, Berkeley, 1971.

9. Ghaboussi, J. Dynamic Stress Analysis of Porous Elastic Solids Saturated with Compressible Fluids. Ph.D. thesis, University of California, Berkeley, 1971.

10. Ghaboussi, J. and Wilson, E. L. "Liquefaction analysis of saturated granular soils." 5th World Conference on Earthquake Engineering, Rome, 1973.

11. Gringarten, A. C. and Ramey, H. J. "Unsteady state pressure distribution created by a well with a single horizontal fracture." SPE Journal, p. 413, August 1974.

12. Goodman, R. E., Taylor, R. L. and Brekke, T. L. "A model for the mechanics of jointed rocks." J. Soil Mech. and Found. Div., ASCE, V. 94, N.S.M., 3 May 1968.

13. Heber-Cinco, L., Samaniego-V., F., and Dominguez-A., N. "Transient pressure behavior for a well with a finite conductivity vertical fracture. 51st Conference Soc. Pet. Eng., October 1976.

14. Hilber, H. and Taylor, R. L. "A finite element model of fluid flow in systems of deformable fractured rock." Report No. UC-SESM 76-5, Department of Civil Engineering, University of California, Berkeley, 1976.

15. Mueller, T. D. and Witherspoon, P. A. "Pressure Interface Effects Within Reservoirs and Aquifers" Trans. AIME, V. 234, p. 471, 1965.

16. Muskat, M. "The Flow of Homogeneous Fluids Through Porous Media". J. W. Edwards, Inc., An Arbor, 1946.

17. Noorishad, J. Finite-Element Analysis of Rock Mass Behavior Under Coupled Action of Body Forces, Flow Forces, and External Loads. Ph.D. dissertation, University of California, Berkeley, 1971.

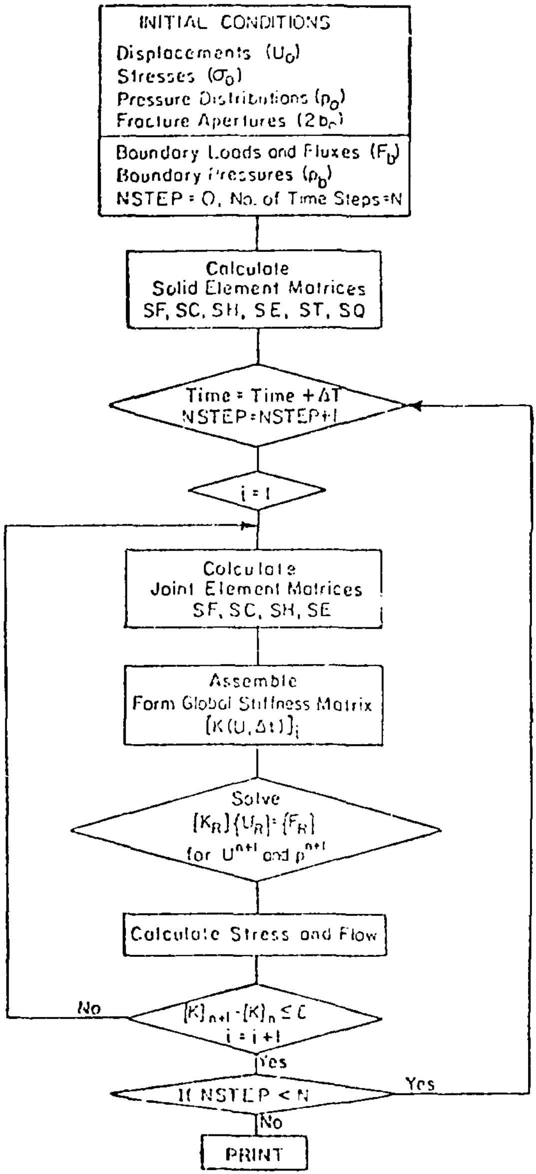
18. Norishad, J., Ayatollahi, M. S. and Witherspoon, P. A. Coupled stress and fluid flow analysis of fractured rocks, submitted to International Journal of Rock Mechanics and Mining Sciences, 1981.

19. Raghavan, R., Uraiet, A., and Thomas, G. W. "Vertical fracture height effect on transient flow behavior." 51st Conf. Soc. Pet. Eng., Oct. 1976.

20. Taylor, R. L. "Analysis of flow of compressible or incompressible fluids in porous elastic solids." Consulting Report to the Naval Civil Engineering Lab., Port Hueneme, California, 1974.

21. Wilson, C. and Witherspoon, P. A. An Investigation of Laminar Flow in Fractured Porous Rocks. Ph.D. thesis, University of California, Berkeley, California, 1970.

22. Zienkiewicz, O. C. The Finite Element Method in Engineering Science. McGraw-Hill, London, 1971.



Flow chart for stress and flow analysis of fractured porous media.

VIII. USER'S GUIDE

The program "ROCMAS" is written in FORTRAN IV and uses both large core and small core memory of the CDC 7600. The large core is used for storage of

(i) nodal points, their coordinates in two directions, their proper code used to describe boundary conditions, initial loads or displacements,

and (ii) elements, their material type properties, the correspondence between structural nodes and flow nodes, and between structural elements and flow elements, flow boundary codes, and any other properties that are unique for each node or each element.

The large core is also used to store large matrices and vectors needed for the solution of the final system of equations and the equation identifiers for the three degrees of freedom at each nodal point.

The small core memory furnishes storage of the COMMON blocks as well as DIMENSION statements.

Since "ROCMAS" is not written to use a dynamic storage option, it is necessary to keep in mind the maximum size of the arrays for which large core storage is provided. For the time being, the following limits should be kept in mind:

Maximum number of nodal points = 300

Maximum number of structural elements (joints and solids) = 300

Maximum number of joint elements = 50

Maximum number of different materials = 12

The input data* should be prepared in the groups of cards described below:

Group	Column	Format	Word	Explanation
I-1	1-5	A5	"TITLE"	Title card to start with computation
I-2	1-72	8A9	HED	Any desired titling, or blank cards
I-3	1-72	8A9	HED	two cards.
I-4	1-5	I5	NUMNP	Total no. of nodal points in the mesh
	6-10	I5	NUMEL	Total no. of elements in the mesh
	11-15	I5	NUMMAT	Total no. of different materials
	16-20	I5	NSHELL	Highest no. of solid material
	21-25	I5	NPC	No. of boundary pressure cards
	26-30	I5	NJMP	No. of joints with modified aperture
	31-35	I5	IRAND	Random aperture generator if = 1, otherwise equal to zero
	36-40	I5	NIT	Total no. of time step iterations
	41-45	I5	IPLOT	Plot output requested, if equal to 1; otherwise equal to zero
	46-50	I5	IPUNCH	Punch requested for final joint element properties if = 1, otherwise = 0
	51-55	F5.0	TTOTAL	Total estimated cp time (decimal seconds)
	56-65	F10.0	CONLIM	Joint stiffness convergence constant
	66-70	I5	NAXI	Axisymmetric problem if 1, two-dimensional problem if 0

* An example of input data preparation is given at the end.

Group	Column	Format	Word	Explanation
I-5	1-10	F10.3	AAM	Mean aperture lognormal distribution
	11-20	F10.3	THETA	Time integration factor
	21-30	F10.3	AAS	Standard deviation lognormal distribution
	31-40	F10.3	ACELX	x-direction acceleration
	41-50	F10.3	ACELY	y-direction acceleration
I-6	1-10	F10.3	XNHP	Maximum net head pressure (optional)
	11-20	F10.3	SPWT	Fluid specific gravity
	21-35	E15.5	VISC	Fluid viscosity
	36-40	I5	IPRINT	No. of time step printouts required
	41-45	I5	NDTN	Variable time step counter if > 1
	46-55	E10.5	DT	Initial time increment
	56-65	E10.5	SYSDIM	System dimension, if P_D, t_D calculated*
	66-75	E10.5	TOTALQ	Total flow, if P_D, t_D calculated*
II-1	1-8	A10	"MATERIAL"	Title card for material specifications
II-2	1-5	A10	"INCOMPRESS"	For incompressible fluid **
			"COMPRESS"	for compressible fluid

*Note that P_D, t_D calculation uses properties of first solid, therefore, it is meaningful only for a special class of problems.

**Only used for uncoupled steady state fluid flow problems. Minor modification of the solution algorithm is required for steady state coupled problems, i.e. when $\alpha \neq 0$ and incompressible fluid assumption is used.

Group	Column	Format	Word	Explanation
II-3	**Properties of solid materials**			
	1-5	I5	MTYPE	Material type, NSHELL ≥ MTYPE ≥ 1
	6-14	E9.4	RO	Mass density
	15-23	E9.4	E(1,MTYPE)	Permeability
	24-32	E9.4	E(2,MTYPE)	Compression modulus
	33-41	E9.4	E(3,MTYPE)	Poisson's ratio
	42-50	E9.4	E(4,MTYPE)	Biot's constant α (pressure displacement coupling coefficient)
	51-59	E9.4	E(5,MTYPE)	Biot's constant M (reciprocal of specific storage in case of flow analysis alone)

One card per material type should be punched. Maximum number of solid material cards is equal to NSHELL.

Group	Column	Format	Word	Explanation
II-4	**Fracture material properties**			
	1-5	I5	MTYPE	Material type
	6-14	E9.4	BLANK	
	15-23	E9.4	E(1,MTYPE)	Normal stiffness
	24-32	E9.4	E(2,MTYPE)	Tangential stiffness
	33-41	E9.4	E(3,MTYPE)	Cohesion
	42-50	E9.4	E(4,MTYPE)	Friction angle
	51-59	E9.4	E(5,MTYPE)	Maximum closure
	60-68	E9.4	E(6,MTYPE)	Biot's constant, α
	69-77	E9.4	E(7,MTYPE)	Biot's constant, M

Group	Column	Format	Word	Explanation
III	Output Information			
	1-6	A10	"OUTPUT"	Title card for output specifications
	1-80	40I2	NPP(I)	Number of perturbabions in time step I
	1-80	40I2	IPAT(J)	Output scheme for each time step

Output schemes:

(1)	IPAT=0	No prints, no plots requested
(2)	IPAT=1	Print requested
(3)	IPAT=2	Print and plot requested

IV Plot Information

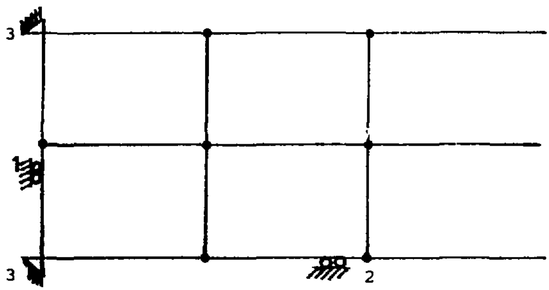
If IPLOT=0 skip this group.

Column	Format	Word	Explanation
1-10	E10.4	XLENGTH	x-dimension of plot (inches)
11-20	E10.4	YLENGTH	y-dimension of plot (inches)
21-30	E10.4	PSCL	Factor for plotting stresses in the solids
31-40	E10.4	CONJT	Multiple for PSCL to plot stresses in joints

Group	Column	Format	Word	Explanation
V	Nodes			
V-1	1-5	A5	"NODES"	Title card for nodal points
V-2	1-5	I5	N	Nodal point number
	6-10	I5	NXP	Increment to reach next nodal point
	11-20	E10.3	R(N)	x-coordinate (R—if axisymmetric) of N
	21-30	E10.3	Z(N)	y-coordinate (z—if axisymmetric) of N
	31-40	E10.3	CD	Displacement code of N
	41-50	E10.3	CDI	Displacement code to be used for preceding node
	51-60	E10.3	DU	Load or displacement at N in x-direction
	61-70	E10.3	DV	Load or displacement at N in y-direction

Note: If CD or CDI are equal to:

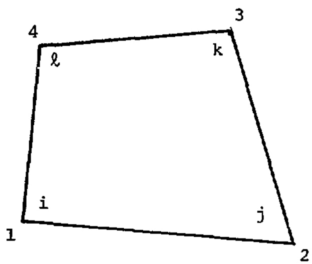
0 DU and DV are specified loads
1 DU is specified displacement, DV is specified load
2 DU is specified load, DV is specified displacement
3 DU and DV are specified displacements (Fig. 7)



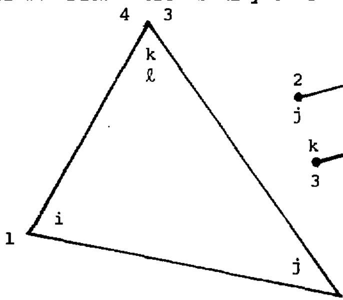
Sketch: **Application of load or displacement boundary codes.**
Nodal point cards need not be in order, except when generating a set where the last node in the row should come after the first. The last nodal point of the system should appear on the last card.

Group	Column	Format	Word	Explanation
VI	Elements			
VI-1	1-7	A7	"ELEMENT"	Title card for elements
VI-2	1-5	I5	M	Element number
	6-10	I5	IX(M,1)	Nodal points 1 to 4 defining the element
	11-15	I5	IX(M,2)	must be counterclockwise for solids and
	16-20	I5	IX(M,3)	lengthwise for joints (Fig. 8)
	21-25	I5	IX(M,4)	
	26-30	I5	IX(M,5)	Material type
	31-35	I5	IXD(1)	Increments used to change IX(M,1) to
	36-40	I5	IXD(2)	reach next generated element
	41-45	I5	IXD(3)	
	46-50	I5	IXD(4)	
	51-55	I5	JXD	Increment used to alternate material type

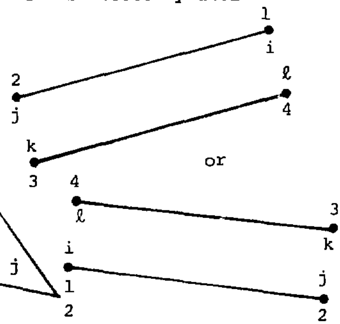
Elements are calculated in order. Use as many cards as necessary until N = NUMEL.



quadrilateral element (solid)



triangular element (solid)



Joint element (fracture)

Sketch: Element nodal point numbering.

Group	Column	Format	Word	Explanation
VII	Boundary distribution load			
	If NPC = 0, skip this group.			
VII-1	1-8	A8	"PRESSURE"	Title card for boundary pressures
VII-2	1-5	I5	I1	Nodal point number
	6-10	I5	I2	Nodal point number
	11-20	F10.3	PS1	Pressure at I1
	21-30	F10.3	PS2	Pressure at I2

VIII Flow conditions

This group must not appear before Group VII.

Group	Column	Format	Word	Explanation
VIII-1	1-4	A4	"FLOW"	Title card for flow at the boundary
VIII-2	1-5	I5	N	Nodal point number. If joint use smaller nodal point across the joint.
	6-10	I5	NL	IB(N) = nonzero, if constant PHIO(N)
	11-20	F10.3	PH	PHIO(N) = pressure or head if SPWT = 0
	21-30	F10.3	QQ	Q(N) = flowrate at N

If IB(N) = 0 and Q(N) = 0.0, omit this card.

Cards are needed only if IB(N) ≠ 0 or if Q(N) ≠ 0.0.

Group	Column	Format	Word	Explanation
IX	Residual stresses			

Skip this group if no initial stress is given.

Group	Column	Format	Word	Explanation
IX-1	1-8	A8	"RESIDUAL"	Title card for initial stresses
IX-2	1-10	I10	N	Element number
	11-20	E10.3	RESID(N,1)	Stress in x-direction
	21-30	E10.3	RESID(N,2)	Stress in y-direction
	31-40	E10.3	RESID(N,3)	Stress in z-direction
	41-50	E10.3	RESID(N,4)	Shear stress in xy plane

Note that compressive stresses are negative. Repeat as many cards as needed to define NUMEL. The program will calculate stresses for intermediate elements by assigning the preceding values.

Group	Column	Format	Word	Explanation
X	1-4	A4	"DONE"	Title card

This card marks the end of the data for generating the mesh physical information for this particular problem.

Group	Column	Format	Word	Explanation
XI	Joint properties modification			
	Use only if NJMP > 0.			
XI	1-5	I5	I	Joint element to be modified
	6-15	F10.3	COEG	Coefficient to modify the aperture
	16-30	F15.5	COEM1	Coefficient to modify normal stiffness
	31-45	F15.5	COEM2	Coefficient to modify tangential stiffness
	46-60	F15.5	COEM3	Coefficient to modify cohesion
	61-75	F15.5	COEM4	Coefficient to modify friction angle
XII	1-5		"BLANK"	If the flow or pressure source is a step function (kept constant in time). Use another title card if the source is an initial pulse.
XIII	1-10	I10	NSTEP	Number of time steps with a constant time increment DT
	11-30	E20.5	DT	Constant time increment for NSTEP
XIV	Use as many cards as needed to reach NDTN in Group I. For steady state problems* use one card, NSTEP = 1 and DT > zero.			
XIV	1-3	E13	"END"	Final card in the data deck.

---

* **Reminder:** For steady state fluid flow problems, put E(6.MTYPE) equal to zero and use "INCOMPRESS" card.

APPENDIX I

SAMPLE PROBLEM

WITH SAMPLE INPUT OUTPUT

SAMPLE PROBLEM

As an example for data preparation, the problem of fluid flow to a well intercepting a vertical fracture is solved. Although the data is originally set up for coupled stress-flow analysis, the problem is first solved in uncoupled state for the purpose of comparison with the exsting solution [Raghavan et al., (17)]. To achieve a conventional fluid flow analysis, one has to assign a zero value to the coupling coefficient α and a value equivalent to $1/S_s$ (inverse specific storage) to M. Later, allowing for the deformability of the medium, a coupled analysis is performed. As it is shown in Table 1, in this case $\alpha \neq 0$ (a value equal to 1.0 is assumed) and $M = 1/nC_f$. Figures 1 through 4 present the results of the modeling and following plates exhibit the setup of the data. PSF system equivalent units are used in the tabulation of the data set.

TABLE 1. Material properties used for the analysis of fluid flow in fractured rock mass.

Material type	Properties		Value
fluid	γ_f, specific weight		9.8×10^3 N/m^3
	C_f^{-1}, incompressibility		1.95 GPa
	η, viscosity		2.8×10^{-4} N-sec/m^2
porous rock	E, Young's modulus		2.45 GPa
	ν, Poisson's ratio		0.25
	γ_r, specific weight		2.45×10^4 N/m^3
	n, porosity		2.15
	k, permeability		10^{-5} m/s
	M, Biot's storage constant	coupled	1.47 GPa
		uncoupled*	14.0 GPa
	α, Biot's coupling constant	coupled	1.0
		uncoupled	0.0
fractures	K_N, initial normal stiffness		1.60 GPa/m
	K_s, initial tangential stiffness		0.50 GPa/m
	C_o, cohesion		0.0
	ϕ, friction angle		30°.0
	2b, initial aperture		1×10^{-3}–1×10^{-14} m
	n, porosity		0.15
	M, Biot's storage constant	coupled	1.47 GPa
		uncoupled*	14.0 GPa
	α, Biot's storage constant	coupled	1.0
		uncoupled	0.0

* In this case M is the reciprocal of the specific coefficient of storage of the porous medium.

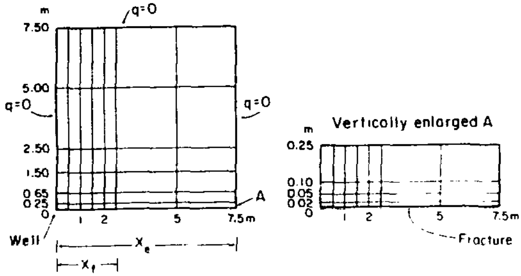


FIG. 1.--TWO-DIMENSIONAL FINITE ELEMENT MESH. (XBL 806-7222)

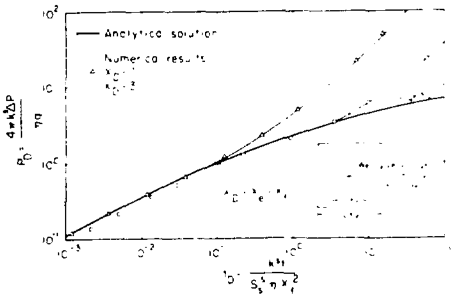


FIG. 2.--P_D VERSUS t_d FOR A SINGLE FRACTURE INTERSECTING A WELL AT THE CENTER OF A RECTANGULAR POROUS MEDIUM. ANALYTICAL SOLUTION AFTER RAGHAVAN ET AL. (1976). (XBL 806-2703)

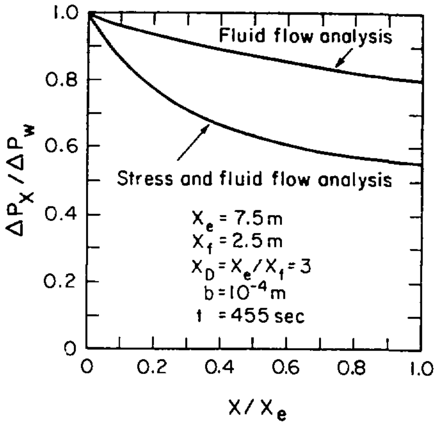


FIG. 3.--PRESSURE DROP ALONG SOFT FRACTURE OF 0.1 mm APERTURE IN FLUID FLOW ANALYSIS AND STRESS-FLUID FLOW ANALYSIS. (XBL 806-2705)

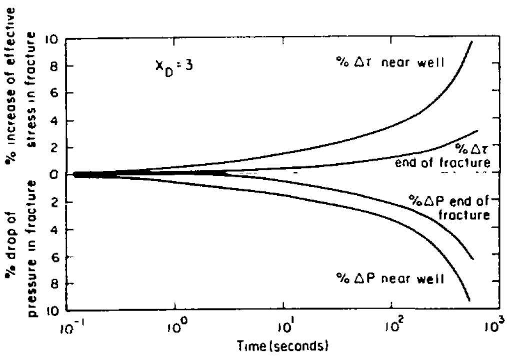


FIG. 4.--THE VARIATION OF PRESSURE AND EFFECTIVE STRESS ALONG THE NEAR AND FAR ENDS OF THE FRACTURE. (XBL 806-2706)

SAMPLE INPUT DATA PREPARATION FOR COUPLED PROBLEM

SYMBOL CODING FORM

TITLE: *INPUT DATA PREPARATION EXAMPLE . Ref. Fig. 5.6 (XD=3)* PROGRAMMER: ______ SHEET *1* OF ____

```
LABEL    COMMAND  ARGUMENT          COMMENTS
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
TITLE
SIMULATION PUMPING OF CONFINED AQUIFER WITH SINGLE VERTICAL FRACTURE
INTERSECTING THE WELL----PLANE-STRAIN PROBLEM
   88   70    3    1                  35         1   50      6250
          2.
                     5.85       E-6        10 1.    E-4 3.1416    4.3   E-5
MATERIAL
COMPRESSIBLE
    1 4.85     3.1 E-13 5.14  E7 2.5  E-1 -1.      2.94  E8
    2          1.    E7 1.    E7          30.      -3.28E-4 -1.      41.1  E6
    3          7.5  E11 7.5  E11          30.      -3.28E-9 -1.      41.1  E6
OUTPUT
 / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / /
 / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / /
NODES
    1    1                     3.        2.
    6    1 8.202               2.        2.
    8    1 2.461  E1           2.        2.
    9    1                     1.
   14    1 8.202
   16    1 2.461  E1           1.
   17    1           6.562 E-2 1.
   22    1 8.202     6.562 E-2
   24    1 2.461  E1 6.562 E-2 1.
   25    1           1.64  E-1 1.
```

SYMBOL CODING FORM

TITLE: PROGRAMMER: SHEET 2 OF

LABEL	COMMAND		ARGUMENT				COMMENTS
30	1	8.202		1.64	E-1		
32	1	2.461	E1	1.64	E-1	1.	
33	1			3.281	E-1	1.	
38	1	8.202		3.281	E-1		
40	1	2.461	E1	3.281	E-1	1.	
41	1			8.203	E-1	1.	
46	1	8.202		8.203	E-1		
48	1	2.461	E1	8.203	E-1	1.	
49	1			1.969		1.	
54	1	8.202		1.969			
56	1	2.461	E1	1.969		1.	
57	1			4.922		1.	
62	1	8.202		4.922			
64	1	2.461	E1	4.922		1.	
65	1			8.202		1.	
70	1	8.202		8.202			
72	1	2.461	E1	8.202		1.	
73	1			1.64	E1	1.	
78	1	8.202		1.64	E1		
80	1	2.461	E1	1.64	E1	1.	
81	1			2.461	E1	1.	
86	1	8.202		2.461	E1		
88	1	2.461	E1	2.461	E1		
ELEMENT							
1	1	2	10	9	2	1	1 1 1

SYMBOL CODING FORM

TITLE: ______ PROGRAMMER: ______ SHEET 3 OF ______

LABEL	COMMAND	ARGUMENT	COMMENTS
5	5 6	14 13 2 1	1 1 1
6	6 7	15 14 3 1	1 1 1
8	9 10	18 17 1 1	1 1 1
15	17 18	26 25 1 1	1 1 1
22	25 26	34 33 1 1	1 1 1
29	33 34	42 41 1 1	1 1 1
36	41 42	50 49 1 1	1 1 1
43	49 50	58 57 1 1	1 1 1
50	57 58	66 65 1 1	1 1 1
57	65 66	14 73 1 1	1 1 1
64	73 74	82 81 1 1	1 1 1
70	79 80	88 87 1	
PRESSURE			
81	82 -50000.	-50000.	
82	83 -50000.	-50000.	
83	84 -50000.	-50000.	
84	85 -50000.	-50000.	
85	86 50000.	-50000.	
86	87 -50000.	-50000.	
87	88 -50000.	-30000.	
88	80 -50000.	-50000.	
80	72 -50000.	-50000.	
72	64 -50000.	-50000.	
64	56 -50000.	-50000.	
56	48 -50000.	-50000.	

P1-6073'9-69

SYMBOL CODING FORM

TITLE: PROGRAMMER: SHEET 4 OF

LABEL (1–9)	COMMAND (10–18)	ARGUMENT (19–36)	COMMENTS (37–72)	(73–80)
48 4	0 -50000.	-50000.		
40 3	2 -50000.	-50000.		
32 2	4 -50000.	-50000.		
24 1	6 -50000.	-50000.		
FLOW				
1		4.3 E-5		
88				
RESIDUAL				
	1 -5.	E4 -5. E4		
8	8 -5.	E4 -5. E4		
DONE				
BLANK				
	5	1. E-3		
	5	1. E-2		
	5	1. E-1		
	5	1. E+0		
	5	1. E+1		
	5	1. E+2		
	5	1. E+3		
	5	1. E+4		
	5	1. E+5		
	5	1. E+6		
END				

SAMPLE OUTPUT FOR UNCOUPLED PROBLEM

I. General parameters and material properties

```
PLANE STRAIN-FLOW ANALYSIS OF JOINTED STRUCTURE
SIMULATION PUMPING OF CONFINED AQUIFER WITH SINGLE VERTICAL   FRACTURE
INTERSECTING THE WELL----PLAIN STRAIN PROBLEM

NUMNP-NUMBER OF NODAL POINTS--------------------     88
NUMEL-NUMBER OF ELEMENTS------------------------     70
NUMMAT-NUMBER OF DIFFERENT MATERIALS------------      3
NSHELL-NUMBER OF SOLID MATERIALS----------------      1
NPC-NUMBER OF BOUNDARY PRESSURE CARDS-----------     16
NJMP-NUMBER OF JOINTS WITH MODIFIED APERTURES---     -0
IRAND-RANDOM APERTURE GENERATOR IF 1------------     -0
NIT-NUMBER OF TIME STEPS------------------------     35
IPLOT-PLOT INFORMATION REQUIRED IF 1------------     -0
IPUNCH-PUNCH IF 1 ------------------------------      1
TTOTAL-ESTIMATED TOTAL CP TIME(DECIMAL SECONDS)-     50

AAM-MEAN-APERTURE LOGNORMAL DISTRIBUTION--------     0.
AAS-STANDARD DEVIATION-LOGNORMAL DISTRIBUTION---     0.
ACELX-X ACCELERATION (FEET/SECOND)--------------     C.
ACELY-Y ACCELERATION (FEET/SECOND)--------------     0.
XNHP-MAXIMUM NET HEAD PRESSURE (PSF)------------     0.
SPWT-FLUID SPECIFIC WEIGHT----------------------    -C.
NOTN-VARIABLE TIME-STEP COUNTER,IF G.T. 1-------     10
IPRT,NO. OF CYCLES FOR DISPL. PRINT-------------     0
DT-INITIAL TIME INCREMENT-----------------------     1.00000E-03
CONLIM JOINT STIFF.CONVERG.CONSTANT ------------      6250
NAXI-AXISYM. PROBLEM IF= 1----------------------     -0
THETA- TIME INTEGRATION CONSTANT----------------      2.000
VISC-FLUID VISCOSITY (PSF)----------------------     5.85000E-06
SYSDIM-SYSTEM DIMENSION REQUIRED IF PO,TO WANTED     3.14160E+00
TOTALQ-TOTAL FLOW REQUIRED IF PO,TO WANTED------     4.30000E-05

SIMULATION PUMPING OF CONFINED AQUIFER WITH SINGLE VERTICAL   FRACTURE
 INTERSECTING THE WELL----PLAIN STRAIN PROBLEM

MATERIAL NO. =  1
  MASS DENSITY------     4.85
   PERMEABILITY------    3.1000E-13
ELASTIC MODULUS ------    5.1400E+07
 POISSONS RATIO------    2.5000E-01
BIOTS CONSTANT(ALPHA)     C.
BIOTS CONSTANT(M)-----    3.0700E+07

MATERIAL NO. =  2
  KN-----              1.0000E+08
  KT-----              1.0000E+08
  C------              C.
  PHI----              3.0000E+01
  MAX. CLOSURE ----   -3.2800E-04
BIOTS CONSTANT(ALPHA)    0.
BIOTS CONSTANT( M )      4.1100E+07

MATERIAL NO. =  3
  KN-----              7.5000E+11
  KT-----              7.5000E+11
  C------              C.
  PHI----              3.0000E+01
  MAX. CLOSURE-----   -3.2800E-09
BIOTS CONSTANT(ALPHA)   -C.
BIOTS CONSTANT( M )      4.1100E+07
```

II. Displacement and Pressure Results

DISPL. AND PRESSURES AT TIME 5.5555E+01

NODAL PT	DISPL IN X-DIREC	DISPL IN Y-DIREC	PRESSURE	DIMENSIONLESS TIME,TD	DIMENSIONLESS PRESSURE,PD
1	-7.76857E-30	-4.10125E-16	2.89381E+04	0.	4.11110E+00
2	-7.86172E-16	-8.20250E-16	2.91475E+04	3.35826E+01	3.30045E+00
3	-1.24544E-15	-8.20250E-16	2.92903E+04	8.39566E+00	2.74759E+00
4	-1.65013E-15	-8.20250E-16	2.93971E+04	3.73140E+00	2.33413E+00
5	-2.12213E-15	-8.20250E-16	2.94774E+04	2.09892E+00	2.02221E+00
6	-2.18923E-15	-2.46075E-15	2.95341E+04	1.34331E+00	1.80358E+00
7	-2.01821E-15	-4.10125E-15	2.99168E+04	3.35826E-01	3.22025E-01
8	-2.51565E-28	-2.05062E-15	2.99486E+04	1.49256E-01	1.58823E-01
9	-1.64050E-17	-7.46621E-16	2.89381E+04	1.49256E-01	4.11110E+00
10	-7.81726E-16	-8.52995E-16	2.91475E+04	3.35826E+01	3.30045E+00
11	-1.24662E-15	-8.80239E-16	2.92903E+04	8.39566E+00	2.74759E+00
12	-1.64982E-15	-8.80746E-16	2.93971E+04	3.73140E+00	2.33413E+00
13	-2.12261E-15	-1.06843E-15	2.94774E+04	2.09892E+00	2.02221E+00
14	-2.18933E-15	-2.46074E-15	2.95341E+04	1.34331E+00	1.80358E+00
15	-2.01820E-15	-4.10123E-15	2.99168E+04	3.35826E-01	3.22025E-01
16	-1.65879E-20	-2.05065E-15	2.99486E+04	1.49256E-01	1.58823E-01
17	-4.10125E-17	-7.71954E-16	2.89598E+04	1.49256E-01	4.02723E+00
18	-7.73185E-16	-8.49702E-16	2.91527E+04	3.35826E+01	3.28058E+00
19	-1.24705E-15	-8.82404E-16	2.92946E+04	8.39566E+00	2.73108E+00
20	-1.65341E-15	-8.82912E-16	2.94000E+04	3.73140E+00	2.32279E+00
21	-2.08180E-15	-1.09420E-15	2.94799E+04	2.09892E+00	2.01363E+00
22	-2.16582E-15	-2.45128E-15	2.95376E+04	1.34331E+00	1.79017E+00
23	-2.01123E-15	-4.08977E-15	2.99158E+04	3.35826E-01	3.25806E-01
24	-6.13987E-17	-2.07989E-15	2.99491E+04	1.49256E-01	1.56935E-01
25	-6.56200E-17	-8.10911E-16	2.89902E+04	1.49256E-01	3.90961E+00
26	-7.69155E-16	-8.45846E-16	2.91611E+04	3.35826E+01	3.24792E+00
27	-1.24660E-15	-8.86264E-16	2.93009E+04	8.39566E+00	2.70660E+00
28	-1.65465E-15	-8.88605E-16	2.94045E+04	3.73140E+00	2.20546E+00
29	-2.02701E-15	-1.13101E-15	2.94837E+04	2.09892E+00	1.99884E+00
30	-2.13161E-15	-2.44264E-15	2.95427E+04	1.34331E+00	1.77040E+00
31	-2.00145E-15	-4.07407E-15	2.99145E+04	3.35826E-01	3.31187E-01
32	-1.50354E-16	-2.11886E-15	2.99498E+04	1.49256E-01	1.94259E-01
33	-1.64050E-16	-8.72984E-16	2.90360E+04	1.49256E-01	3.72236E+00
34	-7.63337E-16	-8.43422E-16	2.91766E+04	3.35826E+01	3.18780E+00
35	-1.24877E-15	-8.91453E-16	2.93114E+04	8.39566E+00	2.66611E+00
36	-1.64757E-15	-9.01493E-16	2.94122E+04	3.73140E+00	2.27529E+00
37	-1.94982E-15	-1.18720E-15	2.94902E+04	2.09892E+00	1.97357E+00
38	-2.07745E-15	-2.42446E-15	2.95510E+04	1.34331E+00	1.73834E+00
39	-1.98658E-15	-4.05101E-15	2.99123E+04	3.35826E-01	3.39423E-01
40	-2.90948E-16	-2.17504E-15	2.99509E+04	1.49256E-01	1.90186E-01
41	-4.10125E-16	-1.03850E-15	2.91466E+04	1.49256E-01	3.30409E+00
42	-8.29049E-16	-8.66925E-16	2.92290E+04	3.35826E+01	2.98517E+00
43	-1.25179E-15	-9.07378E-16	2.93432E+04	8.39566E+00	2.54259E+00
44	-1.60090E-15	-9.58559E-16	2.94360E+04	3.73140E+00	2.18354E+00
45	-1.78825E-15	-1.32779E-15	2.95107E+04	2.09892E+00	1.89425E+00
46	-1.93776E-15	-2.37784E-15	2.95744E+04	1.34331E+00	1.64784E+00
47	-1.95593E-15	-3.98859E-15	2.99072E+04	3.35826E-01	3.59256E-01
48	-6.61953E-16	-2.30999E-15	2.99534E+04	1.49256E-01	1.80420E-01
49	-1.02531E-15	-1.31117E-15	2.93202E+04	1.49256E-01	2.63206E+00
50	-1.09600E-15	-1.04206E-15	2.93516E+04	3.35826E+01	2.51039E+00
51	-1.30506E-15	-9.96649E-16	2.94213E+04	8.39566E+00	2.24061E+00
52	-1.50630E-15	-1.12731E-15	2.94945E+04	3.73140E+00	1.95695E+00
53	-1.62114E-15	-1.54992E-15	2.95608E+04	2.09892E+00	1.70055E+00
54	-1.73955E-15	-2.30788E-15	2.96278E+04	1.34331E+00	1.44023E+00
55	-1.53514E-15	-3.84036E-15	2.99009E+04	3.35826E-01	3.83778E-01
56	-1.29194E-15	-2.56201E-15	2.99568E+04	1.49256E-01	1.67382E-01
57	-1.55147E-15	-1.88149E-15	2.95754E+04	1.49256E-01	1.64401E+00
58	-1.67651E-15	-1.50965E-15	2.95835E+04	3.35826E+01	1.61247E+00
59	-1.71592E-15	-1.39406E-15	2.96073E+04	8.39566E+00	1.52052E+00
60	-1.72226E-15	-1.52532E-15	2.96424E+04	3.73140E+00	1.38446E+00
61	-1.74045E-15	-1.84909E-15	2.96829E+04	2.09892E+00	1.22753E+00
62	-1.77480E-15	-2.26638E-15	2.97251E+04	1.34331E+00	1.06417E+00
63	-2.05371E-15	-3.49802E-15	2.99048E+04	3.35826E-01	3.68620E-01
64	-2.03974E-15	-2.99237E-15	2.99593E+04	1.49256E-01	1.57588E-01
65	-2.87087E-15	-2.28741E-15	2.97358E+04	1.49256E-01	1.00722E+00
66	-2.70659E-15	-1.93731E-15	2.97435E+04	3.35826E+01	5.52869E-01
67	-2.54629E-15	-1.83761E-15	2.97541E+04	8.39566E+00	9.51849E-01
68	-2.40429E-15	-1.91478E-15	2.97705E+04	3.73140E+00	8.88657E-01
69	-2.29181E-15	-2.09962E-15	2.97910E+04	2.09892E+00	8.09225E-01
70	-2.22168E-15	-2.34244E-15	2.98139E+04	1.34331E+00	7.20597E-01
71	-2.24991E-15	-3.27950E-15	2.99221E+04	3.35826E-01	3.01718E-01
72	-2.31036E-15	-3.24284E-15	2.99622E+04	1.49256E-01	1.46319E-01
73	-4.10125E-15	-2.48164E-15	2.99272E+04	1.49256E-01	2.81684E-01
74	-3.82408E-15	-2.57128E-15	2.99278E+04	3.35826E+01	2.79601E-01
75	-3.55568E-15	-2.63919E-15	2.99294E+04	8.39566E+00	2.73303E-01
76	-3.31148E-15	-2.70325E-15	2.99321E+04	3.73140E+00	2.63003E-01
77	-3.11307E-15	-2.77332E-15	2.99356E+04	2.09892E+00	2.49205E-01
78	-2.95723E-15	-2.83441E-15	2.99359E+04	1.34331E+00	2.32495E-01
79	-2.62083E-15	-3.23597E-15	2.99650E+04	3.35826E-01	1.35403E-01
80	-2.60775E-15	-3.59276E-15	2.99770E+04	1.49256E-01	8.90561E-02
81	-2.05062E-15	-2.23955E-15	2.99682E+04	1.49256E-01	1.23196E-01
82	-2.24383E-15	-2.67688E-15	2.99684E+04	3.35826E+01	1.22452E-01
83	-2.38469E-15	-2.93571E-15	2.99685E+04	8.39566E+00	1.20312E-01
84	-2.47953E-15	-3.10342E-15	2.99698E+04	3.73140E+00	1.16896E-01
85	-2.54004E-15	-3.18551E-15	2.99710E+04	2.09892E+00	1.12331E-01
86	-2.56239E-15	-3.22943E-15	2.99724E+04	1.34331E+00	1.06030E-01
87	-2.46666E-15	-3.46551E-15	2.99807E+04	3.35826E-01	7.48482E-02
88	-2.39269E-15	-3.95748E-15	2.99848E+04	1.49256E-01	5.88800E-02

III. Stress and Flow Results

STRESSES AND FLOWS AT TIME 55.555

ITERATION NUMBER 25 PERTURBATION NUMBER 25

ELEMENT OR JOINT	SIGR SIGN	SIGZ SIGS	SIGT NDISP	SIGRZ TDISP	SIGMAX NSTIF	SIGMIN TSTIF	ANGLE STRNGTH	FLWR WIDTH	FLWZ PRFLC	FLWMAX PE	ANGLE
JT 1	-2.00E+04	0.	0.	0.	1.00E+08	1.00E+08	1.15E+04	3.28E-04	6.42E-05	1.10E+01	
JT 2	-2.00E+04	0.	0.	0.	1.00E+08	1.00E+08	1.15E+04	3.28E-04	4.38E-05	7.46E+00	
JT 3	-2.00E+04	0.	0.	0.	1.00E+08	1.00E+08	1.15E+04	3.28E-04	3.27E-05	5.55E+00	
JT 4	-2.00E+04	0.	0.	0.	1.00E+08	1.00E+08	1.15E+04	3.28E-04	2.46E-05	[illegible]	
JT 5	-2.00E+04	0.	0.	0.	1.00E+08	1.00E+08	1.15E+04	3.28E-04	1.74E-05	2.97E+00	
JT 6	-2.00E+04	0.	0.	0.	7.50E+11	7.50E+11	1.15E+04	3.28E-05	2.35E-20	4.01E-15	
JT 7	-2.00E+04	0.	0.	0.	7.50E+11	7.50E+11	1.15E+04	3.28E-05	1.55E-21	2.33E-16	
8	-5.00E+04	-5.00E+04	-1.28E-08	-3.67E-09	-5.00E+04	-5.00E+04	1.00E+02	-6.50E-06	-1.08E-05	-5.20E-06	5.22E+01
9	-5.00E+04	-5.00E+04	-5.71E-09	8.95E-10	-5.00E+04	-5.00E+04	8.56E+01	-4.60E-06	-7.79E-06	-4.24E-06	4.23E+01
10	-5.00E+04	-5.00E+04	-5.75E-09	-6.36E-10	-5.00E+04	-5.00E+04	1.00E+02	-3.43E-06	-2.90E-06	-3.15E-06	4.26E+01
11	-5.00E+04	-5.00E+04	-1.00E-08	3.33E-09	-5.00E+04	-5.00E+04	5.55E+01	-2.55E-06	-2.19E-06	-2.41E-06	4.26E+01
12	-5.00E+04	-5.00E+04	-3.81E-09	-7.17E-09	-5.00E+04	-5.00E+04	-3.77E+01	-1.85E-06	-7.41E-06	-2.17E-06	4.88E+01
13	-5.00E+04	-5.00E+04	3.37E-09	6.68E-10	-5.00E+04	-5.00E+04	8.27E+01	-2.46E-06	-1.00E-06	-2.04E-06	3.26E+01
14	-5.00E+04	-5.00E+04	2.19E-09	-3.43E-09	-5.00E+04	-5.00E+04	-1.17E+01	-2.10E-07	1.58E-07	-1.26E-08	4.41E+01
15	-5.00E+04	-5.00E+04	-1.27E-08	-2.92E-09	-5.00E+04	-5.00E+04	1.00E+02	-5.88E-06	-1.04E-05	-8.80E-06	5.31E+01
16	-5.00E+04	-5.00E+04	-5.96E-09	-5.35E-11	-5.00E+04	-5.00E+04	1.00E+02	-4.55E-06	-3.97E-06	-4.26E-06	4.31E+01
17	-5.00E+04	-5.00E+04	-6.10E-09	-1.05E-10	-5.00E+04	-5.00E+04	1.00E+02	-3.38E-06	-2.91E-06	-3.16E-06	4.29E+01
18	-5.00E+04	-5.00E+04	-9.46E-09	2.75E-09	-5.00E+04	-5.00E+04	5.21E+01	-2.57E-06	-2.23E-06	-2.41E-06	4.30E+01
19	-5.00E+04	-5.00E+04	-3.92E-09	-7.44E-09	-5.00E+04	-5.00E+04	-3.93E+01	-1.89E-06	-2.40E-06	-2.18E-06	4.85E+01
20	-5.00E+04	-5.00E+04	3.11E-09	4.99E-10	-5.00E+04	-5.00E+04	8.42E+01	-2.42E-06	-1.00E-06	-2.01E-06	3.27E+01
21	-5.00E+04	-5.00E+04	2.33E-09	-3.30E-09	-5.00E+04	-5.00E+04	-1.21E+01	-2.22E-07	1.88E-07	-3.36E-08	4.26E+01
22	-5.00E+04	-5.00E+04	-1.19E-08	-5.80E-09	-5.00E+04	-5.00E+04	1.00E+02	-5.03E-06	-9.90E-06	-8.24E-06	5.45E+01
23	-5.00E+04	-5.00E+04	-6.20E-09	-2.88E-10	-5.00E+04	-5.00E+04	1.00E+02	-4.43E-06	-4.20E-06	-4.32E-06	4.42E+01
24	-5.00E+04	-5.00E+04	-6.19E-09	2.08E-10	-5.00E+04	-5.00E+04	8.85E+01	-3.30E-06	-2.52E-06	-3.12E-06	4.33E+01
25	-5.00E+04	-5.00E+04	-8.55E-09	1.95E-09	-5.00E+04	-5.00E+04	4.33E+01	-2.54E-06	-2.29E-06	-2.42E-06	4.35E+01
26	-5.00E+04	-5.00E+04	-3.84E-09	-7.74E-09	-5.00E+04	-5.00E+04	-4.20E+01	-1.93E-06	-2.39E-06	-2.19E-06	4.80E+01
27	-5.00E+04	-5.00E+04	2.86E-09	2.17E-10	-5.00E+04	-5.00E+04	8.76E+01	-2.37E-06	-9.94E-07	-1.96E-06	3.29E+01
28	-5.00E+04	-5.00E+04	2.37E-09	-3.10E-09	-5.00E+04	-5.00E+04	-1.25E+01	-2.39E-07	1.74E-07	-6.51E-08	4.05E+01
29	-5.00E+04	-5.00E+04	-1.03E-08	-5.25E-09	-5.00E+04	-5.00E+04	1.00E+02	-3.60E-06	-8.77E-06	-7.27E-06	5.73E+01
30	-5.00E+04	-5.00E+04	-6.51E-09	-1.99E-09	-5.00E+04	-5.00E+04	1.00E+02	-4.02E-06	-4.53E-06	-4.25E-06	4.67E+01
31	-5.00E+04	-5.00E+04	-6.21E-09	5.36E-10	-5.00E+04	-5.00E+04	8.52E+01	-3.13E-06	-3.00E-06	-3.06E-06	4.44E+01
32	-5.00E+04	-5.00E+04	-7.19E-09	2.54E-10	-5.00E+04	-5.00E+04	6.81E+00	-2.47E-06	-2.39E-06	-2.43E-06	4.45E+01
33	-5.00E+04	-5.00E+04	-3.70E-09	-8.04E-09	-5.00E+04	-5.00E+04	-4.46E+01	-2.01E-06	-2.36E-06	-2.20E-06	4.73E+01
34	-5.00E+04	-5.00E+04	2.37E-09	-4.91E-10	-5.00E+04	-5.00E+04	1.00E+02	-2.24E-06	-9.83E-07	-1.86E-06	3.35E+01
35	-5.00E+04	-5.00E+04	2.23E-09	-2.65E-09	-5.00E+04	-5.00E+04	-1.31E+01	-2.74E-07	1.40E-07	-1.34E-07	3.56E+01
36	-5.00E+04	-5.00E+04	-7.08E-09	-5.14E-09	-5.00E+04	-5.00E+04	-3.92E+01	-1.84E-06	-6.83E-06	-5.78E-06	6.26E+01
37	-5.00E+04	-5.00E+04	-6.35E-09	-2.87E-09	-5.00E+04	-5.00E+04	1.00E+02	-2.97E-06	-4.63E-06	-3.66E-06	5.13E+01
38	-5.00E+04	-5.00E+04	-5.73E-09	-8.05E-10	-5.00E+04	-5.00E+04	1.00E+02	-2.68E-06	-3.15E-06	-2.94E-06	4.73E+01
39	-5.00E+04	-5.00E+04	-5.39E-09	-2.62E-09	-5.00E+04	-5.00E+04	-2.91E+01	-2.28E-06	-2.50E-06	-2.40E-06	4.64E+01
40	-5.00E+04	-5.00E+04	-3.04E-09	-8.06E-09	-5.00E+04	-5.00E+04	1.00E+02	-2.03E-06	-2.27E-06	-2.16E-06	4.66E+01
41	-5.00E+04	-5.00E+04	1.69E-09	-1.98E-09	-5.00E+04	-5.00E+04	1.00E+02	-1.97E-06	-9.71E-07	-1.64E-06	3.51E+01
42	-5.00E+04	-5.00E+04	1.50E-09	-1.75E-09	-5.00E+04	-5.00E+04	-1.41E+01	-3.30E-07	6.84E-08	-2.61E-07	2.45E+01
43	-5.00E+04	-5.00E+04	-4.80E-09	1.39E-10	-5.00E+04	-5.00E+04	1.63E+00	-6.29E-07	-4.37E-06	-3.85E-06	6.91E+01
44	-5.00E+04	-5.00E+04	-4.62E-09	-2.44E-09	-5.00E+04	-5.00E+04	-2.91E+01	-1.51E-06	-3.75E-06	-3.11E-06	5.76E+01
45	-5.00E+04	-5.00E+04	-4.08E-09	-3.86E-09	-5.00E+04	-5.00E+04	-3.50E+01	-1.75E-06	-3.00E-06	-2.54E-06	5.26E+01
46	-5.00E+04	-5.00E+04	-3.20E-09	-5.85E-09	-5.00E+04	-5.00E+04	-3.73E+01	-1.72E-06	-2.42E-06	-2.13E-06	4.99E+01
47	-5.00E+04	-5.00E+04	-1.85E-09	-7.90E-09	-5.00E+04	-5.00E+04	1.00E+02	-1.68E-06	-2.01E-06	-1.88E-06	4.76E+01
48	-5.00E+04	-5.00E+04	7.42E-10	-4.00E-09	-5.00E+04	-5.00E+04	1.00E+02	-1.48E-06	-9.53E-07	-1.27E-06	3.88E+01
49	-5.00E+04	-5.00E+04	5.17E-10	-7.80E-10	-5.00E+04	-5.00E+04	-1.69E+01	-3.57E-07	-5.78E-08	-3.15E-07	2.19E+01
50	-5.00E+04	-5.00E+04	-2.32E-09	-2.82E-09	-5.00E+04	-5.00E+04	-2.15E+01	-1.91E-07	-2.62E-06	-2.46E-06	7.49E+01
51	-5.00E+04	-5.00E+04	-2.00E-09	-4.47E-09	-5.00E+04	-5.00E+04	-2.55E+01	-5.55E-07	-2.48E-06	-2.13E-06	6.47E+01
52	-5.00E+04	-5.00E+04	-1.80E-09	-6.00E-09	-5.00E+04	-5.00E+04	-3.03E+01	-8.31E-07	-2.22E-06	-1.84E-06	5.85E+01
53	-5.00E+04	-5.00E+04	-1.35E-09	-7.02E-09	-5.00E+04	-5.00E+04	-3.50E+01	-9.86E-07	-1.91E-06	-1.55E-06	5.43E+01
54	-5.00E+04	-5.00E+04	-8.00E-10	-7.26E-09	-5.00E+04	-5.00E+04	-4.04E+01	-1.05E-06	-1.59E-06	-1.37E-06	5.09E+01
55	-5.00E+04	-5.00E+04	6.17E-11	-4.73E-09	-5.00E+04	-5.00E+04	1.00E+02	-9.30E-07	-8.56E-07	-8.95E-07	4.38E+01
56	-5.00E+04	-5.00E+04	[illegible]	[illegible]	-5.00E+04	-5.00E+04	1.00E+02	-3.36E-07	-1.63E-07	[illegible]	3.61E+01
57	-5.00E+04	-5.00E+04	1.73E-09	-1.31E-09	-5.00E+04	-5.00E+04	-5.42E+00	-6.86E-08	-1.20E-06	-1.14E-06	7.66E+01
58	-5.00E+04	-5.00E+04	8.86E-10	-2.47E-09	-5.00E+04	-5.00E+04	-1.46E+01	-1.97E-07	-1.16E-06	-1.02E-06	6.76E+01
59	-5.00E+04	-5.00E+04	4.28E-10	-3.29E-09	-5.00E+04	-5.00E+04	-1.83E+01	-3.07E-07	-1.09E-06	-5.16E-07	6.20E+01
60	-5.00E+04	-5.00E+04	1.16E-10	-3.76E-09	-5.00E+04	-5.00E+04	-2.22E+01	-3.89E-07	-9.85E-07	-8.20E-07	5.79E+01
61	-5.00E+04	-5.00E+04	-1.48E-11	-3.85E-09	-5.00E+04	-5.00E+04	-2.59E+01	-4.39E-07	-8.74E-07	-7.25E-07	5.47E+01
62	-5.00E+04	-5.00E+04	-1.82E-10	-3.06E-09	-5.00E+04	-5.00E+04	-2.55E+01	-4.30E-07	-5.46E-07	-4.95E-07	4.84E+01
63	-5.00E+04	-5.00E+04	-4.43E-10	-1.24E-09	-5.00E+04	-5.00E+04	-3.71E+01	-1.68E-07	-1.87E-07	-1.78E-07	4.65E+01
64	-5.00E+04	-5.00E+04	6.97E-10	1.25E-09	-5.00E+04	-5.00E+04	3.97E+01	-1.18E-08	-2.63E-07	-2.53E-07	7.80E+01
65	-5.00E+04	-5.00E+04	2.94E-10	1.40E-09	-5.00E+04	-5.00E+04	2.25E+01	-3.52E-08	-2.55E-07	-2.22E-07	6.58E+01
66	-5.00E+04	-5.00E+04	6.41E-11	1.06E-09	-5.00E+04	-5.00E+04	1.41E+01	-5.72E-08	-2.50E-07	-2.14E-07	6.44E+01
67	-5.00E+04	-5.00E+04	-1.54E-10	8.07E-10	-5.00E+04	-5.00E+04	1.17E+01	-7.66E-08	-2.36E-07	-1.97E-07	6.03E+01
68	-5.00E+04	-5.00E+04	-1.44E-10	5.49E-10	-5.00E+04	-5.00E+04	7.75E+00	-9.26E-08	-2.15E-07	-1.81E-07	5.70E+01
69	-5.00E+04	-5.00E+04	-2.50E-10	-1.20E-10	-5.00E+04	-5.00E+04	-2.26E+00	-1.08E-07	-1.55E-07	-1.36E-07	5.02E+01
70	-5.00E+04	-5.00E+04	-6.33E-10	-6.03E-10	-5.00E+04	-5.00E+04	-2.30E+01	-5.20E-08	-7.57E-08	-6.60E-08	5.04E+01

DISPL.AND PRESS.AT THE END OF TIME STEP NO. 26

APPENDIX II

LISTING OF FORTRAN IV SOURCE PROGRAM

```
      PROGRAM ROCMAS(INPUT=201,OUTPUT,PUNCH=201,PLOT,TAPE8,TAPE9,        STRFLC
     1         TAPE99=PLCT,TAPE98,TAPE1)                                 STRFLC
C                                                                        STRFLC
C************************************************************************STRFLC
C                              PROGRAM ROCMAS                            STRFLC
C************************************************************************STRFLC
C          PLANE-STRAIN AND AXISYMMETRIC QUASI-STATIC STRESS-FLUID FLOW STRFLC
C     ANALYSIS OF FRACTURED ROCK MASS. A DIRECT EQUATION SOLVER IS USED STRFLC
C     TO SOLVE THE COUPLED EQUATIONS.A STIFFNESS PERTURBATION SCHEME    STRFLC
C     FORCES STRESSES AND DEFORMATIONS TO FOLLOW THE PROPER NON-LINEAR  STRFLC
C     CONSTITUTIVE LAW OF THE FRACTURE MATERIALS.                       STRFLC
C     THIS CODE WAS BASICALLY DEVELOPED BY M.S. AYATOLLAHI IN  1978.    STRFLC
C     LATER,IN 1979,IT WAS CORRECTED,REVISED AND EXTENDED,FOR GENERAL   STRFLC
C     APPLICATION, BY J.NOORISHAD.                                      STRFLC
C************************************************************************STRFLC
C     IN SPITE OF THE POUND(WEIGHT),FOOT,SECOND HEADINGS,ANY CONSISTENT STRFLC
C     SYSTEM OF UNITS COULD BE USED.                                    STRFLC
C************************************************************************STRFLC
C     CODE(I)- STRUCTURAL NODAL POINT CODE THAT INDICATES WHAT BOUNDARY STRFLC
C     CONDITION( LOAD OR DISPLACEMENT) IS ASSIGNED AT POINT I           STRFLC
C     E(J,MTYPE)- MATERIAL MODULI (ROCK OR JOINT )                      STRFLC
C     EPSN- AVERAGE DEFORMATION OF A JOINT                              STRFLC
C     IB(N)- FLOW MESH NODAL POINT CODE,IF #0 ASSIGNED VALUE OF HEAD    STRFLC
C     OR PRESSURE REMAINS CONSTANT AT POINT N                           STRFLC
C     INDEX- PRINT PLOT CODE                                            STRFLC
C     IPAT- PRINT AND PLOT CODE-NO PRINT,NOPLOT IF 0,PRINT IF 1,PRINT,  STRFLC
C     PLOT IF 2                                                         STRFLC
C     IPER- TOTAL PERTURBATION INDEX                                    STRFLC
C     IX(M,I), I=1,5- THE FIRST FOUR REPRESENT NODAL POINTS AROUND ELEMESTRFLC
C     M IN STRUCTURAL MESH AND THE LAST INDICATES MTYPE                 STRFLC
C     KN(I)- NORMAL STIFFNESS OF JOINT I CALCULATED INITIALLY FROM E(I,2STRFLC
C     KS(I)- TANGENTIAL STIFFNESS OF JOINT I CALCULATED FROM E(I,3)     STRFLC
C     NP-TIME STEP INDEX                                                STRFLC
C     MTYPE- NUMBER ASSIGNED TO EACH MATERIAL (STARTING WITH 1 )        STRFLC
C     NIT-NUMBER OF TIME STEPS                                          STRFLC
C     NNN- PERTURBATION INDEX                                           STRFLC
C     NP- DUMMY FOR NPP                                                 STRFLC.
C     NPP(J)- NUMBER OF PERTRBATIONS IN TIME STEP NUMBER J              STRFLC
C     Q(N)- FLOW RATE AT FLOW NODAL POINT N                             STRFLC.
C     PHIO(N)-PRESCRIBED HEAD OR PRESSURE AT FLOW POINT N WHERE IB(N)#0 STRFLC.
C     R(I)- X COORDINATE OF STRUCTURAL NODAL POINT I                    STRFLC
C     RESID(N,I), I=1,4  X, Y, Z, AND XY COMPONENTS OF RESIDUAL STRESS  STRFLC.
C     RO(MTYPE)- SPECIFIC MASS OF ROCK MATERIAL                         STRFLC.
C     XLNGTH - X LENGTH OF MESH PLOT                                    STRFLC.
C     YLNGTH - Y LENGTH OF MESH PLOT                                    STRFLC.
C     DISPL - SCALE FACTOR FOR DISPLACEMENT PLOTS                       STRFLC.
C     PSF - SCALE FOR STRESS PLOT                                       STRFLC.
C     SPWT-FLUID SPECIFIC WEIGHT                                        STRFLC.
C     TFL- TIME NEEDED FOR FLOW CALCULATION                             STRFLC.
C     TIT- TIME SPENT FOR ONE PERTURBATION                              STRFLC.
C     TL- TIME LEFT                                                     STRFLC.
C     TST- TIME REQUIRED FOR READ AND PRINT OF INPUT DATA               STRFLC.
C     UR(I),UZ(I)-R AND Z COMPONENTS OF DISPLACEMENT OR LOAD AT POINT I STRFLC.
C     V- RELATIVE DISPLACEMENT OF OPPOSING  NODAL POINTS  IN A JOINT    STRFLC.
C     VISC-FLUID VISCOSITY                                              STRFLC.
C     W(N)- APERTURE OF FLOW ELEMENT N CALCULATED IN EACH ITERTION      STRFLC.
C     WT(I)- INITIAL APERTURE OF JOINT  I IN STRUTURAL MESH             STRFLC.
C     Z(I)- Z OR Y COORDINATE OF STRUCTURAL NODAL POINT I               STRFLC.
C                                                                       STRFLC.
C     NOTE------ VECTORS DISP(N,2),CBG(2N),INP(50,4),IEL(50,2),SIGN(50),STRFLC.
C                AND SIGT(50) ARE NOT USED IN THIS VERSION .            STRFLC.
C                                                                       STRFLC.
```

```
      LARGE A(125000),IO(900)                                           STRFLF
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R.KN(50),R.KS(50),NT(50),IOUT(301),Q(300), LARGE.
     *QP(50),N(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHI0(300),ID(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),DD0(600)                            STRFLF
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LOAD,RADN,   BLANK.
     1                  RR(4),ZZ(4),IFAT(50),ACELX,ACELY,NRES,RO(12),   BLANK.
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),       BLANK.
     3   PRS,PZS,PRT,PZT,EG                                             BLANK.
      COMMCN/GEN/NSHELL,IPUNCH,E(7,12),INDEX,NP,NNN,NCORE,NUMNP,ICOMPR, GEN.2
     1      NUMEL,NDZ,NED(16),DISPL,NJELT,IPER,NUMMAT,PSF,PSFJ,XSCL,SPWT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,NEAND,LNGTH,NEQ,NJMPGEN.4
     *      ,NOFLOW,NUMNP2,NUMFNP,LM(12),NF2                            GEN.5
      COMMCN/APTR/IRAND,NJUMP,AAS,AAN                                   APTR.2
      COMMON/CCPOOL/XMIN,XMAX,YMIN,YMAX,CCXMIN,CCXMAX,CCYMIN,CCYMAX     CCPOOL
      COMMCN/CCFACT/FACTOR                                              CCFACT
C                                                                       STRFLC
      DIMENSION NPP(50),NUF(50)                                         STRFLC
      DIMENSION  IXD(4), IXP(4), LST(8)                                 STRFLC
      LOGICAL FLAG                                                      STRFLC
                                                                        STRFLC
      DATA TITLE/5HTITLE/,ZMAT/8HMATERIAL/,ZOUT/6HOUTPUT/,FLOW/4HFLOW/, STRFLC
     1     ZNODE/5HNODES/,ELEMEN/7HELEMENT/, PRESS/8HPRESSSURE/,        STRFLC
     2     INCOM/10HINCCMPRESS/,RESIX/8HRESIDUAL/,RESTAR/7HRESTART/,    STRFLC
     3     DONE/4HDONE/, BLANK/5HBLANK/,IXD/4*1/, END/3HEND/            STRFLC
C                                                                       STRFLC
      FACTOR = 100.                                                     STRFLC.
      LOAD = 0                                                          STRFLC.
    1 FORMAT (1H10A9/1H 8A9)                                            STRFLC.
                                                                        STRFLC.
    5 READ 6, WORD                                                      STRFLC.
    6 FORMAT (2A10)                                                     STRFLC.
      IF (WORD .EQ. TITLE)  GO TO 1000                                  STRFLC.
      IF (WORD .EQ. ZMAT)  GO TO 2000                                   STRFLC.
      IF (WORD .EQ. ZOUT)  GO TO 3000                                   STRFLC.
      IF (WORD .EQ. ZNODE)  GO TO 4000                                  STRFLC.
      IF (WORD .EQ. ELEMEN)  GO TO 5000                                 STRFLC.
      IF (WORD .EQ. PRESS)  GO TO 6000                                  STRFLC.
      IF (WORD .EQ. FLOW) GO TO 6500                                    STRFLC.
      IF (WORD .EQ. RESIX)  GO TO 8000                                  STRFLC.
      IF (WORD .EQ. RESTAR)  GO TO 9000                                 STRFLC.
      IF (WORD .EQ. DONE)  GO TO 9999                                   STRFLC.
      IF (WORD .EQ. END)  GO TO 300                                     STRFLC.
                                                                        STRFLC.
C     UNIDENTIFIED CARC                                                 STRFLC.
      PRINT 10, WORD                                                    STRFLC.
   10 FORMAT (18H0UNIDENTIFIED CARO A10/40H PROGRAM WILL SEARCH FOR NEXTSTRFLC.
     1 TITLE CARD)                                                      STRFLC.
                                                                        STRFLC.
C     SCAN DECK FOR NEXT CASE IF ANY                                    STRFLC.
   15 READ 6, WORD                                                      STRFLC.
      IF (WORD .EQ. TITLE)  GO TO 1000                                  STRFLC.
      IF (WORD .EQ. END)  GO TO 300                                     STRFLC.
      GO TO 15                                                          STRFLC.
                                                                        STRFLC.
 1000 READ 20, HED, NUPNP, NUMEL, NUMMAT, NSHELL, NPC, NJMP, IRANC,     STRFLC.
     1           NIT, IPLCT, IPUNCH, TTOTAL, CONLIM, NAXI, AAN,THETA,   STRFLC.
     2        AAS,ACELX,ACELY,XNNP,SPWT,VISC,IPRT,NDTN,DT,SYSDIM,TOTALC STRFLC.
   20 FORMAT(8A5/8A9/10I5,F5.0,F10.0,I5/5F10.3/2F10.3,E15.5,            STRFLC.
     12I5,3E10.5)                                                       STRFLC.
      REWIND 8                                                          STRFLC.
```

```
C                                                                          STRFLC
      IF (NSHELL .EQ. 0)  NSHELL = 13                                      STRFLC
      IF (MAXI .GT. 0)  GO TO 22                                           STRFLC
      PRINT 21                                                             STRFLC
   21 FORMAT (49H1 PLANE STRAIN-FLOW ANALYSIS OF JOINTED STRUCTURE)        STRFLC
      GO TO 24                                                             STRFLC
   22 PRINT 23                                                             STRFLC
   23 FORMAT (35H1 AXISYMMETRIC STRESS-FLOW ANALYSIS)                       STRFLC
   24 CONTINUE                                                             STRFLC
      PRINT 25, HED,NUMNP,NUMEL,NUMMAT,NSHELL,NPC,NJMP,IRAND,NIT,          STRFLC
     1                IPLOT,IPUNCH,TTOTAL                                  STRFLC
   25 FORMAT (/8A9//8A9/                                                   STRFLC
     1 50H0 NUMNP-NUMBEF OF NODAL POINTS------------------- I5 /           STRFLC
     2 50H0 NUMEL-NUMBER OF ELEMENTS----------------------- I5 /           STRFLC
     3 50H0 NUMMAT-NUMBER OF DIFFERENT MATERIALS----------- I5 /           STRFLC
     4 50H0 NSHELL-NUMBER OF SOLIO MATERIALS--------------- I5 /           STRFLC
     7 50H0 NPC-NUMBEF OF BOUNDARY PRESSURE CARDS---------- I5 /           STRFLC
     8 50H0 NJMF-NUMBER OF JOINTS WITH MODIFIED APERTURES--- I5 /          STRFLC
     9 50H0 IRAND-RANDOM APERTURE GENERATOR IF 1----------- I5 /           STRFLC
     1 50H0 NIT-NUMBER OF TIME STEPS----------------------- I5 /           STRFLC
     3 50H0 IPLOT-PLOT INFORMATION REQUIRED IF 1----------- I5 /           STRFLC
     4 51H0 IPUNCH-PUNCH IF 1 ----------------------------- I4 /           STRFLC
     7 50H0 TTOTAL-ESTIMATED TOTAL CP TIME(DECIMAL SECONDS)- F5.0 )        STRFLC
      PRINT 26, AAM,AAS,ACELX,ACELY,XNHP,SPWT,NDTN,IPRT,                   STRFLC
     *DT,CONLIM,MAXI,THETA,VISC,SYSDIM,TOTALQ                              STRFLC
   26 FORMAT(/                                                             STRFLC
     1 50H0 AAM-MEAN-APERTURE LOGNORMAL DISTRIBUTION-------- E15.5 /       STRFLC
     2 50H0 AAS-STANDARD DEVIATION-LOGNORMAL DISTRIBUTION--- E15.5 /       STRFLC
     3 50H0 ACELX-X ACCELERATION (FEET/SECOND)-------------- E15.5 /       STRFLC
     4 50H0 ACELY-Y ACCELERATION (FEET/SECOND)-------------- E15.5 /       STRFLC
     5 50H0 XNHF-MAXIMUM NET HEAD PRESSURE (PSF)------------ E15.5 /       STRFLC
     6 50H0 SPWT-FLUID SPECIFIC WEIGHT---------------------- E15.5 /       STRFLC
     7 50H0 NDTN-VARIABLE TIME-STEP COUNTER,IF G.T. 1------- I5/           STRFLC
     8 50H0 IPRT,NO. OF CYCLES FOR DISPL. PRINT-------------I5/            STRFLC
     9 50H0 DT-INITIAL TIME INCREMENT----------------------- E15.5/        STRFLC
     1 50H0 CONLIM JOINT STIFF.CONVERG.CONSTANT ------------F10.0 /        STRFLC
     2 50H0 MAXI-AXISYM. PRCBLEM IF= 1--------------------- I5/            STRFLC
     3 50H0 THETA- TIME INTEGRATION CONSTANT---------------- F10.3/        STRFLC
     4 50H0 VISC-FLUID VISCOSITY (PSF)---------------------- E15.5 /       STRFLC
     5 50H0 SYSDIM-SYSTEM DIMENSION REQUIRED IF PD,TD WANTED E15.5 /       STRFLC
     6 50H0 TOTALQ-TOTAL FLOW REQUIRED IF PD,TD WANTED------ E15.5)        STRFLC
C                                                                          STRFLC
                                                                           STRFLC
      NJELT = 0                                                            STRFLC
      NRES = 0                                                             STRFLC
      NUMNP2=NUMNP+NUMNP                                                   STRFLC
      DO 29 I=1,NUMNP2                                                     STRFLC
   29 ID(I)=0                                                              STRFLC
C ******  INITIAL SET OF SYSTEM EQUATIONS  *****                           STRFLC
      KEQ=0                                                                STRFLC
      DO 36 N=1,NUMNP                                                      STRFLC
      IDEST(N)=0                                                           STRFLC
      TEMP(N)=0.0                                                          STRFLC
      DO 36 I=1,3                                                          STRFLC
      KODE(I,N)=0                                                          STRFLC
      KEQ=KEQ+1                                                            STRFLC
      QN(KEQ)=0.0                                                          STRFLC
   36 IDEQ(I,N)=KEQ                                                        STRFLC
      DO 35  N=1,NUMEL                                                     STRFLC
      DO 35  M=1,4                                                         STRFLC
   35 RESID(N,M) = 0.0                                                     STRFLC
                                                                           STRFLC
```

```
      GO TO 5                                                         STRFLC
C                                                                     STRFLC
C     MATERIAL PROPERTIES                                             STRFLC
 2000 PRINT 1, HED                                                    STRFLC
      READ 2,ICOMPR                                                   STRFLC
    2 FORMAT(A10)                                                     STRFLC
      IF(ICOMPR.EQ.INCOF) PRINT 3                                     STRFLC
    3 FORMAT("     FLUID IS INCOMPRESSIBLE     ")                     STRFLC
      DO 2035  M=1,NUMMAT                                             STRFLC
      READ 2010,MTYPE,RO(MTYPE),(E(J,MTYPE),J=1,7)                    STRFLC
 2010 FORMAT(I5,8E9.4)                                                STRFLC
      PRINT 2015, MTYPE                                               STRFLC
 2015 FORMAT (/15H MATERIAL NO. =I3)                                  STRFLC
      IF(MTYPE.LE.NSHELL) GO TO 2019                                  STRFLC
      PRINT 2030,(E(J,MTYPE),J=1,7)                                   STRFLC
      GO TO 2035                                                      STRFLC
 2019 PRINT 2020,RO(MTYPE),(E(J,MTYPE),J=1,5)                         STRFLC
 2035 CONTINUE                                                        STRFLC
 2020 FORMAT (22H   MASS DENSITY-------F8.2/22H    PERMEABILITY------ STRFLC
     *E14.4/23H ELASTIC MODULUS ------E14.4/22H  POISSONS RATIO------E STRFLC
     *14.4/23H BIOTS CONSTANT(ALPHA) E14.4/23H BIOTS CONSTANT(M)-----E STRFLC
     *14.4)                                                           STRFLC
 2030 FORMAT (10H   KN-----E25.4/10H   KT-----E25.4/10H   C------E25.4/ STRFLC.
     110H   PHI----E25.4/20H   MAX. CLOSURE-----E15.4/                STRFLC.
     *  23H BIOTS CONSTANT(ALPHA) E14.4/22H BIOTS CONSTANT( M )  E14.4) STRFLC
      GO TO 5                                                         STRFLC.
C                                                                     STRFLC.
C     INFORMATION FOR OUTPUT                                          STRFLC.
 3000 READ 3010, (NPP(I), I=1,NIT)                                    STRFLC.
 3010 FORMAT(40I2)                                                    STRFLC.
      ITOT = 0                                                        STRFLC.
      DO 3012  I=1,NIT                                                STRFLC.
 3012  ITOT = ITOT + NPP(I)                                           STRFLC.
      READ 3015, (IPAT(J), J=1,ITOT)                                  STRFLC.
 3015 FORMAT(40I2)                                                    STRFLC.
                                                                      STRFLC.
      PRINT 1, HED                                                    STRFLC.
      K1 = 1                                                          STRFLC.
      DO 3025  I=1,NIT                                                STRFLC.
      K2 = K1 + NPP(I) - 1                                            STRFLC.
      PRINT 3020, NPP(I), I, (IPAT(J), J=K1,K2)                       STRFLC.
 3020 FORMAT (//I6," PERTURBATIONS IN TIME STEP NUMBER "I3,10X,"OUTPUT STRFLC.
     *SCHEME "20I3)                                                   STRFLC.
 3025 K1 = K2 + 1                                                     STRFLC.
      IF(IPLOT.EQ.0) GO TO 3035                                       STRFLC.
      READ 3030, XLNGTH, YLNGTH, PSCL, CONJT                          STRFLC.
 3030 FORMAT (4E10.4)                                                 STRFLC.
 3035 GO TO 5                                                         STRFLC.
C                                                                     STRFLC.
C     ESTABLISH NODAL POINT PROPERTIES                                STRFLC.
 4000 DO 4010  N=1,NUMNP                                              STRFLC.
 4010 R(N) = BLANK                                                    STRFLC.
      N = 0                                                           STRFLC.
      NXP = 0                                                         STRFLC.
 4015 NP = N                                                          STRFLC.
      IF (N .GE. NUMNP)  GO TO 4035                                   STRFLC.
      NX = NXP                                                        STRFLC.
      READ 4020,N,NXP,DR,DZ,CD,CDI,DU,DV                              STRFLC.
 4020 FORMAT(2I5,6E10.3)                                              STRFLC.
      IF(N.LE.0.OR.N.GT.NUMNP) GO TO 4035                             STRFLC.
      CODE(N) = CD                                                    STRFLC.
      R(N) = DR                                                       STRFLC.
```

```
      Z(N) = DZ                                                         STRFLC
      UR(N) = DU                                                        STRFLC
      UZ(N) = DV                                                        STRFLC
      IF(NX.EQ.0) GO TO 4015                                            STRFLC
      IF((N-NP)*NX.GE.0) GO TO 4025                                     STRFLC
      NX = - NX                                                         STRFLC
      PRINT 4021, NP,N                                                  STRFLC
 4021 FORMAT(*  INCREMENT FOR GENERATION BETWEEN NODES* I5* AND*I5* IS OSTRFLC
     1F INCORRECT SIGN ** SIGN CHANGED*)                                STRFLC
                                                                        STRFLC
 4025 LX = (IABS(N-NP) + IABS(NX) - 1)/IABS(NX)                         STRFLC
      DR =(R(N)-R(NP))/LX                                               STRFLC
      DZ =(Z(N)-Z(NP))/LX                                               STRFLC
 4030 NP = NP + NX                                                      STRFLC
      IF(NX.GT.0.AND.NP.GE.N) GO TO 4015                                STRFLC
      IF(NX.LT.0.AND.NP.LE.N) GO TO 4015                                STRFLC
      R(NP) = R(NP-NX) + DR                                             STRFLC
      Z(NP) = Z(NP-NX) + DZ                                             STRFLC
      CODE(NP) = CDI                                                    STRFLC
      UR(NP) = 0.                                                       STRFLC
      UZ(NP) = 0.                                                       STRFLC
      GO TO 4030                                                        STRFLC
                                                                        STRFLC
C     PRINT NODAL POINTS                                                STRFLC
 4035 PRINT 1, HED                                                      STRFLC
      PRINT 4040                                                        STRFLC
 4040 FORMAT(118H0NODAL POINT         TYPE  X-ORDINATE  Y-ORDINATE  X-LO STRFLC
     1AD OR DISPLACEMENT  Y LOAD OR DISPLACEMENT  X-CODE    Y-CODE    ) STRFLC.
      DO 4055  N=1,NUMNP                                                STRFLC.
      IF(R(N).EQ.BLANK) PRINT 4045                                      STRFLC.
 4045 FORMAT(*    NO INPUT FOR THIS NODE  *  )                          STRFLC.
      IF(CODE(N).EQ.0.0) GO TO 4022                                     STRFLC.
      IF(CODE(N).NE.3.0) GO TO 4023                                     STRFLC.
      ID(2*N)=1                                                         STRFLC.
      ID(2*N-1)=1                                                       STRFLC.
      GO TO 4022                                                        STRFLC.
 4023 IF(CODE(N).NE.2.0) GO TO 4024                                     STRFLC.
      ID(2*N)=1                                                         STRFLC.
      GO TO 4022                                                        STRFLC.
 4024 IF(CODE(N).EQ.1) ID(2*N-1)=1                                      STRFLC.
 4022 CONTINUE                                                          STRFLC.
      IF(R(N).NE.BLANK) PRINT 4050,N,CODE(N),R(N),Z(N),UR(N),UZ(N),     STRFLC.
     . ID(2*N-1),ID(2*N)                                                STRFLC.
 4050 FORMAT(I12,F12.3,2E12.3,2E24.7,2I10)                              STRFLC.
      IF (CODE(N) .LT. 0.0)  CODE(N) = CODE(N) / 57.29577951            STRFLC.
 4055 CONTINUE                                                          STRFLC.
      GO TO 5                                                           STRFLC.
                                                                        STRFLC.
C     NODAL POINTS, BAND WIDTH, CHECK CORE CAPACITY, JOINTS AND FLOW    STRFLC.
 5000 PRINT 1, HED                                                      STRFLC.
      PRINT 5010                                                        STRFLC.
 5010 FORMAT (69H0ELEMENT NO.       I      J      K      L     MATERIAL    JOSTRFLC.
     1INT NO    WIDTH)                                                  STRFLC.
                                                                        STRFLC.
      N = 1                                                             STRFLC.
      MBAND = 0                                                         STRFLC.
      JX = 0                                                            STRFLC.
 5015 DO 5020  I=1,4                                                    STRFLC.
 5020 IXP(I) = IXD(I)                                                   STRFLC.
      JX = JXD                                                          STRFLC.
      READ 5025, M, (IX(M,I), I=1,5), IXD, JXD                          STRFLC.
 5025 FORMAT (11I5)                                                     STRFLC.
```

```
      IF (M - N)  5050, 5040, 5035                                      STRFLC
                                                                        STRFLC
 5035 IX(N,1) = IX(N-1,1) + IXP(1)                                      STRFLC
      IX(N,2) = IX(N-1,2) + IXP(2)                                      STRFLC
      IX(N,3) = IX(N-1,3) + IXP(3)                                      STRFLC
      IX(N,4) = IX(N-1,4) + IXP(4)                                      STRFLC
      IX(N,5) = IX(N-1,5) + JX                                          STRFLC
      JX = -JX                                                          STRFLC
                                                                        STRFLC
 5040 K = 0                                                             STRFLC
      DO 5030  I=1,3                                                    STRFLC
      I1 = I + 1                                                        STRFLC
      DO 5030  L=I1,4                                                   STRFLC
      KK=IABS(IX(N,I)-IX(N,L))+1                                        STRFLC
      IF (KK .GT. K)  K = KK                                            STRFLC
 5030 CONTINUE                                                          STRFLC
      IF (K .GT. MBAND)  MBAND = K                                      STRFLC
C                                                                       STRFLC
C.... LOOK FOR A JOINT ELEMENT                                           STRFLC
      IF (IX(N,5) .GT. NSHELL)  GO TO 5041                              STRFLC
      PRINT 5042, N,(IX(N,I), I=1,5), K                                 STRFLC
 5042 FORMAT(I13,4I6,I9,12X,I9)                                         STRFLC
      GO TO 5043                                                        STRFLC
 5041 NJELT = NJELT + 1                                                 STRFLC
      IOUT(NJELT) = N                                                   STRFLC
      PRINT 5045, N, (IX(N,I), I=1,5), NJELT, K                         STRFLC
 5045 FORMAT(I13,4I6,I9,I12,I9)                                         STRFLC
                                                                        STRFLC
 5043 N = N + 1                                                         STRFLC
      IF (N .GT. NUMEL)  GO TO 5060                                     STRFLC
      IF (M - N)  5015, 5040, 5035                                      STRFLC
 5050 PRINT 5055, M                                                     STRFLC.
      LOAD = 1                                                          STRFLC
 5055 FORMAT (* ELEMENT CARD ERROR, N=*I4)                              STRFLC
                                                                        STRFLC
      MB3=MBAND                                                         STRFLC
 5060 MBAND=MBAND+MBAND+MBAND                                           STRFLC
C                                                                       STRFLC.
C                                                                       STRFLC
                                                                        STRFLC.
 5075 NUMFNP=0                                                          STRFLC.
      DO 5090  I=1,NJELT                                                STRFLC.
      W(I)=0.0                                                          STRFLC.
      WT(I)=0.0                                                         STRFLC.
      KN(I)=0.0                                                         STRFLC.
 5090 KS(I)=0.0                                                         STRFLC.
                                                                        STRFLC.
C.... ESTABLISH NUMBERING CONTRACTION FOR THE FLOW NODES                 STRFLC.
      IF(NJELT.EQ.0) GO TO 5100                                         STRFLC.
      DO 5100  N=1,NJELT                                                STRFLC.
      M = IOUT(N)                                                       STRFLC.
      J=IX(M,4)                                                         STRFLC.
      I=IX(M,1)                                                         STRFLC.
      K = MIN0(I,J)                                                     STRFLC.
      L=1                                                               STRFLC.
 5095 IF(IDEST(I).EQ.0) IDEST(I)=K                                      STRFLC.
      IF(IDEST(I).LT.K) K=IDEST(I)                                      STRFLC.
      IF(IDEST(I).LE.K) GO TO 5102                                      STRFLC.
      KK=IDEST(I)                                                       STRFLC.
      DO 5101  II=1,NUMNP                                               STRFLC.
      IF(IDEST(II).EQ.KK) IDEST(II)=K                                   STRFLC.
 5101 CONTINUE                                                          STRFLC.
```

```
                                                                           STRFLC
 5102 IF(IDEST(J).EQ.0)  IDEST(J)=K                                        STRFLC
      IF(IDEST(J).LT.K)  IDEST(I)=IDEST(J)                                 STRFLC
      IF(IDEST(J).LE.K) GO TO 5106                                         STRFLC
      KK=IDEST(J)                                                          STRFLC
      DO 5104 II=1,NUMNP                                                   STRFLC
      IF(IDEST(II).EQ.KK) IDEST(II)=K                                      STRFLC
 5104 CONTINUE                                                             STRFLC
                                                                           STRFLC
 5106 IF(L.EQ.2) GO TO 5100                                                STRFLC
      I=IX(M,2)                                                            STRFLC
      J=IX(M,3)                                                            STRFLC
      K = MIN0(I,J)                                                        STRFLC
      L=2                                                                  STRFLC
      GO TO 5095                                                           STRFLC
                                                                           STRFLC
 5100 CONTINUE                                                             STRFLC
      DO 5110 N=1,NUMEL                                                    STRFLC.
      MTYPE=IX(N,5)                                                        STRFLC.
      IF(MTYPE.GT.NSHELL)GO TO 5110                                        STRFLC
      PERM=E(1,MTYPE)                                                      STRFLC
      IF(ABS(PERM).LT.E-12) GO TO 5110                                     STRFLC
      DO 5111 K=1,4                                                        STRFLC
      I=IX(N,K)                                                            STRFLC
 5111 IF(IDEST(I).EQ.0) IDEST(I)=I                                         STRFLC.
 5110 CONTINUE                                                             STRFLC.
      DO 5105 N=1,NUMNP                                                    STRFLC
      I=IDEST(N)                                                           STRFLC.
      IF(I.EQ.0) GO TO 5105                                                STRFLC.
      IDEST(N)=IDEST(I)                                                    STRFLC.
 5103 IF(I.NE.N) GO TO 5105                                                STRFLC.
      NUMFNP=NUMFNP+1                                                      STRFLC.
      IDEST(N)=NUMFNP                                                      STRFLC.
 5105 CONTINUE                                                             STRFLC.
 5113 PRINT 5112,MBAND,NJELT,NUMFNP                                        STRFLC.
 5112 FORMAT(35H0ST. STIFFNESS MATRIX BAND WIDTH  =I5/26H NUMBER OF JIONSTRFLC.
     $T ELEMENTS  =I5/26H NUMBER OF FLOW NODES     =I5)                    STRFLC.
                                                                           STRFLC.
      GO TO 5                                                              STRFLC.
                                                                           STRFLC.
C     PRESSURE CARDS IF ANY                                                STRFLC.
 6000 PRINT 1, HED                                                         STRFLC.
      PRINT 6010                                                           STRFLC.
 6010 FORMAT(/29H0PRESSURE BOUNDARY CONDITIONS/ 42H    I   J       PRESSSTRFLC.
     1URE-I     PRESSURE-J )                                               STRFLC.
                                                                           STRFLC.
      DO 6040  L=1,NPC                                                     STRFLC.
      READ 6015, I1, I2, PS1, PS2                                          STRFLC.
 6015 FORMAT(2I5,2F10.3)                                                   STRFLC.
      PRINT 6020, I1, I2, PS1, PS2                                         STRFLC.
 6020 FORMAT(2I5,2F15.3)                                                   STRFLC.
      DR = R(I2) - R(I1)                                                   STRFLC.
      DZ = Z(I1) - Z(I2)                                                   STRFLC.
      CC = CODE(I1)                                                        STRFLC.
      IF (CC .EQ. 3)  GO TO 6030                                           STRFLC.
      PI =(2.*PS1 + PS2)/6.                                                STRFLC.
      IF (NAXI .NE. 0)                                                     STRFLC.
     1     PI = (R(I1)*(3.0*PS1+PS2) + R(I2)*(PS1+PS2)) / 12.0             STRFLC.
      SINA = 0.                                                            STRFLC.
      COSA = 1.                                                            STRFLC.
      IF (CC .GE. 0.0)  GO TO 6025                                         STRFLC.
      SINA = SIN(CC)                                                       STRFLC.
```

```
      COSA = COS(CC)                                                    STRFLC
 6025 IF (CC .EQ. 0.0 .OR. CC .EQ. 1.0)  UZ(I1) = UZ(I1) + DR*PI        STRFLC
      IF (CC .NE. 1.0)  UR(I1) = UR(I1) + DZ*PI*COSA + DR*PI*SINA       STRFLC
                                                                        STRFLC
 6030 CC = CODE(I2)                                                     STRFLC
      IF (CC .EQ. 3.0)  GO TO 6040                                      STRFLC
      PI =(2.*PS2 + PS1)/6.                                             STRFLC
      IF (MAXI .NE. 0)                                                  STRFLC
     1     PI = (R(I2)*(3.0*PS2+PS1) + R(I1)*(PS1+PS2)) / 12.0          STRFLC
      SINA = 0.                                                         STRFLC
      COSA = 1.0                                                        STRFLC
      IF (CC .GE. 0.0)  GO TO 6035                                      STRFLC
      SINA = SIN(CC)                                                    STRFLC
      COSA = COS(CC)                                                    STRFLC
 6035 IF (CC .NE. 1.0)  UR(I2) = UR(I2) + DZ*PI*COSA + DR*PI*SINA       STRFLC
      IF (CC .EC. 1.0 .OR. CC .EQ. 0.0)  UZ(I2) = UZ(I2) + DR*PI        STRFLC
 6040 CONTINUE                                                          STRFLC.
      GO TO 5                                                           STRFLC.
C                                                                       STRFLC.
C*****  FLOW NODE PROPERTIES ***                                        STRFLC.
 6500 CONTINUE                                                          STRFLC.
      DO 6501 I=1,NUMFNP                                                STRFLC.
      IB(I)=0                                                           STRFLC.
      PHIO(I)=0.0                                                       STRFLC.
 6501 Q(I)=0.0                                                          STRFLC.
                                                                        STRFLC.
      IF (NUMFNP .GT. 0)  GO TO 7110                                    STRFLC.
      PRINT 7105                                                        STRFLC.
 7105 FORMAT (37H FLOW CARDS MUST FOLLOW ELEMENT CARDS)                 STRFLC.
      LOAD = 1                                                          STRFLC.
                                                                        STRFLC.
 7110 MBFLOW = 0                                                        STRFLC.
                                                                        STRFLC.
      DO 7120 M=1,NUMEL                                                 STRFLC.
      MTYPE=IX(M,5)                                                     STRFLC.
      IF(MTYPE.LE.NSHELL) GO TO 7121                                    STRFLC.
      I=IX(M,1)                                                         STRFLC.
      J=IX(M,2)                                                         STRFLC.
      K=IABS(IDEST(I)-IDEST(J))                                         STRFLC.
      IF(K.GT.MBFLOW) MBFLOW=K                                          STRFLC.
      GO TO 7120                                                        STRFLC.
                                                                        STRFLC.
 7121 DO 7122 I=1,3                                                     STRFLC.
      II=IX(M,I)                                                        STRFLC.
      I1=I+1                                                            STRFLC.
      DO 7122 L=I1,4                                                    STRFLC.
      LL=IX(M,L)                                                        STRFLC.
      K=IABS(IDEST(LL)-IDEST(II))                                       STRFLC.
      IF(K.GT.MBFLOW) MBFLOW=K                                          STRFLC.
 7122 CONTINUE                                                          STRFLC.
 7120 CONTINUE                                                          STRFLC.
      MBFLOW=MBFLOW+1                                                   STRFLC.
C                                                                       STRFLC.
      PRINT 7125                                                        STRFLC.
 7125 FORMAT(118H0FLOW NODAL POINTS  CODE    X-ORDINATE    Y-ORDINATE   NSTRFLC.
     1ET HEAD(PSF)       FLOW RATE(CFS)    CORRESPONDING NODAL POINTS)  STRFLC.
                                                                        STRFLC.
      NX = 1                                                            STRFLC.
 7130 READ 7135, N, NL, PH, QF                                          STRFLC.
 7135 FORMAT (2I5,2F10.3)                                               STRFLC.
      IF (N .GT. NUMNP .OR. N .LE. 0)  GO TO 7170                       STRFLC.
      IF (N .GT. NX)  GO TO 7145                                        STRFLC.
```

```
 7140 L = IDEST(N)                                                          STRFLC
      IB(L) = NL                                                            STRFLC
      PHIO(L) = PH                                                          STRFLC
      Q(L)=QF                                                               STRFLC
      GO TO 7150                                                            STRFLC
                                                                            STRFLC
 7145 L1 = IDEST(NX)                                                        STRFLC
      IF (L1 .LE. L)  GO TO 7165                                            STRFLC
      L = L1                                                                STRFLC
                                                                            STRFLC
 7150 DO 7151  J=1,8                                                        STRFLC
 7151 LST(J) = 0                                                            STRFLC
      J1 = 0                                                                STRFLC
      DO 7155  J=NX,NUMNP                                                   STRFLC
      IF (IDEST(J) .NE. L)   GO TO 7155                                     STRFLC
      J1 = J1 + 1                                                           STRFLC
      LST(J1) = J                                                           STRFLC
 7155 CONTINUE                                                              STRFLC
      PRINT 7160, L, IB(L),R(NX),Z(NX),PHIO(L),Q(L), (LST(J),J=1,J1)       STRFLC
 7160 FORMAT (2I12,2F12.2,2E19.6,4X,8I4)                                    STRFLC
      IF(J1.LE.1) GO TO 7162                                                STRFLC
      JMIN=LST(1)                                                           STRFLC.
      DO 7161 J=2,J1                                                        STRFLC.
 7161 JMIN=MIN0(JMIN,LST(J))                                                STRFLC
      KEQ=KEQ-J1+1                                                          STRFLC.
      JNUM=IDEQ(3,JMIN)                                                     STRFLC.
      DO 100 J=1,J1                                                         STRFLC
      K=LST(J)                                                              STRFLC.
  100 IDEQ(3,K)=JNUM                                                        STRFLC.
      JMIN=JMIN+1                                                           STRFLC.
      J1=0                                                                  STRFLC.
      DO 101  K=JMIN,NUMNP                                                  STRFLC.
      DO 101 J=1,3                                                          STRFLC.
      IF(IDEQ(J,K).EQ.JNUM) J1=J1+1                                         STRFLC.
  101 IF(IDEQ(J,K).GT.JNUM) IDEQ(J,K)=IDEQ(J,K)-J1                          STRFLC.
 7162 IF(L.EQ.NUMFNP) GO TO 7170                                            STRFLC
 7165 NX = NX + 1                                                           STRFLC.
      IF (NX - N)  7145, 7140, 7130                                         STRFLC.
 7170 PRINT 7175, MBFLCW                                                    STRFLC.
 7175 FORMAT(/ * F. CONDUCTIVITY MATRIX BAND WIDTH = * I5)                  STRFLC
                                                                            STRFLC.
                                                                            STRFLC.
      DO 41 I=1,NUMNP                                                       STRFLO.
      K=IDEST(I)                                                            STRFLC.
      KODE(1,I)=ID(2*I-1)                                                   STRFLC
      KODE(2,I)=ID(2*I)                                                     STRFLC
   41 KODE(3,I)=IB(K)                                                       STRFLC
                                                                            STRFLC
C *******    COMPUTE BANDWIDTH OF THE STRUCTURE    ****                      STRFLC
                                                                            STRFLC.
      MBAND=1                                                               STRFLC
      DO 111 N=1,NUMEL                                                      STRFLC.
      DO 111 I=1,4                                                          STRFLC.
      IN=IX(N,I)                                                            STRFLC.
      DO 111 II=1,3                                                         STRFLC
      IA=IDEQ(II,IN)                                                        STRFLC.
      DO 111 J=1,4                                                          STRFLC
      JN=IX(N,J)                                                            STRFLC.
      DO 111 JJ=1,3                                                         STRFLC
  111 MBAND=MAX0(MBAND,IABS(IA-IDEQ(JJ,JN)))                                STRFLC.
      MBAND=MBAND+1                                                         STRFLC.
      PRINT 102,MBAND,KEQ                                                   STRFLC.
```

```
  102 FORMAT(25H  GLOBAL SYSTEM BANDWIDTH,I5/24H  TOTAL SYSTEM EQUATIONSSTRFLC
     1,I5)                                                              STRFLC
      PRINT 51                                                          STRFLC
   51 FORMAT(10H  NODE     ,10H IDEQ(1,N),10H IDEQ(2,N),10HIDEQ(3,N) ,10HSTRFLC
     * ID(1,N)  ,10H ID(2,N)   ,10H ID(3,N)   )                         STRFLC
      DO 53 N=1,NUMNP                                                   STRFLC
   53 PRINT 52 ,N,(IDEQ(I,N),I=1,3),(KODE(J,N),J=1,3)                   STRFLC
   52 FORMAT(I5,8I10)                                                   STRFLC
      GO TO 5                                                           STRFLC
C                                                                       STRFLC
C     INITIAL STRESSES IF ANY                                           STRFLC
 8000 PRINT 1, HED                                                      STRFLC
      PRINT 8010                                                        STRFLC
 8010 FORMAT (37H0     I N I T I A L   S T R E S S E S/56H0ELEMENT    X-STRFLC
     1STRESS    Y-STRESS    Z-STRESS    XY-STRESS)                      STRFLC
                                                                        STRFLC
      NRES = 1                                                          STRFLC
      L = 1                                                             STRFLC.
 8015 READ 8020, N, (RESID(N,I), I=1,4)                                 STRFLC
 8020 FORMAT (I10,4E10.3)                                               STRFLC
      IF (N - L)  8040, 8035, 8025                                      STRFLC
 8025 DO 8030  I=1,4                                                    STRFLC
 8030 RESID(L,I)=RESID(L-1,I)                                           STRFLC.
 8035 PRINT 8037, L, (RESID(L,I), I=1,4)                                STRFLC
 8037 FORMAT ( I5,3X,4F12.3)                                            STRFLC.
      IF (L .EQ. NUMEL)  GO TO 8050                                     STRFLC
      L = L + 1                                                         STRFLC.
      IF (N - L)  8015, 8035, 8025                                      STRFLC.
 8040 PRINT 8045, N                                                     STRFLC.
 8045 FORMAT(* RESIDUAL STRESS INPUT ERROR, N=*I4)                      STRFLC.
      LBAD = 1                                                          STRFLC.
      GO TO 8015                                                        STRFLC.
 8050 GO TO 5                                                           STRFLC.
C                                                                       STRFLC.
C     RESTART PARAMETERS IF NEEDED                                      STRFLC.
 9000 IF (NJELT .GT. 0)  GO TO 9815                                     STRFLC.
      PRINT 9810                                                        STRFLC.
 9810 FORMAT (40H RESTART CARDS MUST FOLLOW ELEMENT CARDS)              STRFLC.
      GO TO 15                                                          STRFLC.
                                                                        STRFLC.
 9815 READ 9805, (KN(I),KS(I),WT(I),W(I), I=1,NJELT)                    STRFLC.
 9805 FORMAT( 4E20.6 )                                                  STRFLC.
      GO TO 5                                                           STRFLC.
C                                                                       STRFLC.
C     ALL INPUT NOW IN --IF CORRECT PROCEED WITH SOLUTION               STRFLC.
 9999 IF (LBAD .NE. 0)  GO TO 15                                        STRFLC.
                                                                        STRFLC.
C      PLOT MESH                                                        STRFLC.
      IF (IPLOT .EQ. 0)  GO TO 124                                      STRFLC.
C                                                                       STRFLC.
C     PREPARE CONSTANTS FOR PLOTTING                                    STRFLC.
      CCYMIN = (10.5- YLNGTH) / 2.0                                     STRFLC.
      CCYMAX = CCYMIN + YLNGTH                                          STRFLC.
      CCXMIN = 0.0                                                      STRFLC.
      CCXMAX = XLNGTH                                                   STRFLC.
      XMIN=R(1)                                                         STRFLC.
      YMIN=Z(1)                                                         STRFLC.
      XMAX=XMIN                                                         STRFLC.
      YMAX=YMIN                                                         STRFLC.
      DO 112 I=2,NUMNP                                                  STRFLC.
      IF (R(I) .GT. XMAX)  XMAX = R(I)                                  STRFLC.
      IF (R(I) .LT. XMIN)  XMIN = R(I)                                  STRFLC.
```

```
      IF (Z(I) .GT. YMAX)  YMAX = Z(I)                                  STRFLC
      IF (Z(I) .LT. YMIN)  YMIN = Z(I)                                  STRFLC
  112 CONTINUE                                                          STRFLC
      XCON = XLNGTH / (XMAX-XMIN)                                       STRFLC
      YCON = YLNGTH / (YMAX-YMIN)                                       STRFLC
      DISPL = 0.02 * (XMAX - XMIN)                                      STRFLC
                                                                        STRFLC
      XSCL = (XMAX - XMIN) / XLNGTH                                     STRFLC
      YSCL = (YMAX - YMIN) / YLNGTH                                     STRFLC
      DSCL = DISPL / XLNGTH                                             STRFLC
      PSF=XSCL/PSCL*0.5                                                 STRFLC
      PSFJ = PSF / CONJT                                                STRFLC.
      PJCL=PSCL*CONJT                                                   STRFLC
                                                                        STRFLC
      CALL CCBGN                                                        STRFLC
      WRITE (98, 115) HED                                               STRFLC
  115 FORMAT (8A9/8A9)                                                  STRFLC
      CALL CCLTR (-1.2,0.5, 1, 2)                                       STRFLC.
      CALL CCLBL (1,1)                                                  STRFLC.
      DO 119  N=1,NUMEL                                                 STRFLC.
      NI=IX(N,1)                                                        STRFLC.
      NJ=IX(N,2)                                                        STRFLC.
      NK=IX(N,3)                                                        STRFLC.
      NL=IX(N,4)                                                        STRFLC.
      XTR(1) = R(NI)                                                    STRFLC.
      XTR(2) = R(NJ)                                                    STRFLC
      XTR(3) = R(NK)                                                    STRFLC.
      XTR(4) = R(NL)                                                    STRFLC.
      XTR(5) = XTR(1)                                                   STRFLC.
      XTR(6) = Z(NI)                                                    STRFLC.
      XTR(7) = Z(NJ)                                                    STRFLC.
      XTR(8) = Z(NK)                                                    STRFLC.
      XTR(9) = Z(NL)                                                    STRFLC.
      IF (IX(N,5) .GT. NSHELL)  GO TO 117                               STRFLC.
      XTR(10) = XTR(6)                                                  STRFLC.
      CALL CCPLOT (XTR(1), XTR(6), 5, 4HJOIN)                           STRFLC.
  117 CONTINUE                                                          STRFLC.
      COR = 3.                                                          STRFLC.
      XCEN = XTR(1) + XTR(2) + XTR(3)                                   STRFLC.
      YCEN = XTR(6) + XTR(7) + XTR(8)                                   STRFLC.
      IF (NK .EQ. NL)  GO TO 118                                        STRFLC.
      COR = 4.                                                          STRFLC.
      XCEN = XCEN + XTR(4)                                              STRFLC.
      YCEN = YCEN + XTR(9)                                              STRFLC.
  118 XCEN=XCEN/COR*XCON+.05                                            STRFLC.
      YCEN=YCEN/COR*YCON+1.1                                            STRFLC.
  119 CONTINUE                                                          STRFLC.
      WRITE (98,121)  XSCL, YSCL                                        STRFLC.
  121 FORMAT (15H 1 IN ON X AXIS/4H   =E12.4,3H FT/15H 1 IN ON Y AXIS/  STRFLC.
     14H   =E12.4,3H FT)                                                STRFLC.
      DO 123  I=1,NUMMAT                                                STRFLC.
      WRITE (98, 2015) I                                                STRFLC.
      IF (I .LE. NSHELL)  GO TO 122                                     STRFLC.
      WRITE (98,2030) (E(J,I),J=1,7)                                    STRFLC.
      GO TO 123                                                         STRFLC.
  122 WRITE(98,2020) RO(I),(E(J,I),J=1,6)                               STRFLC.
  123 CONTINUE                                                          STRFLC.
      XP = CCXMAX + 0.5                                                 STRFLC.
      CALL CCLTR (XP, 10.5, 0, 2)                                       STRFLC.
      CALL CCNEXT                                                       STRFLC.
C**********  INITIALIZE*********                                        STRFLC.
      DO 4 I=1,NJELT                                                    STRFLC.
```

```
      SIGN(I)=0.0                                                       STRFLC
    4 SIGT(I)=0.0                                                       STRFLC
      NF2=NUMFNP+NUMFNP                                                 STRFLC
  124 READ 6,WORD                                                       STRFLC
      NF2=NUMFNP+NUMFNP                                                 STRFLC
      IF(WORD.EQ.BLANK) NF2=NUMFNP                                      STRFLC
      NEQ=KEQ                                                           STRFLC
      MN=MBAND*NEQ                                                      STRFLC
      MN9=MBFLOW*NF2                                                    STRFLC
      N2=1                                                              STRFLC
      M2=MN+1                                                           STRFLC.
      M3=M2+MN9                                                         STRFLC.
      M4=M3+NEQ                                                         STRFLC.
      M5=M4+NEQ                                                         STRFLC.
      M6=M5+NEQ                                                         STRFLC
      M7=M6+NF2                                                         STRFLC.
      M8=M7+NF2                                                         STRFLC.
      M9=M8+NUMFNP                                                      STRFLC.
      I1=1                                                              STRFLC.
      I2=2*NF2+I1                                                       STRFLC.
      I3=NEQ+I2                                                         STRFLC.
      DO 135 I=M3,M9                                                    STRFLC.
      A(I)=0.0                                                          STRFLC.
  135 CONTINUE                                                          STRFLC.
                                                                        STRFLC.
C  ****  INITIAL NODAL LOADS ****                                       STRFLC.
      DO 7501 I=1,NUMNP                                                 STRFLC.
      K1=IDEQ(1,I)                                                      STRFLC.
      K2=IDEQ(2,I)                                                      STRFLC.
      K3=IDEQ(3,I)                                                      STRFLC.
      J=IDEST(I)                                                        STRFLC.
      A(M5+K3-1)=PHIO(J)                                                STRFLC.
      TEMP(I)=PHIO(J)                                                   STRFLC.
      A(M4+K1-1)=A(M4+K1-1)+UR(I)                                       STRFLC.
      A(M4+K2-1)=A(M4+K2-1)+UZ(I)                                       STRFLC.
      DBO(K1)=0.0                                                       STRFLC.
      DBO(K2)=0.0                                                       STRFLC.
 7501 CONTINUE                                                          STRFLC.
      DO 505  K=1,NEQ                                                   STRFLC.
      TLOAD(K)=0.0                                                      STRFLC.
  505 CONTINUE                                                          STRFLC.
      CONTINUE                                                          STRFLC.
                                                                        STRFLC.
C                                                                       STRFLC.
C     CALCULATION  OF APERTURES                                         STRFLC.
      IF(NJELT.GT.0) CALL APERTUR                                       STRFLC.
C                                                                       STRFLC.
  125 TIT=0.0                                                           STRFLC.
      TFL=0.0                                                           STRFLC.
      TL=0.0                                                            STRFLC.
      IP=0                                                              STRFLC.
      TIME=0.0                                                          STRFLC.
      IPER=0                                                            STRFLC.
      NSTEP=0                                                           STRFLC.
      DRT=1.-1./THETA                                                   STRFLC.
      DTH=DT/2.                                                         STRFLC.
      TOTH=THETA*DTH                                                    STRFLC.
      HTOT=DTH-TOTH                                                     STRFLC.
                                                                        STRFLC.
      CALL SECOND(TST)                                                  STRFLC.
C     SOLVE NON-LINEAR STRUCTURE BY SUCCESSIVE APPROXIMATIONS           STRFLC.
C                                                                       STRFLC.
```

```
C                                                                       STRFLC
  170 MP = MP + 1                                                       STRFLC
      NCC=0                                                             STRFLC
      IP=NFP(MP)                                                        STRFLC
      READ 1005,NSTEP,DT                                                STRFLC
C                                                                       STRFLC
  174 CONTINUE                                                          STRFLC
      TIME=TIME+DT                                                      STRFLC
  175 DO 195 NNN=1,IP                                                   STRFLC
      FLAG = .FALSE.                                                    STRFLC
      IPER=IPER+1                                                       STRFLC
      INDEX = IPAT(IPER)                                                STRFLC
C                                                                       STRFLC
  185 CONTINUE                                                          STRFLC
                                                                        STRFLC
C     PO,TO CALCULATED,IF SYSDIM AND TOTALQ IS SUPPLIED                 STRFLC
                                                                        STRFLC
      QQ=TOTALQ                                                         STRFLC
      IF(QQ.NE.0.) GO TO 186                                            STRFLC
      RO=1.0                                                            STRFLC
      TOT=1.0                                                           STRFLC
      GO TO 187                                                         STRFLC
  186 CONTINUE                                                          STRFLC
      RO= SYSDIM*E(1,1)/(VISC*QQ)                                       STRFLC
      TOT=E(1,1)*TIME*E(5,1)/VISC                                       STRFLC
  187 CONTINUE                                                          STRFLC
C                                                                       STRFLC
      IF(FLAG) GO TO 190                                                STRFLC
      CALL STIFF(THETA*DT/2.,A(N2),A(M2),A(M3),A(M4),A(M5),NEQ,NUMFNP,  STRFLC
     , MN,MN9,MBAND,MBFLOW,TIME)                                        STRFLO
C                                                                       STRFLC
C     SOLVE FOR DISPLACEMENTS                                           STRFLC.
C                                                                       STRFLC
      CALL SOLVES(THETA,DT,TIME,A(N2),A(M2),A(M3),A(M4),A(M5),A(M6),    STRFLC
     *KODE,ID(1),ID(I2),NUMNP,NEQ,NUMEL,NSHELL,MBAND,MBFLOW,            STRFLC
     *NUMFNP,ICOMPR,IDEST,INDEX,IPER,NNN,IDEQ,PHIO,Q,IP,QN,A(M7),MN9,   STRFLF
     $ TLOAD)                                                           STRFLC
  321 CONTINUE                                                          STRFLC
      IF(THETA.EQ.1.0) GO TO 323                                        STRFLC
      I=0                                                               STRFLC
      DO 325 K=1,NEQ                                                    STRFLC
      A(M3+I)=A(M3+I)/THETA+DRT*A(M5+I)                                 STRFLC.
  325 I=I+1                                                             STRFLC.
  323 CONTINUE                                                          STRFLC.
      IF(INDEX.NE.0) PRINT 324,MP                                       STRFLC
  324 FORMAT(*DISPL.AND PRESS.AT THE END OF TIME STEP NO.*,I5)          STRFLC
      IF(INDEX.EQ.0) GO TO 192                                          STRFLC
      PRINT 2008,TIME                                                   STRFLC
 2008 FORMAT(1H1, 30H DISPL. AND PRESSURES AT TIME , E15.4// 6X,        STRFLC
     . 10H NODAL PT ,20HDISPL IN X-DIREC     ,20HDISPL IN Y-DIREC       STRFLC.
     .    14H   PRESSURE   22H DIMENSIONLESS TIME,TO,26H DIMENSIONLESS PRSTRFLC
     *ESSURE,PO//)                                                      STRFLC.
      CALL PRINT(NUMNP,IDEQ,NMXI,R,RO,TOT,A(M3),TEMP)                   STRFLC.
  326 FORMAT(I10,5E20.5)                                                STRFLC.
  192 CONTINUE                                                          STRFLC.
  190 CALL STRFLD(A(M3),A(M4),A(M5),TIME,IP,FLAG,NCC,DT)                STRFLC.
      IF(FLAG) GO TO 191                                                STRFLC.
      IF(INDEX.NE.0) GO TO 193                                          STRFLC.
C.....NOT NEEDED IF UNCOUPLED FLOW PROBLEM IS SOLVED.....               STRFLC.
      IF( E(4,1).EQ.0.0 ) GO TO 193                                     STRFLC.
      PRINT 324,MP                                                      STRFLC.
      PRINT 2008,TIME                                                   STRFLC.
```

```
      CALL PRINT (NUMNP,IDEQ,MAXI,R,RO,TOT,A(M3),TEMP)                  STRFLC
  193 CONTINUE                                                          STRFLC
      IPER=IPER+IP-NNN                                                  STRFLC
      GO TO 196                                                         STRFLC
  191 CALL SECOND (T)                                                   STRFLC
      IF(IPER.EQ.1) TIT=T-TST                                           STRFLC
      TL=TTOTAL-T                                                       STRFLC
      IF(TL.LE.TIT.AND.NNN.LT.IP) GO TO 205                             STRFLC
  195 CONTINUE                                                          STRFLC
  196 CONTINUE                                                          STRFLC
      I=0                                                               STRFLC
      DO 501 K=1,NEQ                                                    STRFLC
      A(M5+I)=A(M3+I)                                                   STRFLC
      A(M3+I)=0.0                                                       STRFLC
      TLOAD(K)=0.0                                                      STRFLC
  501 I=I+1                                                             STRFLC
C                                                                       STRFLC
                                                                        STRFLC.
      NCC=NCC+1                                                         STRFLC.
      IF(NCC.GE.NSTEP) GO TO 600                                        STRFLC.
 1005 FORMAT(I10,E20.5)                                                 STRFLC.
      MP=MP+1                                                           STRFLC.
      IP=NPP(MP)                                                        STRFLC.
      GO TO 174                                                         STRFLC.
  600 CONTINUE                                                          STRFLC.
      NDTN=NDTN-1                                                       STRFLC.
  500 CALL SECOND(T)                                                    STRFLC.
      TL=TTOTAL-T                                                       STRFLC.
      IF(TL.LE.TIT.AND.MP.LT.NIT) PRINT 210                             STRFLC.
      IF(MP.LT.NIT.AND.NDTN.GT.0) GO TO 170                             STRFLC.
  210 FORMAT(*NOT ENOUGH TIME FOR ANOTHER PERTURBATION*)                STRFLC.
                                                                        STRFLC.
      IF(IPUNCH.EQ.1.OR.IPUNCH.EQ.3) GO TO 225                          STRFLC.
      GO TO 235                                                         STRFLC.
  205 PRINT 210                                                         STRFLC.
                                                                        STRFLC.
  225 PUNCH 230, (KN(I),KS(I),WT(I),W(I), I=1,NJELT)                    STRFLC.
  230 FORMAT( 4E20.6 )                                                  STRFLC.
  235 PRINT 240, TIT                                                    STRFLC.
  240 FORMAT(18H PERTURBATION TIMEE10.3,8H SECONDS)                     STRFLC.
      GO TO 5                                                           STRFLC.
                                                                        STRFLC.
  300 IF (IPLOT .EQ. 1)  CALL CCEND                                     STRFLC.
      CALL EXIT                                                         STRFLC.
C                                                                       STRFLC.
      END                                                               STRFLC.
      SUBROUTINE APERTUR                                                STRFLC.
C                                                                       STRFLC.
      LARGE A(125000),ID(900)                                           STRFLP.
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R.KN(50),R.KS(50),WT(50),ICUT(301),Q(300), LARGE.
     *QP(50),W(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),D90(600)                            STRFLP.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICOMFR, GEN.2
     1      NUMEL,NO2,HED(16),DISPL,NJELT,IPER,NUMMAT,PSF,PSFJ,KSCL,SPHT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,MBAND,LNGTH,NEQ,NJMPGEN.4
     *      ,MDFLOW,NUMNF2,NUMFAP,LM(12),NF2                            GEN.5
      COMMON/APTR/IRAND,NJUMP,AAS,AAM                                   APTR.2
      IF( IRAND.NE.0) GO TO 10                                          STRFLC.
      DO 15  J=1,NJELT                                                  STRFLC.
      I = IOUT(J)                                                       STRFLC.
```

```
      MAT=IABS(IX(I,5))                                                 STRFLC
      WT(J)=E(5,MAT)                                                    STRFLC
   15 CONTINUE                                                          STRFLC
      GO TO 35                                                          STRFLC
C                                                                       STRFLC
   10 PRINT 16                                                          STRFLC
   16 FORMAT (* APERTURES ARE RANDOMLY GENERATED*)                      STRFLC
      DO 20  K=1,NJELT                                                  STRFLC
      J = IOUT(K)                                                       STRFLC
      MAT=IABS( IX(J,5) )                                               STRFLC
      APR=0.0                                                           STRFLC
      DO 25  I=1,12                                                     STRFLC
      YFL=RANF(0)                                                       STR'LC
   25 APR=APR+YFL                                                       STRFLC
      VTH=(APR-6.0)*AAS+AAM                                             STRFLC
      WT(K) = -EXP(VTH)                                                 STRFLC
   20 CONTINUE                                                          STRFLC
   35 IF( NJMP.EQ.0 ) GO TO 40                                          STRFLC
C                                                                       STRFLC
      DO 50 JI=1,NJMP                                                   STRFLC
      READ 100,I,COEG,COEM1,COEM2,COEM3,COEM4                           STRFLC
  100 FORMAT(I5,F10.3,4F15.5)                                           STRFLC
      PRINT 200 ,I,COEG,COEM1,COEM2,COEM3,COEM4                         STRFLC
  200 FORMAT (//14,7X,6HCOEG= ,F10.3,10X,7HCOEM1= ,F10.3,10X,7HCOEM2= ,F1STRFLC
     10.3,7HCOEM3= ,F10.3,5X,7HCOEM4= ,F10.3 )                          STRFLC.
                                                                        STRFLC
      DO 220 J = 1,NJELT                                                STRFLC
      IF (IOUT(J) .EQ. I)  GO TO 230                                    STRFLC
  220 CONTINUE                                                          STRFLC.
  230 WT(J) = COEG * WT(J)                                              STRFLC.
      MAT=IABS( IX(I,5) )                                               STRFLC.
      E(1,MAT)=COEM1*E(1,MAT)                                           STRFLC.
      E(2,MAT)=COEM2*E(2,MAT)                                           STRFLC.
      E(3,MAT)=COEM3*E(3,MAT)                                           STRFLC.
      E(4,MAT)=COEM4*E(4,MAT)                                           STRFLC.
   50 CONTINUE                                                          STRFLC
C                                                                       STRFLC
   40 CONTINUE                                                          STRFLC
      RETURN                                                            STRFLC.
      END                                                               STRFLC.
      SUBROUTINE STIFF(DT,A1,A2,B,BO,PO,NQ,NNP,MN,MN9,MT,MF,TIME)       STRFLC.
C                                                                       STRFLC.
      LARGE A(125000),IO(900)                                           STRFLF.
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),JR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R,KN(50),R,KS(50),WT(50),ICUT(301),Q(300), LARGE.
     *QP(50),W(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),DBO(600)                            STRFLP.
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LBAD,RADN,   BLANK.
     1                   RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RO(12),  BLANK.
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),       BLANK.
     3   PRS,FZS,PRT,FZT,EG                                             BLANK.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICCMPR, GEN.2
     1      NUMEL,ND2,HED(16),DISFL,NJELT,IPER,NUMMAT,FSF,PSFJ,KSCL,SFWT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,MAXI,NB,MEAND,LNGTH,NEQ,NJMPGEN.4
     *      ,MBFLOW,NUPNF2,NUMFNP,LM(12),NF2                            GEN.5
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QJ(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                         EM.3
      LARGE A1(NQ,1),A2(NNP,1),B(1),BO(1),PO(1)                         STRFLC.
      DIMENSION PP(2),RP(2),TL(8)                                       STRFLC.
      COMMON/STF/SF(8,8),SC(8,4),SH(4,4),SE(4,4)                        STRFLC.
                                                                        STRFLC.
```

```
                                                                        STRFLC
C                                                                       STRFLC
      REWIND 8                                                          STRFLC
      REWIND 9                                                          STRFLC
      ISH=4                                                             STRFLC
      JSH=2                                                             STRFLC
      LBAD= 0                                                           STRFLF
C                                                                       STRFLC
      DC 702 K=1,NEQ                                                    STRFLC
      DO 702 L=1,MBAND                                                  STRFLC
  702 A1(K,L)=0.0                                                       STRFLC
      DO 701 KK=1,NNP                                                   STRFLC
      DO 701 LL=1,MBFLCH                                                STRFLC
      IF(NF2.GT.NUMFNP) A2(KK,MBFLOW+LL)=0.0                            STRFLC
  701 A2(KK,LL)=0.0                                                     STRFLC
C                                                                       STRFLC
C                                                                       STRFLC
      MJ = 0                                                            STRFLC.
C                                                                       STRFLC.
      DO 300 N=1,NUMEL                                                  STRFLC
      DO 200 I=1,4                                                      STRFLC.
      NP(I)=IX(N,I)                                                     STRFLC.
  200 CONTINUE                                                          STRFLC.
      MTYPE=IX(N,5)                                                     STRFLC.
      IF(MTYPE.LE.NSHELL) GO TO 92                                      STRFLC
      MJ=MJ+1                                                           STRFLC
C                                                                       STRFLC.
C                                                                       STRFLC.
C JOINT MATERIAL PROPERTY ASSIGNMENT                                    STRFLC.
C                                                                       STRFLC.
C     KN AND KS  ARE MODIFIED AFTER EACH PERTRBATION,THEREFORE,         STRFLC.
C     AFTER FIRST PERTUBATION OF FIRST TIME STEP CALCULATED STIFFNESSES STRFLC.
C     ARE USED                                                          STRFLC.
                                                                        STRFLC.
C     WHEN RESTARTED STIFFNESS VALUES THAT ARE RESULTS OF PRECEEDING    STRFLC.
C     RUNS ARE READ IN DIRECTLY                                         STRFLC.
C                                                                       STRFLC.
      IF(MP.GT.1) GO TO 61                                              STRFLC.
      IF(NNN.GT.1) GO TO 61                                             STRFLC.
      IF (IPUNCH .GE. 2)  GO TO 61                                      STRFLC.
      KN(MJ) = E(1,MTYPE)                                               STRFLC.
      KS(MJ) = E(2,MTYPE)                                               STRFLC.
   61 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
C********           JOINT ELEMENTS  *******                             STRFLC.
      CALL JTSTIF(B,BO,PO,MJ,N)                                         STRFLC.
      IF(VOL.LT.0.0) IX(N,5)=-IX(N,5)                                   STRFLC.
      CALL ASMBLE(DT,A1,A2,N,S,AJ,DD,EJ,IDEQ,NEQ,NF2,IDEST,JSH)         STRFLC.
      GO TO 300                                                         STRFLC.
C                                                                       STRFLC.
C********           SOLID ELEMENTS  *******                             STRFLC.
C                                                                       STRFLC.
   92 CONTINUE                                                          STRFLC.
      IF( IPER.GT.1.AND.SPHT.EQ.0.0) GO TO 94                           STRFLC.
      IF(NNN.GT.1) GO TO 94                                             STRFLC.
      CALL ELSTIF(B,BO,PO,N)                                            STRFLC.
      CALL ASMBLE(DT,A1,A2,N,SF,SC,SH,SE,IDEQ,NQ,NF2,IDEST,ISH)         STRFLC.
      GO TO 300                                                         STRFLC.
   94 READ (8) SF,SC,SH,SE,NP                                           STRFLC.
   93 CALL ASMBLE(DT,A1,A2,N,SF,SC,SH,SE,IDEQ,NQ,NF2,IDEST,ISH)         STRFLC.
  300 CONTINUE                                                          STRFLC.
      IF(NNN.GT.1) GO TO 500                                            STRFLC.
```

```
      DO 381 I=1,NUMNP                                                  STRFLC
      J=IDEST(I)                                                        STRFLC
      K=IDEQ(3,I)                                                       STRFLC
      IF( KODE(3,I).LE.0 ) GO TO 350                                    STRFLF
      TLOAD(K)=PO(K)*1.0E+20                                            STRFLF
      QN(J)=TLOAD(K)                                                    STRFLF
      GO TO 381                                                         STRFLF
  350 QN(NUMFNP+J)=TLOAD(K)+Q(J)                                        STRFLF
  381 CONTINUE                                                          STRFLF
  500 RETURN                                                            STRFLC
      END                                                               STRFLC
      SUBROUTINE JTSTIF(B,BO,PO,M,N)                                    STRFLC
C                                                                       STRFLC
      LARGE A(125000),ID(900)                                           STRFLP
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R,KN(50),R,KS(50),WT(50),ICUT(301),Q(300), LARGE.
     *QP(50),W(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),DBO(600)                            STRFLP
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LOAD,RADN,   BLANK.
     1                   RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RO(12),  BLANK.
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4) ,      BLANK.
     3   PRS,PZS,PRT,PZT,EG                                             BLANK.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICOMPR, GEN.2
     1      NUMEL,ND2,HED(16),DISPL,NJELT,IPER,NUMMAT,FSF,PSFJ,KSCL,SPWT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,MEAND,LNGTH,NEQ,NJMPGEN.4
     *      ,MBFLOW,NUMNP2,NUMFNP,LM(12),NF2                            GEN.5
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QU(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                         EM.3
C                                                                       STRFLC
      LARGE B(1),BO(1),PO(1)                                            STRFLC
      DIMENSION AS(4,4),TR(2,2),PPP(8),SS(4,4),TTT(6),SSS(6),V(4)       STRFLC.
      DIMENSION AT(8,2),CJ(8,2),DUM(24),PP(8)                           STRFLC
      DIMENSION EPRO(8),CPRO(8)                                         STRFLC
      DATA AT/1.,-1.,1.,-1.,-1.,1.,-1.,1./                              STRFLC.
      DATA AS/2.,1.,-1.,-2.,1.,2.,-2.,-1.,-1.,-2.,2.,1.,-2.,-1.,1.,2./  STRFLC
      DATA  SS/-0.5,0.,0.,0.5, 0.,0.5,-0.5,0., 0.,-0.5,0.5,0.,          STRFLC.
     1          0.5,0.,0.,-0.5/                                         STRFLC
C                                                                       STRFLC
      DATA INCOM/10HINCOMPRESS/                                         STRFLP.
      II=IX(N,1)                                                        STRFLC.
      JJ= IX(N,2)                                                       STRFLC.
      RM = -1.0                                                         STRFLC.
      IF (NAXI .NE. 0)  RM = -(R(JJ) + R(II)) / 2.0                     STRFLC.
      DR=R(JJ)-R(II)                                                    STRFLC.
      DZ=Z(JJ)-Z(II)                                                    STRFLC.
      VOL = SQRT(DR*DR + DZ*DZ)                                         STRFLC.
      IF (VOL .EQ. 0.0)  GO TO 470                                      STRFLC.
                                                                        STRFLC.
C** MATERIAL PROPERTIES                                                 STRFLC.
   50 COMS=KS(M)*VOL/6.0                                                STRFLC.
      COMN=KN(M)*VOL/6.0                                                STRFLC.
C                                                                       STRFLC.
C          INITIALIZE                                                   STRFLC.
      DO 100 II=1,8                                                     STRFLC
      P(II)=0.0                                                         STRFLC
      EPRO(II)=0.0                                                      STRFLC.
      CPRO(II)=0.0                                                      STRFL
      DO 100 JJ=1,8                                                     STRFLC.
  100 S(II,JJ) = 0.0                                                    STRFLC.
      DO 99 I=1,4                                                       STRFLC.
      EJ(I)=0.0                                                         STRFLC
```

```
   99 DD(I)=0.0                                                          STRFLC
      DO 98 I=1,16                                                      STRFLC
   98 AJ(I)=0.0                                                         STRFLC
                                                                        STRFLC
C        DEVELOP RESIDUAL STRESS CONTRIBUTIONS TO THE LOAD VECTOR        STRFLC
C                                                                       STRFLC
C ********************************************************************  STRFLC
C THE FOLLOWING SIGN CONVENTION IS ADOPTED.THE NORMAL STRESS IS POSITIVESTRFLC
C WHEN DIRECTED OUTWARD THE ELEMENT ON THE FACE (II,JJ). THE SHEAR STRESSSTRFLC
C IS POSITIVE WHEN DIRECTED FROM II TO JJ AND KK TO LL INSIDE THE ELEMENSTRFLC
C                                                                       STRFLC.
      TR(1,1)=DR/VOL                                                    STRFLC
      TR(1,2)=DZ/VOL                                                    STRFLC
      IF(IPER.GT.1) GO TO 171                                           STRFLC
      SC = TR(1,1) * TR(1,2)                                            STRFLC
      S2 = TR(1,2) ** 2                                                 STRFLC
      C2 = TR(1,1) ** 2                                                 STRFLC.
  111 RSTRS(1)=RESID(N,1)*S2+RESID(N,2)*C2+2.*RESID(N,4)*SC             STRFLC.
      RSTRS(2)=(RESID(N,2)-RESID(N,1))*SC+RESID(N,4)*(S2-C2)            STRFLC.
      TFORY=RSTRS(1)*VOL*RM                                             STRFLC.
      TFORX=RSTRS(2)*VOL*RM                                             STRFLC.
      RATLO=0.0                                                         STRFLC.
      IF(NAXI.EQ.0) GO TO 112                                           STRFLC.
      II=IX(N,1)                                                        STRFLC
      RATLO=(-1./RM)*(R(II)/2.+VOL/3.0)-0.5                             STRFLC.
  112 PPP(1)=TFORY*(0.5-RATLO)                                          STRFLC.
      PPP(2)=TFORX*(0.5-RATLO)                                          STRFLC.
      PPP(3)=TFORY*(0.5+RATLO)                                          STRFLC.
      PPP(4)=TFORX*(0.5+RATLO)                                          STRFLC.
      PPP(5)=-PPP(3)                                                    STRFLC.
      PPP(6)=-PPP(4)                                                    STRFLC.
      PPP(7)=-PPP(1)                                                    STRFLC.
      PPP(8)=-PPP(2)                                                    STRFLC.
  171 CONTINUE                                                          STRFLC.
                                                                        STRFLC.
      DO 200 II=1,4                                                     STRFLC.
      IN = II + II                                                      STRFLC.
      IS = IN - 1                                                       STRFLC.
      DO 200 JJ=1,4                                                     STRFLC.
      JN = JJ + JJ                                                      STRFLC.
      JS = JN - 1                                                       STRFLC.
      TDUM=AS(II,JJ)                                                    STRFLC.
      IF(NAXI.NE.0) TDUM=-TDUM*RM+SS(II,JJ)*DR                          STRFLC.
      S(IS,JS)=CONS*TDUM                                                STRFLC.
  200 S(IN,JN)=CONN*TDUM                                                STRFLC.
                                                                        STRFLC.
C     ROTATE TO GLOBAL COORDINATES                                      STRFLC
      TR(2,1) = -TR(1,2)                                                STRFLC.
      TR(2,2) = TR(1,1)                                                 STRFLC.
      IF(TR(1,1).EQ.1.) GO TO 450                                       STRFLC.
                                                                        STRFLC.
      DO 400 NN=1,4                                                     STRFLC.
      JJ = NN + NN                                                      STRFLC.
      DO 410  II=1,8                                                    STRFLC.
      TDUM=S(II,JJ-1)*TR(1,1)+S(II,JJ)*TR(2,1)                          STRFLC.
      S(II,JJ) = S(II,JJ-1)*TR(1,2) + S(II,JJ) *TR(2,2)                 STRFLC.
  410 S(II,JJ-1)=TDUM                                                   STRFLC
      DO 420  II=1,8                                                    STRFLC.
      TDUM=S(JJ-1,II)*TR(1,1)+S(JJ,II)*TR(2,1)                          STRFLC.
      S(JJ,II) = S(JJ-1,II)*TR(1,2) + S(JJ,II)*TR(2,2)                  STRFLC.
  420 S(JJ-1,II)=TDUM                                                   STRFLC
  400 CONTINUE                                                          STRFLC.
```

```
C                                                                       STRFLC
  450 CONTINUE                                                          STRFLC
      IF(IPER.NE.1) GO TO 465                                           STRFLC
      DO 460 I=1,4                                                      STRFLC
      K=IX(N,I)                                                         STRFLC
      II = I + I                                                        STRFLC
      J = II - 1                                                        STRFLC
  461 K1=IDEQ(1,K)                                                      STRFLC
      K2=IDEQ(2,K)                                                      STRFLC
      BO(K1)=BO(K1)+PPP(J)*TR(1,2)+PPP(II)*TR(2,2)                      STRFLC
      BO(K2)=BO(K2)-PPP(J)*TR(2,2)+PPP(II)*TR(1,2)                      STRFLC
  460 CONTINUE                                                          STRFLC
  465 CONTINUE                                                          STRFLC
C                                                                       STRFLC
C                                                                       STRFLC
      COM=1.0/(12.0*VISC)                                               STRFLC
      DO 60 L=1,4                                                       STRFLC
      K=IX(N,L)                                                         STRFLC
      K1=IDEQ(1,K)                                                      STRFLC
      K2=IDEQ(2,K)                                                      STRFLC
   60 V(L)=PO(K2)*TR(1,1)-PO(K1)*TR(1,2)                                STRFLC
      EPSN=.5*(V(4)-V(1)+V(3)-V(2))                                     STRFLC
      W0=WT(M)                                                          STRFLC
      IF(EPSN.GE.W0)GO TO 61                                            STRFLC
      PRINT 62,N                                                        STRFLC
   62 FORMAT(*DISPLACEMENT GREATER THAN ALLOWED IN ELEMENT NO.*I5)      STRFLC
   61 W(M)=ABS(ABS(W0)+EPSN)                                            STRFLC
      IF(W(M).LT.1.0E-8) W(M)=0.0                                       STRFLC
      EN=W(M)**3                                                        STRFLC
      QP(M)=-EN*COM*RM                                                  STRFLC
                                                                        STRFLC
      DO 71 I=1,4                                                       STRFLC
   71 DD(I)=QP(M)/VOL                                                   STRFLC.
      DD(1,2)=-DD(1,2)                                                  STRFLC
      DD(2,1)=DD(1,2)                                                   STRFLC
      K=IX(N,5)                                                         STRFLC
      IF(ICOMPR.EQ.INCCM) GO TO 73                                      STRFLC
      EE=VOL/(6.0*E(7,K))                                               STRFLC
      EE=-EE*W(M)*RM                                                    STRFLC.
      DO 72 I=1,2                                                       STRFLC
      DO 72 J=1,2                                                       STRFLC.
   72 EJ(I,J)= EE                                                       STRFLC.
      EJ(1,1)=2.0*EJ(1,1)                                               STRFLC.
      EJ(2,2)=EJ(1,1)                                                   STRFLC.
   73 CONTINUE                                                          STRFLC.
                                                                        STRFLC
      DL=-E(6,K)*VOL*RM/4.0                                             STRFLC.
      TSIN=DL*TR(1,2)                                                   STRFLC
      TCOS=DL*TR(1,1)                                                   STRFLC.
      DO 300 I=1,4                                                      STRFLC.
      II=I+I                                                            STRFLC.
      AJ(II,1)=AT(II)*TCOS                                              STRFLC.
      AJ(II-1,1)=AT(II-1)*TSIN                                          STRFLC.
      AJ(II,2)=AJ(II,1)                                                 STRFLC.
      AJ(II-1,2)=AJ(II-1,1)                                             STRFLC.
  300 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
      IF(NNN.GT.1) GO TO 80                                             STRFLC.
      IF(SPWT.EQ.0.) GO TO 80                                           STRFLC.
      DY=-TR(1,2)                                                       STRFLC.
      DG=QP(M)*SPWT                                                     STRFLC.
      GY=DG*DY/2.0                                                      STRFLC.
```

```
      I1=IX(N,1)                                                        STRFLC
      I2=IX(N,2)                                                        STRFLC
      K1=IDEQ(3,I1)                                                     STRFLC
      K2=IDEQ(3,I2)                                                     STRFLC
      TLOAD(K1)=TLOAD(K1)+GY                                            STRFLC
      TLOAD(K2)=TLOAD(K2)-GY                                            STRFLC
   80 CONTINUE                                                          STRFLC
C                                                                       STRFLC
      IF(IPER.GT.1) GO TO 640                                           STRFLC
      DO 600 I=1,2                                                      STRFLC
      DO 600 J=1,2                                                      STRFLC
      K=IX(N,J)                                                         STRFLC.
      L=IDEST(K)                                                        STRFLC.
      EPRO(I)=EPRO(I)+EJ(I,J)*PHIO(L)                                   STRFLC.
  600 CONTINUE                                                          STRFLC.
      DO 610 I=1,8                                                      STRFLC.
      DO 610 J=1,2                                                      STRFLC
      K=IX(N,J)                                                         STRFLC.
      L=IDEST(K)                                                        STRFLC.
      CPRO(I)=CPRO(I)+AJ(I,J)*PHIO(L)                                   STRFLC.
  610 CONTINUE                                                          STRFLC.
      DO 620 J=1,2                                                      STRFLC.
      K=IX(N,J)                                                         STRFLC.
      K3=IDEQ(3,K)                                                      STRFLC.
      BO(K3)=BO(K3)-EPRO(J)                                             STRFLC.
  620 CONTINUE                                                          STRFLC.
      DO 630 J=1,4                                                      STRFLC.
      K=IX(N,J)                                                         STRFLC
      K1=IDEQ(1,K)                                                      STRFLC.
      K2=IDEQ(2,K)                                                      STRFLC.
      BO(K1)=BO(K1)+CPRO(J+J-1)                                         STRFLC.
      BO(K2)=BO(K2)+CPRO(J+J)                                           STRFLC.
  630 CONTINUE                                                          STRFLC.
  640 CONTINUE                                                          STRFLC.
      RETURN                                                            STRFLC.
  470 PRINT 471,N                                                       STRFLC.
  471 FORMAT(17H  BAD JOINT    ,N=I3/)                                  STRFLC.
      LBAD=LBAD+1                                                       STRFLC.
      RETURN                                                            STRFLC.
      END                                                               STRFLC.
      SUBROUTINE FORM9(S1,T1,IP)                                        STRFLC.
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LBAD,RADN,   BLANK.
     1                    RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RO(12), BLANK.
     2     NTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),        BLANK.
     3   PRS,PZS,PRT,PZT,EG                                             BLANK.
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QU(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                         EM.3
      DIMENSION HS(6),HT(6),II(6),JJ(6)                                 STRFLC.
      DATA II/1,3,5,7,9,10/,JJ/2,4,6,8,11,12/                           STRFLC.
C                                                                       STRFLC.
      DO 50 I=1,48                                                      STRFLC.
   50 PD(I)=0.0                                                         STRFLC.
      SM=1.0-S1                                                         STRFLC.
      SP=1.0+S1                                                         STRFLC.
      TM=1.0-T1                                                         STRFLC.
      TP=1.0+T1                                                         STRFLD.
C                                                                       STRFLC.
      H(1)=SM*TM/4.                                                     STRFLC.
      H(2)=SP*TM/4.                                                     STRFLC.
      H(3)=SP*TP/4.                                                     STRFLC.
      H(4)=SM*TP/4.                                                     STRFLC.
      H(5)=(1.0-S1*S1)                                                  STRFLC.
```

```
      H(6)=(1.0-T1*T1)                                                  STRFLC
C                                                                       STRFLC
      HS(1)=-TM/4.                                                      STRFLC
      HS(2)=-HS(1)                                                      STRFLC
      HS(3)=TP/4.                                                       STRFLC
      HS(4)=-HS(3)                                                      STRFLC
      HS(5)=-2.*S1                                                      STRFLC
      HS(6)=0.0                                                         STRFLC
C                                                                       STRFLC
      HT(1)=-SM/4.                                                      STRFLC
      HT(2)=-SP/4.                                                      STRFLC
      HT(3)=-HT(2)                                                      STRFLC
      HT(4)=-HT(1)                                                      STRFLC
      HT(5)=0.0                                                         STRFLC
      HT(6)=-2.*T1                                                      STRFLC
C                                                                       STRFLC
      PZT=HT(1)*ZZ(1)+HT(2)*ZZ(2)+HT(3)*ZZ(3)+HT(4)*ZZ(4)               STRFLC
      PZS=HS(1)*ZZ(1)+HS(2)*ZZ(2)+HS(3)*ZZ(3)+HS(4)*ZZ(4)               STRFLC
      PRS=HS(1)*RR(1)+HS(2)*RR(2)+HS(3)*RR(3)+HS(4)*RR(4)               STRFLC
      PRT=HT(1)*RR(1)+HT(2)*RR(2)+HT(3)*RR(3)+HT(4)*RR(4)               STRFLC
      XJ=PRS*PZT-PRT*PZS                                                STRFLC
C                                                                       STRFLC.
      PSR=PZT/XJ                                                        STRFLC.
      PTR=-PZS/XJ                                                       STRFLC.
      PSZ=-PRT/XJ                                                       STRFLO
      PTZ=PRS/XJ                                                        STRFLC.
C                                                                       STRFLC.
      DO 100 I=1,6                                                      STRFLC.
      HR(I)=PSR*HS(I)+PTR*HT(I)                                         STRFLC.
  100 HZ(I)=PSZ*HS(I)+PTZ*HT(I)                                         STRFLC.
      IF (IP.NE.0) GO TO 150                                            STRFLC.
      R=1                                                               STRFLC.
      GO TO 170                                                         STRFLC.
  150 R=H(1)*RR(1)+H(2)*RR(2)+H(3)*RR(3)+H(4)*RR(4)                     STRFLC.
C                                                                       STRFLC.
C     FORM STRAIN DISPLACEMENT MATRIX                                   STRFLC.
C                                                                       STRFLC.
  170 DO 200 K=1,6                                                      STRFLC.
      I=II(K)                                                           STRFLC.
      J=JJ(K)                                                           STRFLC.
      PD(1,I)=HR(K)                                                     STRFLC.
      PD(2,J)=HZ(K)                                                     STRFLC.
      IF (IP) 180,190,180                                               STRFLC.
  180 PD(3,I)=H(K)/R                                                    STRFLC.
  190 PD(4,I)=HZ(K)                                                     STRFLC.
  200 PD(4,J)=HR(K)                                                     STRFLC.
      DO 300 K=1,4                                                      STRFLC.
      QQ(1,K)=HR(K)                                                     STRFLC.
  300 QQ(2,K)=HZ(K)                                                     STRFLC.
C                                                                       STRFLC.
      FAC=XJ*R                                                          STRFLC.
      RETURN                                                            STRFLC.
      END                                                               STRFLC.
      SUBROUTINE ELSTIF(B,BD,PD,N)                                      STRFLC.
                                                                        STRFLC.
      LARGE A(125000),ID(900)                                           STRFLF.
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R.KN(50),R.KS(50),HT(50),ICUT(301),Q(300), LARGE.
     *QP(50),H(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),DBO(600)                            STRFLF.
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LBAD,RADN,   BLANK.
```

```
     1                     RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RC(12),      BLANK.
     2        MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),          BLANK.
     3    PRS,PZS,PRT,PZT,EG                                                  BLANK.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICOMPR,       GEN.2
     1        NUMEL,NO2,MED(16),DISPL,NJELT,IPER,NUMMAT,PSF,PSFJ,XSCL,SPWT,   GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,MBAND,LNGTH,NEQ,NJMP      GEN.4
     *        ,MBFLOW,NUMNF2,NUMFNP,LM(12),NF2                                GEN.5
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QU(4),HR(6),HZ(6)             EM.2
     * ,EJ(2,2)                                                               EM.3
C                                                                             STRFLC
      LARGE B(1),BO(1),PO(1)                                                  STRFLC
      DIMENSION DX(4),EE(1),ENU(1),EN(1),EM(1),OUM(24),                       STRFLC
     $  PR(10),TTT(6),SSS(6),QB(4),D(4,4)                                    STRFLC
      COMMON/STF/SF(8,8),SC(8,4),SH(4,4),SE(4,4)                              STRFLC
      DIMENSION EPRO(10),CPRO(10)                                             STRFLC
      DATA INCOM/10HINCOMPRESS/,SSS/-.57735027,.57735027,0.0,-.7745967,       STRFLC
     ,0.0,.7745967/,TTT/1.0,1.0,0.0,.55555556,.88888889,.55555556/            STRFLC
C                                                                             STRFLC
      DO 6 I=1,10                                                             STRFLC
      EPRO(I)=0.0                                                             STRFLC
      CPRO(I)=0.0                                                             STRFLO
      PR(I)=0.0                                                               STRFLC.
    6 P(I)=0.0                                                                STRFLC.
      DO 2 J=1,16                                                             STRFLC
      SE(J)=0.0                                                               STRFLC.
    2 SH(J)=0.0                                                               STRFLC
      DO 3 JJ=1,32                                                            STRFLC.
      ST(JJ)=0.0                                                              STRFLC.
    3 SC(JJ)=0.0                                                              STRFLO.
      DO 1 I=1,4                                                              STRFLC.
    1 DX(I)=0.0                                                               STRFLC.
    5 CONTINUE                                                                STRFLC.
      DO 70 I=1,4                                                             STRFLC.
      M=IX(N,I)                                                               STRFLC.
      RR(I)=R(M)                                                              STRFLC.
      ZZ(I)=Z(M)                                                              STRFLC.
   70 CONTINUE                                                                STRFLC.
      K=IX(N,5)                                                               STRFLC.
      FACT=E(2,K)/((1.-2.*E(3,K))*(1.+E(3,K)))                                STRFLC.
      C1=(1.-E(3,K))*FACT                                                     STRFLC.
      C2=E(3,K)*FACT                                                          STRFLC.
      C3=(.5-E(3,K))*FACT                                                     STRFLC.
      EEN=E(4,K)                                                              STRFLC.
      PERM=E(1,K)/VISC                                                        STRFLC.
      IF(NAXI.EQ.0) D7=0.0                                                    STRFLC.
      IF (ICOMPR.EQ.INC(M) EEN=1.0                                            STRFLC.
      DO 85 I=1,64                                                            STRFLC.
   85 SF(I)=0.0                                                               STRFLC.
                                                                              STRFLC.
C     FORM STRAIN AND FLOW MATRICES AT THE CENTER OF THE ELEMENT              STRFLC.
C                                                                             STRFLC.
      DO 520 I=1,3                                                            STRFLC.
      D(I,4)=0.0                                                              STRFLC.
      D(4,I)=0.0                                                              STRFLC.
      DO 510 J=1,3                                                            STRFLC.
  510 D(I,J)=C2                                                               STRFLC.
  520 D(I,I)=C1                                                               STRFLC.
      D(4,4)=C3                                                               STRFLC.
      CALL FORMB(0.0,0.0,NAXI)                                                STRFLC.
      DO 540 I=1,8                                                            STRFLC.
  540 SQ(I)=PERM*QQ(I)                                                        STRFLC.
      DO 533 I=1,4                                                            STRFLC.
```

```
      DO 533 J=1,8                                                      STRFLC
      DO 533 K=1,4                                                      STRFLC
  533 ST(I,J)=ST(I,J)+D(I,K)*PD(K,J)                                    STRFLC
                                                                        STRFLC
      K=IX(N,5)                                                         STRFLC
                                                                        STRFLC
      NTS=2                                                             STRFLC
      IF(NAXI.NE.0) NTS=3                                               STRFLC
      NN=(NTS-2)*3                                                      STRFLC
                                                                        STRFLC
      DO 500 LR=1,NTS                                                   STRFLC
      S1=SSS(LR+NN)                                                     STRFLC.
      DO 500 LZ=1,NTS                                                   STRFLC.
      T1=SSS(LZ+NN)                                                     STRFLC
      CALL FORMB(S1,T1,NAXI)                                            STRFLC
      FAC=FAC*TTT(LR+NN)*TTT(LZ+NN)                                     STRFLC
C                                                                       STRFLC
C ******* FORM  NODAL  LOAD VECTOR *****                                STRFLC.
C                                                                       STRFLC.
      IF(ACELY.EQ.0.) GO TO 453                                         STRFLC.
      FACF=FAC*RO(K)*ACELY                                              STRFLC.
      DO 451 I=1,4                                                      STRFLC.
      J=I+I                                                             STRFLC.
  451 P(J)=P(J)-H(I)*FACF                                               STRFLC.
  453 CONTINUE                                                          STRFLC.
      IF(IPER.NE.1) GO TO 58                                            STRFLC.
      DO 57 I=1,8                                                       STRFLC.
      DO 57 J=1,4                                                       STRFLC.
   57 PR(I)=PR(I)+RESID(N,J)*PD(J,I)*FAC                                STRFLC.
   58 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
C     K MATRIX                                                          STRFLC.
C                                                                       STRFLC.
      DO 90 I=1,8                                                       STRFLC.
      D1=(C1*PD(1,I)+C2*PD(2,I)+C2*PD(3,I))*FAC                         STRFLC.
      D2=(C2*PD(1,I)+C1*PD(2,I)+C2*PD(3,I))*FAC                         STRFLC.
      D3=(C2*PD(1,I)+C2*PD(2,I)+C1*PD(3,I))*FAC                         STRFLC.
      D4=(C3*PD(4,I))*FAC                                               STRFLC.
      DO 90 J=I,8                                                       STRFLC.
   90 SF(J,I)=SF(J,I)+D1*PD(1,J)+D2*PD(2,J)+D3*PD(3,J)+D4*PD(4,J)       STRFLC.
C                                                                       STRFLC.
C     C AND E MATRICES                                                  STRFLC.
C                                                                       STRFLC.
      FACN=FAC*EEN                                                      STRFLC.
      DO 100 I=1,8                                                      STRFLC.
      DB=PD(1,I)+PD(2,I)+PD(3,I)                                        STRFLC.
      DO 100 J=1,4                                                      STRFLC.
  100 SC(I,J)=H(J)*DB*FACN+SC(I,J)                                      STRFLC.
      IF (ICOMPR.EQ.INC(N)) GO TO 150                                   STRFLC.
      FACM=FAC/E(5,K)                                                   STRFLC.
      DO 130 I=1,4                                                      STRFLC.
      DO 130 J=1,4                                                      STRFLC.
  130 SE(I,J)=H(I)*H(J)*FACM+SE(I,J)                                    STRFLC.
  150 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
C     H MATRIX                                                          STRFLC.
C                                                                       STRFLC.
      FACK=FAC*PERM                                                     STRFLC.
      DO 170 I=1,4                                                      STRFLC.
      DX(I)=DX(I)+FACK*(QQ(1,I)*ACELX+QQ(2,I)*(-1.0) )*SPNT             STRFLC.
      DO 170 J=1,4                                                      STRFLC.
      HH=QQ(1,I)*QQ(1,J)+QQ(2,I)*QQ(2,J)                                STRFLC.
```

```
  170 SH(I,J)=HH*FACK+SH(I,J)                                          STRFLC
  500 CONTINUE                                                         STRFLC
C                                                                      STRFLC
C ******* FORM GLOBAL  NODAL  LOAD VECTOR *****                        STRFLC
C                                                                      STRFLC
      IF(NNN.GT.1) GO TO 503                                           STRFLC
      DO 501 J=1,4                                                     STRFLC
      K=IX(N,J)                                                        STRFLC
      K1=IDEQ(1,K)                                                     STRFLC
      K2=IDEQ(2,K)                                                     STRFLC
      TLOAD(K1)=TLOAD(K1)-P(J+J-1)                                     STRFLC
      TLOAD(K2)=TLOAD(K2)-P(J+J)                                       STRFLC
      IF(IPER.GT.1) GO TO 501                                          STRFLC
      BO(K1)=BO(K1)-PR(J+J-1)                                          STRFLC
      BO(K2)=BO(K2)-PR(J+J)                                            STRFLC
  501 CONTINUE                                                         STRFLC
      IF(SPHT.EQ.0) GO TO 503                                          STRFLC
      DO 502 I=1,4                                                     STRFLC
      J=IX(N,I)                                                        STRFLC
      K=IDEQ(3,J)                                                      STRFLC
      TLOAD(K)=TLOAD(K)-DX(I)                                          STRFLC
  502 CONTINUE                                                         STRFLC
  503 CONTINUE                                                         STRFLC
      DO 505 I = 1,8                                                   STRFLC
      DO 505 J = 1,I                                                   STRFLC
  505 SF(J,I) = SF(I,J)                                                STRFLC
C                                                                      STRFLC
      IF(IPER.GT.1) GO TO 830                                          STRFLC
      DO 800 I=1,4                                                     STRFLC
      DO 800 J=1,4                                                     STRFLC
      K=IX(N,J)                                                        STRFLC
      L=IDEST(K)                                                       STRFLC
      EPRO(I)=EPRO(I)+SE(I,J)*PHIO(L)                                  STRFLC
  800 CONTINUE                                                         STRFLC
      DO 810 I=1,8                                                     STRFLC
      DO 810 J=1,4                                                     STRFLC
      K=IX(N,J)                                                        STRFLC
      L=IDEST(K)                                                       STRFLC
      CPRO(I)=CPRO(I)+SC(I,J)*PHIO(L)                                  STRFLC
  810 CONTINUE                                                         STRFLC
      DO 820 J=1,4                                                     STRFLC
      K=IX(N,J)                                                        STRFLC
      K1=IDEQ(1,K)                                                     STRFLC
      K2=IDEQ(2,K)                                                     STRFLC
      K3=IDEQ(3,K)                                                     STRFLC
      BO(K1)=BO(K1)+CPRC(J+J-1)                                        STRFLC
      BO(K2)=BO(K2)+CPRC(J+J)                                          STRFLC
      BO(K3)=BO(K3)-EPRC(J)                                            STRFLC
  820 CONTINUE                                                         STRFLC
  830 CONTINUE                                                         STRFLC
  615 CONTINUE                                                         STRFLC
      WRITE (9) ST,SQ,NP                                               STRFLC
      WRITE (8) SF,SC,SH,SE,NP                                         STRFLC
C                                                                      STRFLC
  700 RETURN                                                           STRFLC
C                                                                      STRFLC
C                                                                      STRFLC
      END                                                              STRFLC
      SUBROUTINE ASMBLE(DT,A1,A2,N,SF,SC,SH,SE,IDEQ,NQ,NNP,IDEST,NH)   STRFLC
C                                                                      STRFLC
      COMMON/BLANK/S(8,8),P(18),RSTRS(4),VCL,RRR(5),ZZZ(5),LOAD,RADN,  BLANK
     1               RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RO(12),     BLANK
```

```
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),           BLANK.
     3    PRS,FZS,PRT,PZT,EG                                                 BLANK.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICCMFR,  GEN.2
     1      NUMEL,ND2,MED(16),DISPL,NJELT,IPER,NUMMAT,PSF,PSFJ,XSCL,SPHT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,MBAND,LNGTH,NEQ,NJMPGEN.4
     *      ,MBFLOW,NUMNF2,NUMFNP,LM(12),NF2                                GEN.5
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QJ(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                             EM.3
C                                                                           STRFLC
      LARGE A1(NQ,1),A2(NNP,1),IDEST(1),IDEQ(3,1)                          STRFLC
C                                                                           STRFLC
      DIMENSION SF(8,1),SC(8,1),SH(NH,1),SE(NH,1)                          STRFLC
                                                                            STRFLC
      L=1                                                                   STRFLC
      DO 703 I=1,4                                                          STRFLC
      J=NP(I)                                                               STRFLC
      DO 704 K=1,2                                                          STRFLC
      LM(L)=IDEQ(K,J)                                                       STRFLC
  704 L=L+1                                                                 STRFLC
  703 LM(I+8)=IDEQ(3,J)                                                     STRFLC
      IJ=12                                                                 STRFLC
      IF(MTYPE.GT.NSHELL) IJ=10                                             STRFLC
      DO 701 I=1,8                                                          STRFLC
      II=LM(I)                                                              STRFLC
      DO 702 J=1,8                                                          STRFLC
      JJ=LM(J)-II+1                                                         STRFLC
  702 IF(JJ.GT.0) A1(II,JJ)=A1(II,JJ)+SF(I,J)                               STRFLC
      DO 701 J=9,IJ                                                         STRFLC.
      JJ=LM(J)-II+1                                                         STRFLC.
  701 IF(JJ.GT.0) A1(II,JJ)=A1(II,JJ)+SC(I,J-8)                             STRFLC.
      DO 705 I=9,IJ                                                         STRFLC.
      II=LM(I)                                                              STRFLC.
      L=1                                                                   STRFLC.
      DO 706 K=1,4                                                          STRFLC.
      K2=L+L                                                                STRFLC.
      K1=K2-1                                                               STRFLC.
      KK=LM(K1)-II+1                                                        STRFLC.
      LL=LM(K2)-II+1                                                        STRFLC.
      IF(KK.GT.0) A1(II,KK)=A1(II,KK)+SC(K1,I-8)                            STRFLC.
      IF(LL.GT.0) A1(II,LL)=A1(II,LL)+SC(K2,I-8)                            STRFLC.
  706 L=L+1                                                                 STRFLC.
      DO 705 J=9,IJ                                                         STRFLC.
      JJ=LM(J)-II+1                                                         STRFLC.
  705 IF(JJ.GT.0) A1(II,JJ)=A1(II,JJ)-SH(I-8,J-8)*DT-SE(I-8,J-8)            STRFLC.
      IJ=4                                                                  STRFLC.
      IF(MTYPE.GT.NSHELL) IJ=2                                              STRFLC.
      DO 708 I=1,IJ                                                         STRFLC.
      I1=NP(I)                                                              STRFLC.
      LL=IDEST(I1)                                                          STRFLC.
      DO 708 J=I,IJ                                                         STRFLC.
      J1=NP(J)                                                              STRFLC.
      KK=IDEST(J1)                                                          STRFLC.
      LLF=MIN0(LL,KK)                                                       STRFLC.
      MBF=IABS(LL-KK)+1                                                     STRFLC.
      A2(LLF,MBF)=A2(LLF,MBF)+SH(I,J)                                       STRFLC.
      IF(NNP.GT.NUMFNP) A2(LLF,MBFLOW+MBF)=A2(LLF,MBFLOW+MBF)-SE(I,J)       STRFLC.
  708 CONTINUE                                                              STRFLC.
 1000 RETURN                                                                STRFLC.
      END                                                                   STRFLC.
      SUBROUTINE SOLVES(THETA,DT,TIME,A1,A2,B,BO,PO,HI,ID,MBH,NB,NUMNP,    STRFLC.
     *NEQ,NEL,NSH,MBAND,MBFLOW,NUMFNP,ICONPR,IDEST,INDEX,IPER,NNN,IDEQ,    STRFLC.
     * PHIC,Q,IP,  Q,QA,AF2,TL)                                              STRFLC.
```

```
                                                                        STRFLC
      LARGE A1(NEQ,1),A2(1),B(1),BO(1),PO(1),ID(3,1),MB(1),TL(1),     STRFLC
     *MBH(1),HI(1),IDEST(1),IDEQ(3,1),PHIO(1),Q(1),QQ(1),QA(1)        STRFLC
      DIMENSION  Q2(600)                                                STRFLC
      DATA INCOM/10HINCOMPRESS/                                         STRFLF
C                                                                       STRFLC
C                                                                       STRFLC
C*****SET-UP LOAD VECTOR AND SOLVE                                      STRFLC
C                                                                       STRFLC
      DTH = DT/2.                                                       STRFLC
      TDTH = THETA*DTH                                                  STRFLC
      HTDT = DTH - TDTH                                                 STRFLC
      TDTH2=2.0*TDTH                                                    STRFLC
      IF( ICOMPR.EQ.INCOM ) TDTH2=TDTH                                  STRFLP
      HTDT2=2.0*HTDT                                                    STRFLC
      DO 230 I=1,NUMNP                                                  STRFLC
      DO 230 J=1,3                                                      STRFLC
      K=IDEQ(J,I)                                                       STRFLC.
      IF(ID(J,I).LE.0) GO TO 230                                        STRFLO.
      CALL MODIFY(K,A1,NEQ)                                             STRFLC
  230 CONTINUE                                                          STRFLC
      NM=NUMFNP*MBFLOW                                                  STRFLC
      IF(NF2.EQ.NM) GO TO 351                                           STRFLC
      L1=NM+1                                                           STRFLC.
      L2=NUMFNP+1                                                       STRFLC
      L3=NUMFNP+L2                                                      STRFLC
  351 IF(IPER.GT.1) GO TO 900                                           STRFLC
      CALL PROFIL(A2(1),MBH(1),NUMFNP,MBFLOW)                           STRFLC.
      IF(NF2.GT.NM) CALL PROFIL(A2(L1),MBH(L3),NUMFNP,MBFLOW)           STRFLC
  900 CALL TRIA(NEQ,MBAND,A1,MB)                                        STRFLC.
      IF(NNN.GT.1) GO TO 250                                            STRFLC.
      DO 340 I=1,NUMNP                                                  STRFLC.
      J=IDEQ(3,I)                                                       STRFLC.
      K=IDEST(I)                                                        STRFLO.
      Q2(K)=B(J)                                                        STRFLC.
      Q2(NUMFNP+K)=Q2(K)                                                STRFLC.
  340 PHIO(K)=PO(J)                                                     STRFLC.
      DO 330 I=1,NUMFNP                                                 STRFLC
      IF( IB(I).LE.0 ) QQ(I)=QQ(I)+TDTH2*QQ(NUMFNP+I)                   STRFLP.
      IF(NF2.LE.NM) GO TO 330                                           STRFLC.
      HI(NUMFNP+I)=PHIO(I)                                              STRFLC.
  330 HI(I)=HI(I)+TDTH*PHIO(I)                                          STRFLC.
  331 CONTINUE                                                          STRFLO.
      IF( ICOMPR.NE.INCOM ) GO TO 345                                   STRFLP.
      DO 260 I=1,NUMFNP                                                 STRFLP.
  260 QA(I)=0.0                                                         STRFLF.
      GO TO 250                                                         STRFLP.
  345 CONTINUE                                                          STRFLF.
      CALL MLTPLY(A2(1),Q2(1),HI(1),QA(1),MBH(1),NUMNP,NUMFNP)          STRFLC.
      IF(IPER.GT.1) GO TO 250                                           STRFLC.
      IF(NF2.GT.NM) CALL MLTPLY(A2(L1),Q2(L2),HI(L2),QA(L2),MBH(L3),    STRFLC.
     X NUMNP,NUMFNP)                                                    STRFLC.
  250 CONTINUE                                                          STRFLC.
      IF(NNN.NE.1) GO TO 240                                            STRFLC.
      DO 242 I=1,NUMFNP                                                 STRFLC.
  242 QA(I)=QA(I)+QQ(I)                                                 STRFLO.
      IF(NF2.LE.NM) GO TO 240                                           STRFLC.
      IF(IPER.GT.1) GO TO 240                                           STRFLC.
      DO 245 I=1,NUMFNP                                                 STRFLC.
  245 QA(I)=QA(I)+QA(I+NUMFNP)                                          STRFLC.
  240 CONTINUE                                                          STRFLC.
      DO 241 I=1,NUMNP                                                  STRFLC.
```

```
      L=IDEST(I)                                                        STRFLC
      K=IDEQ(3,I)                                                       STRFLC
      TL(K)=0.0                                                         STRFLC
  241 B(K)=QA(L)                                                        STRFLC
      DO 255 I=1,NEQ                                                    STRFLC
  255 B(I)=B(I)+BO(I)+TL(I)                                             STRFLC
      CALL BACKS(NEQ,MBAND,A1,B,MB)                                     STRFLC
  276 IF(NNN.NE.IP) RETURN                                              STRFLC
      DO 270 I=1,NUMNP                                                  STRFLC
      K3=IDEQ(3,I)                                                      STRFLC
      L=IDEST(I)                                                        STRFLC
      Q2(NUMFNP+L)=B(K3)                                                STRFLC
  270 CONTINUE                                                          STRFLC
      DO 280 J=1,NUMFNP                                                 STRFLC
      IF( IB(J).LE.0 ) QQ(J)=QQ(J)+HTOT2*QQ(NUMFNP+J)                   STRFLC
  280 HI(J)=HI(J)+HTOT*PHIO(J)+DTH*Q2(NUMFNP+J)                         STRFLC
  275 RETURN                                                            STRFLC
 2009 FORMAT(I10,5E20.5)                                                STRFLC
      END                                                               STRFLC
      SUBROUTINE MODIFY(N,A1,NEQ)                                       STRFLC
      LARGE A1(NEQ,1)                                                   STRFLC
      A1(N,1)=1.0E+20                                                   STRFLC
       RETURN                                                           STRFLC
      END                                                               STRFLC
      SUBROUTINE PROFIL(A2,MB,NEQ,MBAND)                                STRFLC
      LARGE A2(NEQ,1),MB(1)                                             STRFLC
C                                                                       STRFLC
      NN=NEQ*MBAND                                                      STRFLC
      DO 300 N=1,NEQ                                                    STRFLC
      NI=0                                                              STRFLC
      NJ=0                                                              STRFLC
      L=0                                                               STRFLC
      IL=N+NEQ                                                          STRFLC
      DO 100 I=IL,NN,NEQ                                                STRFLC
      L=L+1                                                             STRFLC
      IF(A2(I).NE.0.0) NI=I                                             STRFLC
      IF (N-L) 100,100,80                                               STRFLC
   80 IF(A2(I-L).NE.0.0) NJ=I-L                                         STRFLC
  100 CONTINUE                                                          STRFLC
      MB(N)=NI                                                          STRFLC
      MB(N+NEQ)=NJ                                                      STRFLC
  300 CONTINUE                                                          STRFLC
      RETURN                                                            STRFLC
      END                                                               STRFLC
      SUBROUTINE TRIA(NEQ,M,A1,MB)                                      STRFLC
C                                                                       STRFLC
      LARGE A1(1),MB(1)                                                 STRFLC
C                                                                       STRFLC
      NE=NEQ-1                                                          STRFLC
      MN=M-1                                                            STRFLC
      MM=MN*NEQ                                                         STRFLC
      MK=NEQ-MN                                                         STRFLC
      DO 300 N = 1, NE                                                  STRFLC
      NT=N-MK                                                           STRFLC
      IF(NT.GT.0) MM=MM-NEQ                                             STRFLC
      MB(N)=0                                                           STRFLC
      IF(A1(N).EQ.0.0) GO TO 300                                        STRFLC
      L=N                                                               STRFLC
      IL=N+NEQ                                                          STRFLC
      IH=N+MM                                                           STRFLC
      JB = 0                                                            STRFLC
      IB = 0                                                            STRFLC
```

```
      DO 200 I=IL,IH,NEQ                                                  STRFLC
      L=L+1                                                               STRFLC
      J=L                                                                 STRFLC
      IB=IB+1                                                             STRFLC
      C=A1(I)/A1(N)                                                       STRFLC
      IF (C.EQ.0.0) GO TO 200                                             STRFLC
      DO 180 K=I,IH,NEQ                                                   STRFLC
      A1(J)=A1(J)-C*A1(K)                                                 STRFLC
  180 J=J+NEQ                                                             STRFLC
      A1(I)=C                                                             STRFLC
      JB=IB                                                               STRFLC
  200 CONTINUE                                                            STRFLC
      MB(N)=JB                                                            STRFLC
  300 CONTINUE                                                            STRFLC
      MB(NEQ)=0                                                           STRFLC
      RETURN                                                              STRFLC
      END                                                                 STRFLC
      SUBROUTINE MLTPLY(A2,B,H1,QQ,MB,NEQ,NUMFNP)                         STRFLC.
C                                                                         STRFLC.
      LARGE A2(NUMFNP,1),MB(1),H1(1),QQ(1)                                STRFLC.
      DIMENSION B(1)                                                      STRFLC.
C                                                                         STRFLC.
      MM=NUMFNP-1                                                         STRFLC.
      DO 300 N1=1,NUMFNP                                                  STRFLC.
      BB=A2(N1)*H1(N1)                                                    STRFLC.
      L=N1                                                                STRFLC.
      IL=N1+NUMFNP                                                        STRFLC.
      IH=MB(N1)                                                           STRFLC.
      IF(IH)120,120,50                                                    STRFLC.
   50 DO 100 I=IL,IH,NUMFNP                                               STRFLC.
      L=L+1                                                               STRFLC.
      BB=BB+A2(I)*H1(L)                                                   STRFLC.
  100 CONTINUE                                                            STRFLC.
  120 L=N1                                                                STRFLC.
      IL=N1+MM                                                            STRFLC.
      IH=MB(N1+NUMFNP)                                                    STRFLC.
      IF (IH) 250,250,150                                                 STRFLC.
  150 DO 200 I=IL,IH,MM                                                   STRFLC.
      L=L-1                                                               STRFLC.
      BB=BB+A2(I)*H1(L)                                                   STRFLC.
  200 CONTINUE                                                            STRFLC.
  250 B(N1)=BB+B(N1)                                                      STRFLC.
      QQ(N1)=B(N1)                                                        STRFLC.
  300 CONTINUE                                                            STRFLC.
      RETURN                                                              STRFLC.
      END                                                                 STRFLC.
      SUBROUTINE BACKS(NN,MM,A1,B,MB)                                     STRFLC.
C                                                                         STRFLC.
      LARGE A1(1),B(1),MB(1)                                              STRFLC.
C                                                                         STRFLC.
      MMM=MM-1                                                            STRFLC.
      N=0                                                                 STRFLC.
  270 N=N+1                                                               STRFLC.
      C=B(N)                                                              STRFLC.
      IF(A1(N).NE.0.0) B(N)=B(N)/A1(N)                                    STRFLC.
      IF(N.EQ.NN) GO TO 300                                               STRFLC.
      IL=N+1                                                              STRFLC.
      IH=N+MB(N)                                                          STRFLC.
      M=N                                                                 STRFLC.
      DO 285 I=IL,IH                                                      STRFLC.
      M=M+MM                                                              STRFLC.
  285 B(I)=B(I)-A1(M)*C                                                   STRFLC.
```

```
      GO TO 270                                                         STRFLC
C                                                                       STRFLC
  300 IL=N                                                              STRFLC
      N=N-1                                                             STRFLC
      IF(N.EQ.0) RETURN                                                 STRFLC
      IH =N+MB(N)                                                       STRFLC
      M=N                                                               STRFLC
      C=B(N)                                                            STRFLC
      DO 400  I=IL,IH                                                   STRFLC
      M=M+NN                                                            STRFLC
  400 C=C-A1(M)*B(I)                                                    STRFLC
      B(N)=C                                                            STRFLC
      GO TO 300                                                         STRFLC
C                                                                       STRFLC
      END                                                               STRFLC
      SUBROUTINE STRFLO(B,BO,PO,TIME,IP,FLAG,NCC,JT)                    STRFLC
C                                                                       STRFLC
      LARGE A(125000),ID(900)                                           STRFLP
      LARGE IX(301,5),RESIO(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R.KN(50),R.KS(50),WT(50),IGUT(301),Q(300), LARGE.
     *QP(50),N(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),DBO(600)                            STRFLP
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LBAD,RAON,   BLANK.
     1                    RR(4),ZZ(4),IFAT(50),ACELX,ACELY,NRES,RO(12), BLANK.
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),       BLANK.
     3    PRS,PZS,PRT,PZT,EG                                            BLANK.
      COMMON/GEN/NSHELL,IPUNCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICOMPR, GEN.2
     1      NUMEL,NO2,HED(16),DISPL,NJELT,IPER,NUMMAT,FSF,PSFJ,KSCL,SFWT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,AP(4),CONLIM,NAXI,NB,MEAND,LNGTH,NEQ,KJMPGEN.4
     *      ,MBFLOW,NUMNP2,NUMFNP,LM(12),NFZ                            GEN.5
      COMMON/CCPOOL/XMIN,XMAX,YMIN,YMAX,CCXMIN,CCXMAX,CCYMIN,CCYMAX     CCPOCL.
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QU(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                         EM.3
      LARGE B(1),BO(1),PO(1)                                            STRFLC.
      DIMENSION SIG(7),TP(6),Q8(4)                                      STRFLC
      LOGICAL FLAG                                                      STRFLC
C                                                                       STRFLC
C     COMPUTE ELEMENT STRESSES                                          STRFLC.
                                                                        STRFLC.
    1 MPRINT=0                                                          STRFLC.
      REWIND 9                                                          STRFLC.
      QPODR=0.0                                                         STRFLC.
      MJ=  0                                                            STRFLC.
      PI=4.0*ATAN(1.0)                                                  STRFLC.
      RAON=180.0/PI                                                     STRFLC.
      RAD2=0.5*RAON                                                     STRFLC.
      PI2=2.0*ATAN(1.0)                                                 STRFLC.
      IF(INDEX.NE.0) PRINT 2001,TIME,MP,IPER                            STRFLC.
      IF (IPER .EQ. 1)  XMI =-1.0E15                                    STRFLC.
C                                                                       STRFLC.
      IF (INDEX .LT. 2)  GO TO 10                                       STRFLC.
      IF (XMIN .LT. XMI)  GO TO 7                                       STRFLC.
      XCON = (XMAX-XMIN) * 0.125 /(CCXMAX-CCXMIN)                       STRFLC.
      YCON = (YMAX-YMIN) * 0.125 / (CCYMAX-CCYMIN)                      STRFLC.
      XPC = 0.05                                                        STRFLC.
      YPC = 0.05                                                        STRFLC.
      XMI = XMIN                                                        STRFLC.
      XMA = XMAX                                                        STRFLC.
      YMI = YMIN                                                        STRFLC.
      YMA = YMAX                                                        STRFLC.
      DEL = XPC   * (XMAX - XMIN)                                       STRFLC.
```

```
      XMIN = XMIN - DEL                                                 STRFLC
      XMAX = XMAX + DEL                                                 STRFLC
      DEL = YPC   * (YMAX - YMIN)                                       STRFLC
      YMIN = YMIN - DEL                                                 STRFLC
      YMAX = YMAX + DEL                                                 STRFLC
      DEL = XPC   * (CCXMAX - CCXMIN)                                   STRFLC
      CCXMIN = CCXMIN - DEL                                             STRFLC
      CCXMAX = CCXMAX + DEL                                             STRFLC
      DEL = YPC   * (CCYMAX - CCYMIN)                                   STRFLC
      CCYMIN = CCYMIN - DEL                                             STRFLC
      CCYMAX = CCYMAX + DEL                                             STRFLC
                                                                        STRFLC
    7 WRITE (98, 5) HED, MP, IPER                                       STRFLC
    5 FORMAT (8A9/8A9/17H ITERATION NUMBERI4,20H PERTURBATION NUMBERI4) STRFLC
      CALL CCLTS (-1.5, 0.5, 1, 2)                                      STRFLC
      CALL CCLBL (1,1)                                                  STRFLC
      CALL CCPLOT( XMI,  YMI,  1, 6HNOJOIN, 8, 1)                       STRFLC
      CALL CCPLOT (XMIN, YMIN, 1, 6HNOJOIN, 1, 1)                       STRFLC
      CALL CCPLOT (XMA,  YMI,  1, 6HNOJOIN, 8, 1)                       STRFLC
      CALL CCPLOT (XMAX, YMIN, 1, 6HNOJOIN, 1, 1)                       STRFLC
      CALL CCPLOT (XMI,  YMA,  1, 6HNOJOIN, 9, 1)                       STRFLC
      CALL CCPLOT (XMIN, YMAX, 1, 6HNOJOIN, 1, 1)                       STRFLC
      CALL CCPLOT (XMA,  YMA,  1, 6HNOJOIN, 9, 1)                       STRFLC
      CALL CCPLOT (XMAX, YMAX, 1, 6HNOJOIN, 1, 1)                       STRFLC
C                                                                       STRFLC
   10 DO 300 N=1,NUMEL                                                  STRFLC
                                                                        STRFLC
      IF (INDEX .EQ. 0)  GO TO 15                                       STRFLC
      MPRINT = MPRINT - 1                                               STRFLC
      IF (MPRINT .GT. 0)  GO TO 15                                      STRFLC
      MPRINT = 50                                                       STRFLC
C                                                                       STRFLC
   15 IX(N,5)=IABS(IX(N,5))                                             STRFLC
      MTYPE = IX(N,5)                                                   STRFLC
C                                                                       STRFLC.
      IF(INDEX.NE.2) GO TO 110                                          STRFLC
      DO 16 I=1,4                                                       STRFLC
      J=IX(N,I)                                                         STRFLC
      K1=IDEQ(1,J)                                                      STRFLC.
      K2=IDEQ(2,J)                                                      STRFLC
      XTR(I)=R(J)+B(K1)*DISPL                                           STRFLC
      II=I+5                                                            STRFLC
   16 XTR(II)=Z(J)+B(K2)*DISPL                                          STRFLC.
      XTR(5)=XTR(1)                                                     STRFLC.
      XTR(10)=XTR(6)                                                    STRFLC.
                                                                        STRFLC
      COR = 3                                                           STRFLC.
      XCEN = XTR(1) + XTR(2) + XTR(3)                                   STRFLC.
      YCEN = XTR(8) + XTR(6) + XTR(7)                                   STRFLC.
      IF (N3 .EQ. N4)  GO TO 20                                         STRFLC.
      COR = 4                                                           STRFLC.
      XCEN = XCEN + XTR(4)                                              STRFLC.
      YCEN = YCEN + XTR(9)                                              STRFLC.
   20 XCEN = XCEN / COR                                                 STRFLC.
      YCEN = YCEN / COR                                                 STRFLC.
      IF (MTYPE .GT. NSHELL)  GO TO 290                                 STRFLC.
                                                                        STRFLC.
C     PLOT GRID INCLUDING DISPLACEMENTS                                 STRFLC.
      CALL CCPLOT (XTR(1), XTR(6), 5, 4HJOIN)                           STRFLC.
                                                                        STRFLC.
      KOR = COR                                                         STRFLC.
      DO 50  NC = 1,KOR                                                 STRFLC.
```

```
      N1=IX(N,NC)                                                       STRFLC
      NI=IDEQ(1,N1)                                                     STRFLC
      IF (B(NI) .EQ. 0.0)  GO TO 30                                     STRFLC
      XC = XCON                                                         STRFLC
      IF (XTR(NC) .GT. XCEN)  XC = -XCON                                STRFLC
      YC = YCON                                                         STRFLC
      IF (XTR(NC+5) .GT. YCEN)  YC = -YCON                              STRFLC
      XC = XTR(NC) + XC                                                 STRFLC
      YC = XTR(NC+5) + YC                                               STRFLC
      NS=8                                                              STRFLC
      IF(B(NI).GT.0.0) NS=0                                             STRFLC
      CALL CCPLOT(XC, YC, 1, 6HNOJCIN, NS, 1)                           STRFLC
   30 CONTINUE                                                          STRFLC
                                                                        STRFLC
C                                                                       STRFLC
  118 IF(MTYPE.GT.NSHELL) GO TO 290                                     STRFLC
      READ (9) ST,SQ,NP                                                 STRFLC
      DO 31 I=1,4                                                       STRFLC
      SIG(I)=RESID(N,I)                                                 STRFLC
   31 QU(I)=0.0                                                         STRFLC
      POAVE=0.0                                                         STRFLC
      PAVE=0.0                                                          STRFLC
      DO 50 I=1,4                                                       STRFLC
      NI=NP(I)                                                          STRFLC
      L=IDEQ(1,NI)-1                                                    STRFLC
      M=2*I-1                                                           STRFLC
      MM=M+1                                                            STRFLC
      DO 40 K=M,MM                                                      STRFLC.
      L=L+1                                                             STRFLC.
      DO 40 J=1,4                                                       STRFLC.
   40 SIG(J)=SIG(J)+ST(J,K)*B(L)                                        STRFLC.
      L=IDEQ(3,NI)                                                      STRFLC.
      POAVE=POAVE+TEMP(NI)/4.0                                          STRFLC
      PAVE=PAVE+B(L)/4.0                                                STRFLC.
      DO 45 K=1,2                                                       STRFLC.
   45 QU(K)=QU(K)+SQ(K,I)*B(L)                                          STRFLC.
   50 CONTINUE                                                          STRFLC
      PDIFF=E(4,MTYPE)*(PAVE-POAVE)                                     STRFLC
      DO 55 I=1,3                                                       STRFLC.
   55 SIG(I)=SIG(I)+PDIFF                                               STRFLC.
      GEFF=SPWT*E(1,MTYPE)/VISC                                         STRFLC.
      QU(1)=-QU(1)                                                      STRFLC.
      QU(2)=-(QU(2)+GEFF)                                               STRFLC.
      CC=(SIG(1)+SIG(2))/2.0                                            STRFLC.
      BB=(SIG(1)-SIG(2))/2.0                                            STRFLC.
      CR=SQRT(BB**2+SIG(4)**2)                                          STRFLC.
      SIG(5)=CC+CR                                                      STRFLC.
      SIG(6)=CC-CR                                                      STRFLC.
      IF (SIG(4).GT.10E-15.OR.BB.GT.10E-15) GO TO 80                    STRFLC.
      EPS=0.78539816                                                    STRFLC.
      SIG(7)=100.0                                                      STRFLC.
      GO TO 90                                                          STRFLC.
   80 SIG(7)=RAD2*ATAN2(SIG(4),BB)                                      STRFLC.
      EPS=ATAN2(SIG(4),BB)/2.0                                          STRFLC.
   90 AA=ABS(QU(1))                                                     STRFLC.
      IF (AA.GT.10E-30) GO TO 100                                       STRFLC.
      ANG=P12                                                           STRFLC.
      GO TO 200                                                         STRFLC.
  100 BB=ABS(QU(2)/QU(1))                                               STRFLC.
      ANG=SQRT(BB)                                                      STRFLC.
      ANG=ATAN(ANG)                                                     STRFLC.
  200 QU(3)=QU(1)*(COS(ANG)**2)+QU(2)*(SIN(ANG)**2)                     STRFLC.
```

```
      QU(4)=ANG*RADN                                                    STRFLC
      IF(INDEX.EQ.8) GO TO 271                                          STRFLC
      PRINT 270,N,(SIG(I),I=1,7),(QU(J),J=1,4)                          STRFLC
  270 FORMAT(I8,12E10.2)                                                STRFLC
 2001 FORMAT(1H1/*            STRESSES AND FLOWS AT TIME       *,F10.3//*  STRFLC
     1ITERATION NUMBER    *,I4,*      PERTURBATICN NUMBER  *,I4,//      STRFLC
     2* ELEMENT*,4X,*SIGR*,6X,*SIGZ*,5X,*SIGT*,6X,*SIGRZ*,5X,*SIGMAX*,  STRFLC
     35X,*SIGMIN*,4X,*ANGLE*,5X,*FLWR *,6X,*FLWZ *,5X,*FLWMAX*,4X,*ANGLESTRFLC
     4*/*IF JOINT*,4X,*SIGN*,6X,*SIGS*,5X,*NDISP*,6X,*TDISP*,5X,*NSTIF*,STRFLC
     55X,*TSTIF*,4X,*STRNGTH*,5X,*WIDTH*,5X,*FRFLO*,3X,*   RE*)         STRFLC
C                                                                       STRFLC
  271 CONTINUE                                                          STRFLC
C     PLOT STRESSES                                                     STRFLC.
      IF (INDEX .LT. 2)  GO TO 220                                      STRFLC.
      CC = COS(EPS)                                                     STRFLC.
      SS = SIN(EPS)                                                     STRFLC.
      XL = SIG(5) * CC * PSF                                            STRFLC.
      XTR(1) = XCEN - XL                                                STRFLC.
      XTR(2) = XCEN + XL                                                STRFLC.
      XL = SIG(5) * SS * PSF                                            STRFLC.
      XTR(5) = YCEN - XL                                                STRFLC.
      XTR(6) = YCEN + XL                                                STRFLC.
      CALL CCPLCT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
                                                                        STRFLC.
      IF(SIG(5).GE.0.0) GO TO 210                                       STRFLC.
      XTR(1) = XTR(1) - 0.02 * SS                                       STRFLC.
      XTR(2) = XTR(2)  - 0.02 * SS                                      STRFLC.
      XTR(5) = XTR(5) + 0.02 * CC                                       STRFLC.
      XTR(6) = XTR(6) + 0.02 * CC                                       STRFLC.
      CALL CCPLCT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
                                                                        STRFLC.
  210 XL = SIG(6) * SS * PSF                                            STRFLC.
      XTR(1) = XCEN + XL                                                STRFLC.
      XTR(2) = XCEN - XL                                                STRFLC.
      XL = SIG(6) * CC * PSF                                            STRFLC.
      XTR(5) = YCEN - XL                                                STRFLC.
      XTR(6) = YCEN + XL                                                STRFLC.
      CALL CCPLOT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
      IF(SIG(6).GE.0.0) GO TO 220                                       STRFLC.
      XTR(1) = XTR(1) - 0.02 * SS                                       STRFLC.
      XTR(2) = XTR(2) - 0.02 * SS                                       STRFLC.
      XTR(5) = XTR(5) - 0.02 * CC                                       STRFLC.
      XTR(6) = XTR(6) - 0.02 * CC                                       STRFLC.
      CALL CCPLCT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
C                                                                       STRFLC.
  220 GO TO 300                                                         STRFLC.
                                                                        STRFLC.
  290 CALL JTSTR(B,BO,PO,M,,N,FLAG,IP)                                  STRFLC.
  300 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
      IF(FLAG.OR.NNN.EQ.IP) GO TO 302                                   STRFLC.
      PRINT 304, IPER                                                   STRFLC.
  304 FORMAT (52H0PROBLEM CONVERGED IN THIS ITERATION AT PERTURBATIONI4)STRFLC.
                                                                        STRFLC.
  302 IF (INDEX .NE. 2)  GO TC 330                                      STRFLC.
      WRITE (98,305) XSCL, YSCL, DSCL, PSCL, PJCL                       STRFLC.
  305 FORMAT (15H 1 IN CN X-AXIS/4H    =E12.4,3H FT/15H 1 IN ON Y-AXIS/  STRFLC.
     14H    =E12.4,3H FT/18H 1 IN DISPLACEMENT/4H    =E12.4,3H FT/5H 1 IN/STRFLC.
     24H    =E12.4,11H PSF STRESS/5H 1 IN/4H    =E12.4,14H PSF JT STRESS) STRFLC.
                                                                        STRFLC.
      DO 320  I=1,NUMMAT                                                STRFLC.
      IF(I.GT.NSHELL) WRITE(98,315) I,(E(J,I),J=1,5)                    STRFLC.
```

```
      IF(I.LE.NSHELL) WRITE(98,308) I,RO(I),(E(K,I),K=1,6)              STRFLC
  308 FORMAT(/9H MATERIALI3/20H  MASS DENSITY      =F8.3/16H  PERMEABILITSTRFLC
     .Y =E14.3/21H ELASTIC MODULUS    =E14.3/21H  POISSON RATIO     =F9.STRFLC
     .3/23HBIOTS CONSTANT ALPHA  =F10.3/19HBIOTS CONSTANT M  =E14.3/22H STRFLC
     .THERMAL EXPAN.COEF. =E14.3)                                       STRFLC
                                                                        STRFLC
  315 FORMAT(/9H MATERIALI3/20H  KN                 =E12.3/20H  KS      STRFLC
     1         =E12.3/20H  C                  =E12.3/20H  PHI          =STRFLC
     2E12.3/20H  MAX CLOSURE        =E12.3)                             STRFLC
  320 CONTINUE                                                          STRFLC
                                                                        STRFLC
      XP = CCXMAX + 0.5                                                 STRFLC
      CALL CCLTR (XP, 10.5, 0, 2)                                       STRFLC
      CALL CCNEXT                                                       STRFLC
  330 RETURN                                                            STRFLC
C                                                                       STRFLC
      END                                                               STRFLC
      SUBROUTINE JTSTR(B,BO,PO,M,N,FLAG,IP)                             STRFLC
C                                                                       STRFLC.
      LARGE A(125000),ID(900)                                           STRFLC
      LARGE IX(301,5),RESID(301,4),R(300),Z(300),UR(300),UZ(300)        LARGE.
     * ,CODE(300),IDEST(300),R,KN(50),R,KS(50),MT(50),IOUT(301),Q(300), LARGE.
     *QP(50),H(50),VEL(50),FR(50),RE(50),QN(900),DISPI(300,2),TEMP(300),LARGE.
     * PHIO(300),IB(300),IDEQ(3,300),KODE(3,300),IEL(50,2),INP(50,4)    LARGE.
     *,TLOAD(900),SIGN(50),SIGT(50),D50(600)                            STRFLF.
      COMMON/BLANK/S(8,8),P(10),RSTRS(4),VOL,RRR(5),ZZZ(5),LBAD,RADN,   BLANK.
     1                   RR(4),ZZ(4),IPAT(50),ACELX,ACELY,NRES,RC(12),  BLANK.
     2      MTYPE,XI,XCEN,YCEN,XTR(10),FAC,H(6),PD(4,12),QQ(2,4),       BLANK.
     3    PRS,FZS,PRT,FZT,EG                                            BLANK.
      COMMON/GEN/NSHELL,IPURCH,E(7,12),INDEX,MP,NNN,NCORE,NUMNP,ICOMPR, GEN.2
     1      NUMEL,ND2,MED(16),DISPL,NJELT,IPER,NUMMAT,FSF,PSFJ,XSCL,SPHT,GEN.3
     3VISC,YSCL,DSCL,FSCL,PJCL,NP(4),CONLIM,NAXI,NB,MBAND,LNGTH,NEQ,NJMPGEN.4
     *      ,MBFLOW,NUMNF2,NUMFAP,LM(12),NF2                            GEN.5
      COMMON/CCPOOL/XMIN,XMAX,YMIN,YMAX,CCXMIN,CCXMAX,CCYMIN,CCYMAX     CCPOOL
      COMMON/EM/ST(4,8),SQ(2,4),AJ(8,2),DD(2,2),QU(4),HR(6),HZ(6)       EM.2
     * ,EJ(2,2)                                                         EM.3
      COMMON/CCFACT/FACTOR                                              CCFACT.
C                                                                       STRFLC
      LARGE B(1),BO(1),PO(1)                                            STRFLC.
      DIMENSION PPP(8),V(4),U(4)                                        STRFLC.
      LOGICAL FLAG                                                      STRFLC.
      REAL L                                                            STRFLC.
                                                                        STRFLC.
C  *******ESTABLISH DISPLACEMENTS ALONG AND NORMAL TO JOINT              STRFLC.
C                                                                       STRFLC.
      M = M + 1                                                         STRFLC.
      CAYN = KN(M)                                                      STRFLC.
      CAYS = KS(M)                                                      STRFLC.
      EM1 = E(1,MTYPE)                                                  STRFLC.
      EM2 = E(2,MTYPE)                                                  STRFLC.
      EM3 = E(3,MTYPE)                                                  STRFLC.
      EM4 = E(4,MTYPE)                                                  STRFLC.
      FT=0.0                                                            STRFLC.
      STREN=0.0                                                         STRFLC.
      POAVE=0.0                                                         STRFLC.
                                                                        STRFLC.
      I=IX(N,1)                                                         STRFLC.
      J= IX(N,2)                                                        STRFLC.
      DR=R(J)-R(I)                                                      STRFLC.
      DZ=Z(J)-Z(I)                                                      STRFLC.
      RR1 = 0.5 * (R(J) + R(I))                                         STRFLC.
      ZZ1 = 0.5 * (Z(J) + Z(I))                                         STRFLC.
```

```
      L=SQRT(DR*DR+DZ*DZ)                                               STRFLC
      DR=DR/L                                                           STRFLC
      DZ=DZ/L                                                           STRFLC
      DO 100 II=1,4                                                     STRFLC
      K=IX(N,II)                                                        STRFLC
      K1=IDEQ(1,K)                                                      STRFLC
      K2=IDEQ(2,K)                                                      STRFLC
      POAVE=POAVE+TEMP(K)/4.0                                           STRFLC
      V(II)=-B(K1)*DZ+B(K2)*DR                                          STRFLC
  100 U(II)=B(K1)*DR+B(K2)*DZ                                           STRFLC
C                                                                       STRFLC
C *********  COMPUTE EFFECTIVE STRAIN                                   STRFLC
C EPSN POSITIVE MEANS JOINT IS OPEN                                     STRFLC
C EPST POSITIVE MEANS (KK,LL) MOVES ALONG U+ MORE THAN (II,JJ)          STRFLC
C                                                                       STRFLC
      EPST=0.5*(U(4)-U(1)+U(3)-U(2))                                    STRFLC
      EPST=-EPST                                                        STRFLC
      IF(ABS(EPST) .LE. 1.0E-15) EPST = 0.0                             STRFLC
      EPSN=0.5*(V(4)-V(1)+V(3)-V(2))                                    STRFLC
      IF(ABS(EPSN) .LE. 1.0E-15) EPSN = 0.0                             STRFLC
C                                                                       STRFLC
C  COMPUTE NORMAL AND SHEAR FORCE PER UNIT LENGTH AND CALCULATE STRENGTHSTRFLC
C INITIAL STRESSES ARE ALWAYS COMPRESSIVE(NEGATIVE)                     STRFLC
C                                                                       STRFLC
      C2=DR**2                                                          STRFLC
      S2=DZ**2                                                          STRFLC
      SC=DR*DZ                                                          STRFLC
      FNRES = RESID(N,1)*S2 + RESID(N,2)*C2 + RESID(N,4)*2.*SC          STRFLC
      FNRES=FNRES+POAVE                                                 STRFLC
      FTRES = (RESID(N,2)-RESID(N,1))*SC + RESID(N,4)*(S2-C2)           STRFLC
      ETHICK = WT(M)                                                    STRFLC
      FN = CAYN * EPSN + FNRES                                          STRFLC
                                                                        STRFLC
      IF (INDEX .NE. 2)  GO TO 200                                      STRFLC.
      IF (ABS(XTR(7)-XTR(6)) .LE. 0.01 * (YMAX - YMIN))                 STRFLC
     1              XCEN = 0.4*XTR(1) + 0.6*XTR(2)                      STRFLC
      IF (ABS(XTR(2)-XTR(1)) .LE. 0.01*(XMAX-XMIN))                     STRFLC
     1              YCEN = 0.4*XTR(6) + 0.6*XTR(7)                      STRFLC.
      XL = FN * DZ * PSFJ                                               STRFLC.
      XTR(1) = XCEN - XL                                                STRFLC.
      XTR(2) = XCEN + XL                                                STRFLC
      XL = FN * DR * PSFJ                                               STRFLC.
      XTR(5) = YCEN + XL                                                STRFLC.
      XTR(6) = YCEN - XL                                                STRFLC.
      CALL CCPLOT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
      IF(FN.GE.0.0) GO TO 200                                           STRFLC.
      XTR(1) = XTR(1) - 0.02 * DR                                       STRFLC.
      XTR(2) = XTR(2) - 0.02 * DR                                       STRFLC.
      XTR(5) = XTR(5) + 0.02 * DZ                                       STRFLC.
      XTR(6) = XTR(6) + 0.02 * DZ                                       STRFLC.
      CALL CCPLOT (XTR(1), XTR(5), 2, 4HJOIN)                           STRFLC.
  200 CONTINUE                                                          STRFLC.
C                                                                       STRFLC.
      IF(FNRES.GT.0.) GO TO 220                                         STRFLC.
                                                                        STRFLC.
C      FNRES .LE. 0                                                     STRFLC.
      IF (ETHICK .EQ. 0.) GO TO 215                                     STRFLC.
      IF (EPSN .LE. 0.0)  GO TO 205                                     STRFLC.
                                                                        STRFLC.
C     ETHICK .NE. 0 AND EPSN .GT. 0                                     STRFLC.
      CAYN = -FNRES / EPSN                                              STRFLC.
      IF (CAYN .EQ. 0.0)  CAYN = 1.0E-8                                 STRFLC.
```

```
      IF (CAYN .GT. EM1)  CAYN = EM1                                      STRFLC
      GO TO 230                                                           STRFLC
                                                                          STRFLC
C     FNRES .LE. 0 AND WT .NE. 0 AND EPSN .LE. 0                          STRFLC
  205 CAYN = (FN - FNRES) / ETHICK                                        STRFLC
      IF (CAYN .LT. EM1)  CAYN = EM1                                      STRFLC
      GO TO 230                                                           STRFLC
                                                                          STRFLC
C     ETHICK = 0, FNRES .LE. 0  .OR.  FNRES .GT. 0 AND EPSN .LT. 0        STRFLC
  215 CAYN = CAYN * 1.0E10                                                STRFLC
      CAYS = CAYS * 1.0E10                                                STRFLC
      GO TO 260                                                           STRFLC
                                                                          STRFLC
C      FNRES .GT. 0                                                       STRFLC
  220 IF (EPSN .LT. 0.0 .AND. ETHICK .EQ. 0.0)  GO TO 215                 STRFLC
      IF (EPSN .EQ. 0.0)  GO TO 230                                       STRFLC
      CAYN = -FNRES / EPSN                                                STRFLC
      IF (EPSN .LT. 0.0)  CAYN = CAYN + EM1                               STRFLC
                                                                          STRFLC
C     CALCULATION OF  KS                                                  STRFLC
  230 FT = CAYS * EPST + FTRES                                            STRFLC
      AFN = ABS(FN)                                                       STRFLC
      EPSNLM = ABS(FNRES) / EM1                                           STRFLC
      IF (EPSN .GT. EPSNLM .OR. FN .GT. 0.0)  AFN = 0.0                   STRFLC
      STREN = EM3 + AFN * TAN (EM4/57.29577951)                           STRFLC
                                                                          STRFLC
      IF (EPST .EQ. 0.0 ) GO TO 260                                       STRFLC
      IF (EM3 .EQ. 0.0 .AND. EM4 .EQ. 0.0)  GO TO 260                     STRFLC
      IF (EPST .LT. 0.0)  STREN = - STREN                                 STRFLC
      CAYS = (-FTRES + STREN) / EPST                                      STRFLC.
      IF (CAYS .EQ. 0.0)  CAYS = 9.0E-9                                   STRFLC
                                                                          STRFLC
      IF(CAYS.GT.EM2) CAYS=EM2                                            STRFLC
C     ABS(FTRES) .LE. ABS(STREN)                                          STRFLC
      IF (ABS(FTRES) .GT. ABS(STREN))  GO TO 235                          STRFLC
      GO TO 260                                                           STRFLC
                                                                          STRFLC
C     ABS(FTRES) .GT. ABS(STREN)                                          STRFLC
  235 IF (FTRES * EPST .GE. 0.0)  GO TO 260                               STRFLC
                                                                          STRFLC
C     FTRES AND EPST HAVE OPPOSITE SIGNS                                  STRFLC
      EPSLIM = 2.0 * STREN / EM2                                          STRFLC.
      IF (ABS(EPST) .GT. EPSLIM)  GO TO 260                               STRFLC.
                                                                          STRFLC
C     ABS(EPST) .LE. EPSLIM                                               STRFLC
      CAYS = (-FTRES - STREN) / EPST + EM2                                STRFLC
                                                                          STRFLC
  260 IF (ABS(CAYN-KN(M)) .GT. CONLIM .OR. ABS(CAYS-KS(M)) .GT. CONLIM) STRFLC
     1      FLAG = .TRUE.                                                 STRFLC.
      KN(M)=CAYN                                                          STRFLC.
      KS(M) = CAYS                                                        STRFLC.
C                                                                         STRFLC.
C   **********  CALCULATE FLOW IN FRACTURES  **********                   STRFLC.
C                                                                         STRFLC.
      IF(INDEX.EQ.0) GO TO 500                                            STRFLC.
  115 W0=WT(M)                                                            STRFLC.
      IF(EPSN.GE.W0) GO TO 150                                            STRFLC.
      PRINT 140,M                                                         STRFLC.
  140 FORMAT(*DISPLACEMENT GREATER THAN ALLOWED IN JOINT ELEMENT NO.*I5)STRFLC.
                                                                          STRFLC.
  150 W(M)=ABS(ABS(W0)+EPSN)                                              STRFLC.
      COM=1.0/(12.0*VISC)                                                 STRFLC.
```

```
      QP(M)=W(M)**2*COM/L                                              STRFLC
      RAD=1.0                                                          STRFLC
      I=IX(N,1)                                                        STRFLC
      J=IX(N,2)                                                        STRFLC
      II=IDEST(I)                                                      STRFLC
      JJ=IDEST(J)                                                      STRFLC
      IF(NAXI.NE.0) RAD=(R(I)+R(J))/2.0                                STRFLC
      I3=IDEQ(3,I)                                                     STRFLC
      J3=IDEQ(3,J)                                                     STRFLC
      VEL(M)=QP(M)*(B(J3)-B(I3))                                       STRFLC
      IF( DZ.NE.0.0 ) VEL(M)=VEL(M)+SFWT*QP(M)*L*DZ                    STRFLP
      FR(M)=VEL(M)*W(M)*RAD                                            STRFLC
      RE(M)=FR(M)/VISC                                                 STRFLC
      PRINT 270,N,FN,FT,EPSN,EPST,CAYN,CAYS,STREN,W(M),FR(M),RE(M)     STRFLC
  270 FORMAT(* JT *,I4,12E10.2)                                        STRFLC
  500 RETURN                                                           STRFLC
      END                                                              STRFLC
      SUBROUTINE PRINT(NUMNP,IDEQ,NAXI,R,RD,TDT,A,TEMP)                STRFLC.
      LARGE IDEQ(3,1),R(1),A(1),TEMP(1)                                STRFLC.
                                                                       STRFLC.
      TD=0.0                                                           STRFLC.
      PDD=0.0                                                          STRFLC
      DO 100 I=1,NUMNP                                                 STRFLC.
      K1=IDEQ(1,I)                                                     STRFLC.
      K2=IDEQ(2,I)                                                     STRFLC.
      K3=IDEQ(3,I)                                                     STRFLC.
      IF(TDT.EQ.1.0.AND.RD.EQ.1.0) GO TO 100                           STRFLC.
      IF( R(I).EQ.0.0 ) GO TO 50                                       STRFLC.
      TD=TDT/(R(I)*R(I))                                               STRFLC.
   50 CONTINUE                                                         STRFLC.
      PDD=RD*(TEMP(I)-A(K3))                                           STRFLC
  100 PRINT 200,I,A(K1),A(K2),A(K3),TD,PDD                             STRFLC.
  200 FORMAT(I10,6E18.5)                                               STRFLC.
      RETURN                                                           STRFLC.
      END                                                              STRFLC.
      SUBROUTINE PRMAT(A,NR,NC,MAX,TITLE)                              STRFLC.
C                                                                      STRFLC.
      DIMENSION A(8,1)                                                 STRFLC.
C                                                                      STRFLC.
      PRINT 1002,TITLE                                                 STRFLC.
      DO 100 J=1,NC,8                                                  STRFLC.
      JH=J+7                                                           STRFLC.
      IF (JH-NC) 75,75,50                                              STRFLC.
   50 JH=NC                                                            STRFLC.
   75 PRINT 1000,(N,N=J,JH)                                            STRFLC.
      DO 100 I=1,NR                                                    STRFLC.
  100 PRINT 1001,I,(A(I,K),K=J,JH)                                     STRFLC.
C                                                                      STRFLC.
      RETURN                                                           STRFLC.
C                                                                      STRFLC.
 1000 FORMAT (///8X,8I14)                                              STRFLC.
 1001 FORMAT (I4,4X,8E14.7)                                            STRFLC.
 1002 FORMAT (/////8H MATRIX ,A10)                                     STRFLC.
      END                                                              STRFLC.
```