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DNYCOR: An Uncertainty Dynamic Modal Analysis Program

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DYNCOR: An uncertainty dynamic modal analysis program

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Abstract

DYNCOR is a computer program which is designed to perform uncertainty dynamic modal anaysis of linear elastic two-dimensional structures undergoing small displacement response. DYNCOR uses finite element techniques with triangular plane strain or stress element. The Duhamel's integral is evaluated using Newmark's procedure. The uncertainty is introduced through the physical parameters of the system and is measured using a perturbation technique.

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1. Introduction

This program handles the dynamic uncertainty analysis of linear elastic two-dimensional structures undergoing small displacement response. the medium is assumed to be a correlative field statically homogeneous and isotropic [1]. Thus the uncertainty is introduced through the following physical parameter: the modulus of Elasticity, the Poisson's ratio and the Density. Thir first and second statistical moment are assumed to be known and provide the basis of the proposed uncertainty Finite Element modal analysis, with which the equations of dynamic undamped equilibrium are solved.

In section 2 the algorithm is described. It leads to the evaluation of the first and second statistical moment of the natural frequencies, the displacements field and the stress field.

A comparison of the expected natural frequencies obtained by DYNCOR, with other programs is given in [2].

2. Method Used

A two-dimensional Ritz-Galerkin procedure with linear triangular elements is used for the discretization of the cross section of interest.

The geometric boundaries are considered as known with certainty. The input motion is prescribed at the boundary nodes either as uniform acceleration in all base nodes or as a travelling acceleration with a given velocity.

To pursue an uncertainty dynamic analysis the following components of the algoritm are needed.

i. Evaluation of the quasistatic displacement vector

ii. Evaluation of the natural frequencies and their coefficient of variation performing a modal analysis coupled with a perturbation scheme as defined by Bolotin [3]. The equations are given in Appendix 1.

iii. Evaluation of the dynamic displacement vector according to Newmark's scheme, as well as its coefficient of variation.

iv. Evaluation of the stress vector and its coefficient of variation.

3. Required Input Data

Following is a description of the required format for the input data and explanations of some of the input parameters. Also an example problem is shown in figure 1. It concerns the dynamic uncertainty analysis of a [500 x 500] m square domain subjected to an input earthquake perturbation at its boundary y = 0. The boundaries y = 500, x = 0, and x = 500 are consiered free.

The acceleration signal of the earthquake has a maximum acceleration of 0.5 g (g = gravity) and the increment of time is 0.01 sec. The signal is travelling at a velocity of 200 m/sec.

The physical parameters describing the geologic medium, namely the modulus of Elasticity, the Poison's ratio, and the Density are given at each node of the 6 x 6 mesh of the discretized region Ω. Figure 2 illustrates the displacements computed by the program at two different time intervals. The definition of the different variables is given at the beginning of the listing. The data cards are the following:

1st card

Read title of the problem (12A6)

2nd card

Read codes as specified in listing (12I5)

3rd card

Read different options as specified in listing (12I5)

4th card

Read number of elements, nodes, boundary nodes, and number of vibrational modes (12I5)

READ INPUT DATA OF FINITE ELEMENT MESH

5th card

Read the nodes constituting an element (4I4)

6th card

Read the expected value and variance of the Modulus of Elasticity (2F10.0)

7th card

Read the expected value and variance of Poisson's ratio (2F10.0)

8th card

Read the expected value and variance of the Density (2F10.0)

9th card

Read the coordinates of each node (I4, 2F10.3)

10th card

Read Boundary nodes (2I5)

READ INPUT DATA OF DYNAMIC ANALYSIS

11th card

Read number of given accelerations, number of time steps, the increment of time steps in which displcements are not printed, the time limit for the computation of a run, the time interval, and the mean velocity of the traveling perturbation (3I5, 3F10.0)

12th card

Read the given acceleration signal (8F9.6)

13th card

Read the damping value for each mode of vibraticn (2F10.0)

The eigenvalues and eigenvectors are computed using subroutine RSBEIG which combines BANDR, TQLRAT, and TQL2 obtained from Argonne National Laboratory as part of the EISPACK subroutine package.

References

[1] Dendrou, B.A. and Houstis, E.N., "An Inference-finite Element Model for Field Problems," Appl. Math. Modelling, 1978, Vol. 1, June.

[2] Dendrou, B.A. and Houstis, E.N., "Uncertainty Finite Element Dynamic Analysis," Appl. Math. Modelling. (Submitted 1978.)

[3] Bolotin, V.V., "Statistical Methods in Structural Mechanics," Holden-Day, Inc., 1969.

APPENDIX 1

The displacement field is decomposed into:

$$\underline{d}(t) = \underline{d}^{B} + \underline{d}^{IN}(t)$$

Then the Syst. Equation of the undamped motion is

$$\underset{\sim}{m}\, \ddot{\underline{d}}^{IN} + \underset{\sim}{k}\underline{d}^{IN} = - \underset{\sim}{m}\, \ddot{\underline{d}}^{B}$$

To uncouple the system of the differential equations, we assume the following transformation to exist.

$$\underline{d}^{IN} = \underset{\sim}{A}\, \underline{q}$$

where $\underset{\sim}{A}$ matrix of eigenvector

We say that we transform the physical coordinates to natural coordinates.

The equation of motion becomes

$$\underset{\sim}{M}\, \ddot{\underline{q}} + \underset{\sim}{K}\, \underline{q} = 0$$

where M, K are DIAGONAL MATRICES $\underset{\sim}{K} = \underset{\sim}{A}^{T}\underset{\sim}{k}\underset{\sim}{A}$

$$\underset{\sim}{M} = \underset{\sim}{A}^{T}\underset{\sim}{m}\underset{\sim}{A}$$

The variability introduced through

$$\underset{\sim}{K} = \underset{\sim}{\bar{K}} + \sum_{i=1}^{n} \beta_i\, \underset{\sim}{D}_i\, \underset{\sim}{\bar{K}}\ ;\ i = 1, \ldots n$$

$$\underset{\sim}{M} = \overline{\underset{\sim}{M}} + \sum_{i=1}^{n} \alpha_i \, \underset{\sim}{D}_i \, \overline{\underset{\sim}{M}} \; ; \; i = 1, \ldots n$$

where α : are the Coefficient of mass variability
for each vibration mode

Then

$$VAR^2(\underset{\sim}{M}) = \sum_{i=1}^{n} VAR^2(\alpha_i) \cdot \overline{\underset{\sim}{M}}^2 = n[VAR^2(\alpha) \cdot \overline{\underset{\sim}{M}}^2]$$

$$VAR^2(\underset{\sim}{K}) = n[VAR^2(\beta) \cdot \overline{\underset{\sim}{K}}^2]$$

Therefore

$$VAR^2(\alpha) = \frac{1}{n} \frac{VAR^2(\underset{\sim}{M})}{\underset{\sim}{M}^2} = \frac{1}{n\underset{\sim}{M}^2}\left[VAR^2(\gamma) \cdot V^2 + VAR^2(v)(\gamma)^2\right]$$

$$VAR^2(\beta) = \frac{1}{n} \frac{VAR^2(\underset{\sim}{K})}{\underset{\sim}{K}^2} = \frac{1}{n\overline{\underset{\sim}{K}}_1^2}\left[VAR^2(E)\left(\frac{\partial \overline{\underset{\sim}{K}}}{\partial E}\right)^2 + VAR^2(\nu) \cdot \left(\frac{\partial \overline{\underset{\sim}{K}}}{\partial \nu}\right)^2\right]$$

Assuming that the natural displacements are of the form

$$\underline{q} = \underline{q}\, e^{j\omega_r t}$$

Thus for each vibrational mode we obtain

$$-\underset{\sim}{M}\, \omega_r^2 \, \underline{q}_r + \underset{\sim}{K} q_r = 0$$

The perturbed values are:

$$\omega_i = \overline{\omega}_i + \sum_{i=1}^{n} (\omega^{m}_{ri}\alpha_r) + \sum_{i=1}^{n} (\omega^{K}_{ri}\beta_r)$$

$$\underline{q}_i = \overline{\underline{q}}_i + \sum_{i=1}^{n} (\underline{q}^{M}_{ri}\alpha_r) + \sum_{i=1}^{n} (q^{K}_{ri}\beta_r)$$

$$\omega^{M}_{ri} = - \frac{\overline{\omega}_i \; q_i^T D_r \overline{\underset{\sim}{M}\overline{q}_i}}{z\overline{\underline{q}}_i^T \overline{\underset{\sim}{M}} \; \overline{\underset{\sim}{q}}_i} \quad , \qquad r = 1, \ldots, n$$

$$\omega^{K}_{ri} = - \frac{\overline{q}_i^T \underset{\sim}{D}_r \underset{\sim}{K} \overline{\underline{q}}_i}{z \; \overline{\omega}_i \overline{\underline{q}}_i^T \underset{\sim}{M} \overline{\underline{q}}_i}$$

Finally, the variance of the frequency is:

$$\mathrm{VAR}^2(\omega_i) = \sum_{r=1}^{n} \left[\mathrm{VAR}^2(\alpha_i) \cdot (\omega^{M}_{ri})^2 + \mathrm{VAR}^2(\beta_i) \cdot (\omega^{K}_{ri})^2\right]$$

```
      PROGRAM DYNCOR (INPUT,OUTPUT,TAPE1,PUNCH)
C
C     ------------------------------------------------------------------
C
C                                                VERSION   DND677
C
C     DYNAMIC  CORRELATIVE  ANALYSIS
C
C
C     THIS PROGRAM PERFORMS A  DYNAMIC  MODAL  ANALYSIS
C     FOR  THE CASE OF A TRAVELING INPUT WAVE AT THE BOUNDARIES
C     OF THE DISCRETIZED UNDER STUDY REGION .
C     IT IS BASED ON A  FINITE ELEMENT METHOD  AND USES  A TRIANGULAR
C     PLANE STRAIN OR/ STRESS ELEMENT  WITH  SIX DEGREES OF FREEDOM.
C     THE DUHAMEL S INTEGRAL IS EVALUATED USING NEWMARKS AND
C     WILSON  PROCEDURE .
C     THE PHYSICAL PROPERTIES OF THE MEDIUM ARE ASSUMED LINEAR
C     THE UNCERTAINTY IS HANDLED USING A PERTURBATION TECHNIQUE
C     ACCORDING TO A  SCHEME SUGESTED BY BOLOTIN .
C      THE  RANDOM  PHYSICAL  PROPERTIES  OF  THE  MEDIUM
C      BELONG  TO  A  CORRELATIVE  STATISTICAL  FIELD
C
C     ------------------------------------------------------------------
C
C     DESCRIPTION OF THE DIFFERENT POSSIBLE CODES THAT ARE
C     AVAILABLE IN THIS PROGRAM
C
C          ICOD1  = 0   NO PRINT  OF DEBUGING
C                 = 1   PRINT  DEBUGING  INFORMATION
C
C          ICOD2  = 0   COMPUTATIONS OF VIBRATION MODES
C                 = 1   READ MODES FROM  INPUT DATA
C
C          ICOD3  = 1   PRINT DISPLACEMENTS DUE TO A UNIT
C                      DISTURBANCE AT EACH BASE NODE
C          ICOD4  = 1   SUPPRESS PRINT OF INPUT DATA
C          ICOD5  = 0   INCLUSION OF INITIAL STRESSES
C          ICOD6  = 1   COMPUTATION OF VIBRATIONAL MODES AND
C                      CORRESPONDING FREQUENCIES  ONLY
C          ICOD7  = 1   PUNCH VIBRAT. MODES AND FREQUENCIES
C          ICOD8  = 1   SUPPRESS PRINT OF VIBRAT. MODES + FREQ.
C     -----------------------------------------------------------
C
C     DESCRIPTION  OF  THE  DIFFERENT  OPTIONS  AVAILABLE
C     TO PERFORM  THE  DYNAMIC  ANALYSIS
C
C          IFLAG1 = 0   PLANE  STRAIN  CONDITION
C                   1   PLANE  STRESS  CONDITION
C          IFLAG2 = 0   DYNAMIC  RESPONCE ASSUMING A TRAVELING
C                       PERTURBATION  AT  BOUNDARIES
C                 = 1   DYNAMIC  RESPONCE ASSUMING A UNIFORM
C                       PERTURBATION  AT  BOUNDARIES
C          IFLAG3 = 1   DYNAMIC  PART  OF  THE RESPONCE ONLY
C          IFLAG4 = 1   TOTAL  DISPLACEMENTS (INERTIAL+QUASISTATIC)
C                       AND TOTAL STRESSES
C          IFLAG5 = 1   SUPPRESS  UNCERTAINTY ANALYSIS
C          IFLAG6 = 1   BETA PARAMETER OF INTEGRAT. = 1/4
C                 = 0   BETA PARAMETER OF INTEGRATION. = 1/6
C                 =-1   BETA PARAMETER                 = 1/8
C
C     -------------------------------------------------------------
C
C     INPUT         (DEFINITION  OF  VARIABLES)
C
C
C          NELEM =  NUMBER OF ELEMENTS
C          NNODE =  NUMBER OF NODES
C          NODBC =  NUMBER OF NODES AT BOUNDARIES
C          NMODE =  NUMBER OF VIBRATIONAL  MODES
C
C          K     =  ELEMENT NUMBER
C          NPI   =  NODAL POINT NUMBER 1
```

```
C         NPJ    =  NODAL POINT NUMBER 2
C         NPK    =  NODAL POINT NUMBER 3
C
C         E( )  = MODULUS OF ELASTICITY IN  KG/(CM)2
C         POIS( = POISSONS RATIO
C         DEN( )= UNIT WEIGHT   IN   GR/ (CM)3
C
C         VE( )     = VARIANCE OF MODULUS OF ELASTICITY
C         VPOIS( ) = VARIANCE OF POISON S  RATIO
C         VDEN( )  = VARIANCE OF DENSITY
C
C         XORD( ) = X-ORDINATE IN METERS
C         YORD( ) = Y-ORDINATE IN METERS
C
C         NNB ( ) = NUMBER OF NODE AT BOUDARIES
C
C         NGAC     = NUMBER OF GIVEN  ACCELERATIONS
C                    AT THE  BOUNDARY  NODES
C         NTSTEP   = NUMBER OF TIME  STEPS
C         NDTC     = INCREMENT  OF  TIME  STEPS  IN  WHICH
C                    DISPLACEMENTS AND STRESSES ARE NOT PRINTED
C         TLIMIT   = TIME  LIMIT  FOR THE COMPUTATION OF A RUN
C         DT       = TIME  INTERVAL  FOR  ACCELERATION VALUES SEC
C         RMVEL     = MEAN  VELOCITY  OF  THE  TRAVELING
C                    PERTURBATION  AT  THE  BOUNDARIES
C     -----------------------------------------------------------
C
C     OUTPUT
C
C         STATIC DISPLACEMENTS OF NODES
C         N - FIRST FREQUENCIES, AND CORRESPONDING  MODE SHAPES
C         GROUND VELOCITY
C         TOTAL  DISPLACEMENTS OF NODES
C         STRESSES AND THEIR PEAK VALUES
C         VARIANCE OF THE FREQUENCY
C         VARIANCE OF DISPLACEMENTS
C         VARIANCE OF STRESSES
C
C     ---------------------------------------------------------------
C
      COMMON /COD1/ ICOD1,ICOD2,ICOD3,ICOD4
      COMMON /COD2/ ICOD5,ICOD6,ICOD7,ICOD8
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
      COMMON /DYNA1/ NTSTEP,NTDC,LK,NC,TLIMIT
      COMMON /VOLM/ AREA
      COMMON /MXSTR/ SMAX(50),SMIN(50),IMAX(50),IMIN(50),SMAXD(50),SMIND
     1(50),IMAXD(50),IMIND(50)
C
      REAL ST(100,100),STI(100,20),SMASS(100),B(100),R(260,10),W(100),EV
     1(100),VCXX(50),VCYY(50)
      INTEGER NEBC(40)
C
C
      DIMENSION XORD(50), YORD(50), NNB(15), NPI(50), NPJ(50), NPK(50),
     1E(50), POIS(50), AJ(50), BJ(50), AK(50), BK(50), DEN(50), A1(6,6),
     2 B1(6,6), S(6,6), AEIG(100,15), ACC(800), V(110), DIS(100), YH(50)
     3, YV(50), DSX(50), DSY(50), BINF(15,15), MK(15), F(15), C4(15), C5
     4(15), ACCEL(15), VEL(15), LM(3), DAMP(15), STRXI(50), STRYI(50), S
     5TRXYI(50), DXZERO(100)
C
      REAL VALFA(50),VBETA(50),KST(50),OMEGAM(15,15),OMEGAK(15,15),VW(15
     1),VOL(50)
C
      DIMENSION TITLE(12)
      DIMENSION VE(100), VPOIS(100), VDEN(100)
      REAL VDM(15,15),VD(15),VACW(15),VACD(15),VHOR(50),VVER(50),VDD(260
     1,10),VDW(260,10),DSVX(50),DSVY(50)
C
C     ---------------------------------------------------
C
```

```
      READ 106, TITLE
      READ 107, ICOD1,ICOD2,ICOD3,ICOD4,ICOD5,ICOD6,ICOD7,ICOD8
      READ 107, IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      READ 107, NELEM,NNODE,NODBC,NMODE
C
      PRINT 108, TITLE,NELEM,NNODE,NODBC,NMODE
      PRINT 109, ICOD1,ICOD2,ICOD3,ICOD4,ICOD5,ICOD6,ICOD7,ICOD8
C
      PRINT 110, IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
C
      IDEBUG=ICOD1
      NNODED=NNODE
      NELEMD=NELEM
      NODBCD=NODBC
      NBCD=2*NODBC
      NMODED=NMODE
      NDGRFD=2*NNODE
      NWDTHD=20
      NGACD=800
      IDEBUG=1
C
C
C     ------------------------------------------------------------
C
      CALL INPMESH (NPI,NPJ,NPK,E,POIS,DEN,VE,VPOIS,VDEN,NNODED,XORD,YOR
     1D,NNB,NODBCD,NELEMD)
C
C     ------------------------------------------------------------
C
C     ------------------------------------------------------------
C
      CALL INPDYN (ACC,NGACD,DAMP,STRXI,STRYI,STRXYI,NELEMD,NMODED,VD)
C
C     ------------------------------------------------------------
C
      NEV=NMODE
      NN=2*NNODE
C
C     ------------------------------------------------------------
C
      CALL MASS (NPI,NPJ,NPK,XORD,YORD,DEN,AJ,AK,BJ,BK,NNODED,SMASS,NDGR
     1FD,NELEMD,VOL,IDEBUG)
C
C     ------------------------------------------------------------
C
      CALL STIFF (E,POIS,COMM,NPI,NPJ,NPK,AJ,AK,BJ,BK,NNODED,ST,NDGRFD,N
     1WDTHD,NELEMD,NODBCD,IDEBUG)
C
C     ------------------------------------------------------------
C
      CALL STATDIS (NNB,STI,ST,B,NDGRFD,NWDTHD,NODBCD,IDEBUG)
C
C     ------------------------------------------------------------
C
      CALL MFREQ (NNB,NEBC,NODBCD,ST,STI,NNODED,NWDTHD,EV,W,BINF,NMODED,
     1AEIG,NDGRFD,SMASS,R,NBCD,VE,VDEN,E,VW,VALFA,VBETA,KST,OMEGAM,OMEGA
     2K,VOL,VDM,IDEBUG)
C
C     ------------------------------------------------------------
C
C
C
C     TIME  SHIFTS  OF  BASE DEGREES  OF  FREEDOM
C
      NTSTEPD=NTSTEP+3
      IF (IFLAG2) 103,101,103
  101 KK=NNB(1)
C
C
      XD=XORD(KK)
      DO 102 K=1,NODBC
C
         MK(K)=0
```

```
      KK=NNB(K)
      DIST=ABS(XORD(KK)-XD)
      TK=DIST/RMUEL
      XMK=TK/DT
C
C
  102 MK(K)=XMK
      NC=MK(NODBC)
      GO TO 105
  103 DO 104 K=1,NODBC
  104 MK(K)=0
      NC=1
  105 LK=NC+1
      LLKU=LK
C
C     ---------------------------------------------------------------
C
      CALL DYNDIS (NPI,NPJ,NPK,POIS,COMM,E,STI,AEIG,W,DAMP,BINF,ACC,NMOD
     1ED,STRXI,STRYI,STRXYI,NELEMD,AJ,AK,BJ,BK,NNODED,MK,NTSTEPD,NODBCD,
     2NGACD,NDGRFD,NWDTHD,DSX,DSY,VEL,C4,C5,F,ACCEL,DXZERU,V,DIS,YH,YV,R
     3,VOL,VW,VD,VE,VPOIS,VDEN,VDM,VACD,VACW,VDD,VDW,VHOR,VVER,DSVX,DSVY
     4,LLKV,VCXX,VCYY)
C
C     -----------------------------------------------------------
C
C     FORMAT  STATEMENT
C
      STOP
C
  106 FORMAT (12A6)
  107 FORMAT (12I5)
  108 FORMAT (1H112A6///,5X, 51H   NUMBER  OF  ELEMENTS---------------
     1-----------,I3/,5X, 51H   NUMBER OF  NODAL  POINTS---------------
     2--------,I3/,5X, 51H   NUMBER  OF  BASE  NODES-------------------
     3-----,I3/,5X, 51H   NUMBER  OF  VIBRATIONAL MODES----------------
     4--,I3/)
  109 FORMAT (5X, 68HCOD1     COD2     COD3     COD4     COD5     COD6     COD7     CO
     1D8                ,/,7X,12(I2,5X))
  110 FORMAT (5X, 60HIFLAG1   IFLAG2    IFLAG3    IFLAG4    IFLAG5
     1    IFLAG6,/7X,12(I2,5X))
C
      END
      SUBROUTINE INPMESH (NPI,NPJ,NPK,E,POIS,DEN,VE,UPOIS,VDEN,NNODED,XO
     1RD,YORD,NNB,NODBCD,NELEMD)
C
C     **************************************************************
C
C      READ  INPUT  DATA  OF  FINITE  ELEMENT  MESH
C
      REAL E(NNODED),POIS(NNODED),DEN(NNODED),VE(NNODED),VDEN(NNODED),VP
     1OIS(NNODED),XORD(NNODED),YORD(NNODED)
      INTEGER NNB(NODBCD),NPI(NELEMD),NPJ(NELEMD),NPK(NELEMD)
C
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NDAND
C
C
      PRINT 111
      DO 101 M=1,NELEM
         READ 112, K,NPI(M),NPJ(M),NPK(M)
         PRINT 115, K,NPI(M),NPJ(M),NPK(M)
C
  101 CONTINUE
C
C
      DO 102 I=1,NNODE
  102 READ 108, E(I),VE(I)
      DO 103 J=1,NNODE
  103 READ 108, POIS(J),VPOIS(J)
      DO 104 K=1,NNODE
  104 READ 108, DEN(K),VDEN(K)
C
C
```

```
      PRINT 109
C
      DO 105 I=1,NNODE
  105 PRINT 110, E(I),POIS(I),DEN(I)
C
      PRINT 116
C
      DO 106 M=1,NNODE
         READ 113, K,XORD(M),YORD(M)
         XORD(M)=XORD(M)*100.
         YORD(M)=YORD(M)*100.
C
         PRINT 117, K,XORD(M),YORD(M)
  106 CONTINUE
C
      PRINT 118
C
      DO 107 K=1,NODBC
C
         READ 114, M,NNB(K)
         PRINT 119, M,NNB(K)
C
  107 CONTINUE
C
      RETURN
C
  108 FORMAT (2F10.0)
  109 FORMAT (//5X, 22HMOD.EL.   POIS.   DEN.,//)
  110 FORMAT (5X,3(E15.3,2X))
  111 FORMAT (2X, 28H ELEM.=I   J   K             ,//)
  112 FORMAT (4I4,3E12.4)
  113 FORMAT (1I4,2F10.3)
  114 FORMAT (1I5,1I5)
  115 FORMAT (2X,4I4,3E12.4)
  116 FORMAT (5X, 25H  NODE    X-ORD    Y-ORD  ,//)
  117 FORMAT (5X,I4,2F10.3,2X)
  118 FORMAT (5X, 32H  NODAL  POINTS  ON  THE  BASE  )
  119 FORMAT (5X,2I5)
C
      END
      SUBROUTINE INPDYN (ACC,NGACD,DAMP,STRXI,STRYI,STRXYI,NELEMD,NMODED
     1,UD)
C
C     ****************************************************************
C
C      READ  INPUT  DATA  OF  DYNAMIC  ANALYSIS
C
      REAL ACC(NGACD),STRXI(NELEMD),STRYI(NELEMD),STRXYI(NELEMD),DAMP(NM
     1ODED),UD(NMODED)
C
      COMMON /COD2/ ICOD5,ICOD6,ICOD7,ICOD8
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMUEL,DT
      COMMON /DYNA1/ NTSTEP,NDTC,LK,NC,TLIMIT
C
      PRINT 105
C
C
      READ 106, NGAC,NTSTEP,NDTC,TLIMIT,DT,RMUEL
      PRINT 110, NGAC,NTSTEP,NDTC,TLIMIT,DT,RMUEL
C
      READ 107, (ACC(J),J=1,NGAC)
C
      DO 101 I=1,NGAC
  101 ACC(I)=ACC(I)*1000.
      READ 108, (DAMP(N),UD(N),N=1,NMODE)
      PRINT 111, (N,DAMP(N),N=1,NMODE)
      DO 102 N=1,NELEM
         STRXI(N)=0.
         STRYI(N)=0.
  102 STRXYI(N)=0.
      IF (ICOD5) 104,103,104
```

3

```
  103 READ 109, (M,STRXI(N),STRYI(N),STRXYI(N),N=1,NELEM)
  104 PRINT 112, (M,STRXI(N),STRYI(N),STRXYI(N),N=1,NELEM)
      RETURN
C
  105 FORMAT (5X, 30HINPUT DATA OF DYNAMIC ANALYSIS,/)
  106 FORMAT (3I5,3F10.0)
  107 FORMAT (8F9.6)
  108 FORMAT (2F10.0)
  109 FORMAT (1I4,3F15.4)
  110 FORMAT (5X, 49H     NGAC    NTSTEP    NDTC     TLIMIT      DT    RMVEL,/
     1,14X,3I5,3F10.4)
  111 FORMAT (5X, 16H MODE  DAMPING  ,1X/,(I5,1F8.5))
  112 FORMAT (5X, 18H INITIAL  STRESSES,1X/, 47H     ELEMENT      X-STRESS
     1   STRYRESS   XY-STRESS,/,5X,(1I10,3F15.4))
C
      END
      SUBROUTINE MASS (NPI,NPJ,NPK,XORD,YORD,DEN,AJ,AK,BJ,BK,NNODED,SMAS
     1S,NDGRFD,NELEMD,VOL,IDEBUG)
C
C     *****************************************************************
C
C     EVALUATION  OF  LUMPED  MASSES  AT  NODES
C
C
      COMMON /COD1/ ICOD1,ICOD2,ICOD3,ICOD4
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
C
      REAL XORD(NNODED),YORD(NNODED),DEN(NNODED),AJ(NELEMD),AK(NELEMD),B
     1J(NELEMD),BK(NELEMD),SMASS(NDGRFD),VOL(NNODED)
      INTEGER NPI(NELEMD),NPJ(NELEMD),NPK(NELEMD)
C
C
C     CALCULATING  MASSES
C
      NN=2*NNODE
      DO 101 I=1,NN
  101 SMASS(I)=0.
      DO 104 N=1,NELEM
         I=NPI(N)
         J=NPJ(N)
         K=NPK(N)
C
         DENS=(DEN(I)+DEN(J)+DEN(K))/3.
         AJ(N)=XORD(J)-XORD(I)
         AK(N)=XORD(K)-XORD(I)
         BJ(N)=YORD(J)-YORD(I)
         BK(N)=YORD(K)-YORD(I)
         AREA=(AJ(N)*BK(N)-BJ(N)*AK(N))/2.
         IF (AREA) 102,102,103
  102    PRINT 108, N
         GO TO 106
  103    DL=AREA*DENS/3.
         ROW=DL/10000.
         II=2*I-1
         JJ=2*J-1
         KK=2*K-1
         SMASS(II)=SMASS(II)+ROW
         SMASS(JJ)=SMASS(JJ)+ROW
         SMASS(KK)=SMASS(KK)+ROW
         SMASS(II+1)=SMASS(II+1)+ROW
         SMASS(JJ+1)=SMASS(JJ+1)+ROW
         SMASS(KK+1)=SMASS(KK+1)+ROW
C
C     *******  DEBUG  ******
C
         IF (IDEBUG.EQ.1) GO TO 104
C
         PRINT 107, SMASS(II),SMASS(JJ),SMASS(KK),SMASS(II+1),SMASS(JJ+1
     1   ),SMASS(KK+1)
  104 CONTINUE
C
```

```
      DO 105 I=1,NNODED
         II=2*I-1
  105 VOL(I)=SMASS(II)*1000./DEN(I)
C
  106 RETURN
C
  107 FORMAT (5X,6(F10.3,2X)/)
  108 FORMAT (2X, 37H ZERO OR NEGATIVE AREA,  EL.  NO. =  ,1I4)
C
      END
      SUBROUTINE STIFF (E,POIS,COMM,NPI,NPJ,NPK,AJ,AK,BJ,BK,NNODED,ST,ND
     1GRFD,NWDTHD,NELEMD,IDEBUG)
C
C     ******************************************************************
C
C     EVALUATION  OF  STIFFNESS  MATRIX
C
      REAL E(NNODED),POIS(NNODED),AJ(NELEMD),AK(NELEMD),BJ(NELEMD),BK(NE
     1LEMD),ST(NDGRFD,NWDTHD)
C
      COMMON /COD1/ ICOD1,ICOD2,ICOD3,ICOD4
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /VOLM/ AREA
C
      REAL A1(6,6),B1(6,6),S(6,6)
      INTEGER NPI(NELEMD),NPJ(NELEMD),NPK(NELEMD),LM(3)
C
C
C     STIFFNESS  MATRIX
C
      DO 107 N=1,NELEM
C
         I=NPI(N)
         J=NPJ(N)
         K=NPK(N)
         EMOD=(E(I)+E(J)+E(K))/3.
         POISR=(POIS(I)+POIS(J)+POIS(K))/3.
C
         IF (IFLAG1.GT.0) GO TO 101
         EMOD=EMOD/(1.-POISR**2)
         POISR=POISR/(1.-POISR)
  101    CONTINUE
C
         AREA=(AJ(N)*BK(N)-AK(N)*BJ(N))*.5
         COMM=.25*EMOD/((1.-POISR**2)*AREA)
         A1(1,1)=BJ(N)-BK(N)
         A1(1,2)=0.
         A1(1,3)=BK(N)
         A1(1,4)=0.
         A1(1,5)=-BJ(N)
         A1(1,6)=0.
         A1(2,1)=0.
         A1(2,2)=AK(N)-AJ(N)
         A1(2,3)=0.
         A1(2,4)=-AK(N)
         A1(2,5)=0.
         A1(2,6)=AJ(N)
         A1(3,1)=AK(N)-AJ(N)
         A1(3,2)=BJ(N)-BK(N)
         A1(3,3)=-AK(N)
         A1(3,4)=BK(N)
         A1(3,5)=AJ(N)
         A1(3,6)=-BJ(N)
         B1(1,1)=COMM
         B1(1,2)=COMM*POISR
         B1(1,3)=0.
         B1(2,1)=COMM*POISR
         B1(2,2)=COMM
         B1(2,3)=0.
         B1(3,1)=0.
         B1(3,2)=0.
```

```
          B1(3,3)=COMM*(1.-POISR)*.5
C
          DO 102 J=1,6
          DO 102 I=1,3
             S(I,J)=0.
          DO 102 K=1,3
  102     S(I,J)=S(I,J)+B1(I,K)*A1(K,J)
          DO 103 J=1,6
          DO 103 I=1,3
  103     B1(J,I)=S(I,J)
          DO 104 J=1,6
          DO 104 I=1,6
             S(I,J)=0.
          DO 104 K=1,3
  104     S(I,J)=S(I,J)+B1(I,K)*A1(K,J)
C
          LM(1)=NPI(N)
          LM(2)=NPJ(N)
          LM(3)=NPK(N)
       DO 107 L=1,3
          I=2*LM(L)-1
          II=2*L-1
       DO 107 M=1,3
          IF (LM(L).GT.LM(M)) GO TO 107
          J=2*(LM(M)-LM(L))+1
          JJ=2*M-1
          ST(I,J)=ST(I,J)+S(II,JJ)
          ST(I,J+1)=ST(I,J+1)+S(II,JJ+1)
          IF (L-M) 105,106,105
  105     ST(I+1,J-1)=ST(I+1,J-1)+S(II+1,JJ)
  106     ST(I+1,J)=ST(I+1,J)+S(II+1,JJ+1)
  107 CONTINUE
C
C       DETERMINATION  OF  THE  HALF  BAND  WIDTH
C
C
        NB=2
        DO 110 N=1,NELEM
           I=IABS(NPI(N)-NPJ(N))
           J=IABS(NPI(N)-NPK(N))
           K=IABS(NPJ(N)-NPK(N))
           N1=MAX0(I,J,K)
           IF (N1-15) 109,108,108
  108      PRINT 115, N
           GO TO 113
  109      IF (N1.GT.NB) NB=N1
  110 CONTINUE
C
        NBAND=2*NB+2
        MM=NBAND
        PRINT 116, NBAND
C
        IF (ICOD2) 113,111,113
  111 REWIND 1
        WRITE (1) ((ST(I,J),I=1,NN),J=1,NBAND)
C
C ****** DEBUG ******
C
        IF (IDEBUG.EQ.1) GO TO 113
C
        DO 112 I=1,NN
           PRINT 114, (ST(I,J),J=1,NBAND)
C
C       PUNCH 20, (ST(I,J), J= 1, NBAND )
C
  112 CONTINUE
C
C        PUNCH 20, ( SMASS(I), I = 1,NN )
C
  113 RETURN
C
  114 FORMAT (2X,8(F10.3,2X))
```

```
  115 FORMAT (2X, 37H  HALF  BAND  WIDTH  TOO LARGE  EL. =,1I3)
  116 FORMAT (2X, 36H HALF  BAND  WIDTH  IS  EQUAL  TO   ,1I3)
C
      END
      SUBROUTINE STATDIS (NNB,STI,ST,B,NDGRFD,NWDTHD,NODBCD,IDEBUG)
C
C     ****************************************************************
C
C     EVALUATION  OF  STATIC  DISPLACEMENTS
C
      REAL STI(NDGRFD,NWDTHD),ST(NDGRFD,NWDTHD),B(NDGRFD)
C
      COMMON /COD1/ ICOD1,ICOD2,ICOD3,ICOD4
      COMMON /COD2/ ICOD5,ICOD6,ICOD7,ICOD8
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
C
      INTEGER NNB(NODBCD)
C
C
C     STATIC  DISPLACEMENT   MATRIX STI(N,K)
C
      DO 105 K=1,NODBC
C
         DO 101 I=1,NN
  101    STI(I,K)=0.
C
         KK=2*NNB(K)-1
         L1=KK
         IF (KK.GT.NBAND) L1=NBAND
         DO 102 I=1,L1
            II=KK-I+1
            STI(II,K)=-ST(II,I)
            ST(II+1,I)=0.
            IF (L1.LT.NBAND) ST(II,I+1)=0.
  102    ST(II,I)=0.
C
         L2=NBAND
         JJ=NN-KK+1
         IF (JJ.LT.NBAND) L2=JJ
C
         DO 103 I=2,L2
            II=KK+I-1
            STI(II,K)=-ST(KK,I)
            ST(KK+1,I)=0.
  103    ST(KK,I)=0.
         ST(KK,1)=1.
         ST(KK+1,1)=1.
C
         DO 104 L=1,NODBC
            II=2*NNB(L)-1
            STI(II,K)=0.
  104    STI(II+1,K)=0.
  105 STI(KK,K)=1.
C
      NUMEQD=NDGRFD
C
C     ----------------------------------------------------------------
C
      CALL SOLVE (1,ST,B,NUMEQD,NWDTHD)
C
C     ----------------------------------------------------------------
C
      DO 108 K=1,NODBC
         DO 106 I=1,NN
  106    B(I)=STI(I,K)
C
C     ----------------------------------------------------------------
C
         CALL SOLVE (2,ST,B,NUMEQD,NWDTHD)
C
C     ----------------------------------------------------------------
```

```
C
        DO 107 I=1,NN
  107   STI(I,K)=B(I)
  108 CONTINUE
C
      IF (ICOD3) 109,111,109
C
  109 DO 110 K=1,NODBC
        PRINT 112, K
        PRINT 113
      DO 110 N=1,NNODE
        N1=2*N-1
  110 PRINT 114, N,STI(N1,K),STI(N1+1,K)
  111 RETURN
C
  112 FORMAT (2X, 91H STATIC DISPL.        DUE  TO  A   UNIT  DISPL. AT
     1    BASE  NODE            ORDERED NUMBER =,1I3/)
  113 FORMAT (2X, 23H    NP   X-ORD   Y-ORD )
  114 FORMAT (2X,1I8,2E20.6)
C
      END
      SUBROUTINE SOLVE (KKK,A,B,NUMEQD,NWDTHD)
C
C     ****************************************************************
C
C     SOLUTION  OF  LINEAR  SYSTEM  OF  EQUATIONS
C
      REAL A(NUMEQD,NWDTHD),B(NUMEQD)
C
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
C
C
      MM=NBAND
      IF (KKK.EQ.2) GO TO 104
      MM=NBAND
      IF (KKK.EQ.2) GO TO 104
C
C
      NRS=NN-1
      NR=NN
      IF (KKK-1) 101,101,104
  101 DO 103 N=1,NRS
        M=N-1
        MR=MINO(MM,NR-M)
        PIVOT=A(N,1)
      DO 103 L=2,MR
        C=A(N,L)/PIVOT
        I=M+L
        J=0
        DO 102 K=L,MR
          J=J+1
  102   A(I,J)=A(I,J)+C*A(N,K)
  103 A(N,L)=C
      GO TO 107
  104 DO 105 N=1,NRS
        M=N-1
        MR=MINO(MM,NR-M)
        C=B(N)
        B(N)=C/A(N,1)
      DO 105 L=2,MR
        I=M+L
  105 B(I)=B(I)-A(N,L)*C
      B(NR)=B(NR)/A(NR,1)
      DO 106 I=1,NRS
        N=NR-I
        M=N-1
        MR=MINO(MM,NR-M)
      DO 106 K=2,MR
        L=M+K
  106 B(N)=B(N)-A(N,K)*B(L)
  107 RETURN
C
```

```
      SUBROUTINE MFREQ (NNB,NEBC,NODBCD,ST,STI,NNODED,NWDTHD,EV,W,BINF,N
     1MODED,AEIG,NDGRFD,SMASS,R,NBCD,VE,VDEN,E,VW,VALFA,VBETA,KST,OMEGAM
     2,OMEGAK,VOL,VDM,IDEBUG)
C
C     ******************************************************************
C
C     EVALUATION  OF  VIBRATIONAL  MODES
C
      COMMON /COD1/ ICOD1,ICOD2,ICOD3,ICOD4
      COMMON /COD2/ ICOD5,ICOD6,ICOD7,ICOD8
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
      COMMON /VOLM/ AREA
C
C     ********************************************************************
C
      REAL STI(NDGRFD,NWDTHD),EV(NMODED),W(NMODED),AEIG(NDGRFD,NMODED),B
     1INF(NMODED,NODBCD),SMASS(NDGRFD),KST(NDGRFD),ST(NDGRFD,NWDTHD),R(N
     2DGRFD,NWDTHD),E(NNODED),VE(NNODED),VDEN(NNODED),VW(NNODED),VALFA(N
     3NODED),VBETA(NNODED),OMEGAM(NMODED,NMODED),OMEGAK(NMODED,NMODED),V
     4OL(NNODED),VDM(NMODED,NODBCD)
C
C
      INTEGER NNB(NODBCD),NEBC(NBCD)
C
C
C     COMPUTE  AND  PRINT  FREQUENCIES
C     **************************************************
C
      IF (ICOD2) 110,101,110
  101 CONTINUE
      DO 102 I=1,NODBC
         II=2*I-1
         NEBC(II)=2*NNB(I)-1
  102 NEBC(II+1)=NEBC(II)+1
C
      REWIND 1
      READ (1) ((ST(I,J),I=1,NN),J=1,NBAND)
C
C     ------------------------------------------------------------------
C
      CALL BEING (AEIG,ST,R,W,SMASS,EV,NMODED,NDGRFD,NWDTHD,NEBC,NBCD,ID
     1EBUG)
C
C     ------------------------------------------------------------------
C
      PRINT 122
      DO 103 J=1,NMODE
         EV(J)=ABS(EV(J))
         W(J)=SQRT(EV(J))
  103 PRINT 123, J,W(J)
C
      IF (ICOD8) 106,104,106
  104 DO 105 N=1,NMODE
         PRINT 124, N,W(N)
         PRINT 129
      DO 105 M=1,NNODE
         KK=2*M-1
  105 PRINT 125, M,AEIG(KK,N),AEIG(KK+1,N)
C
C     PUNCH   OF  FREQUENCIES  AND  MODE  SHAPES
C
  106 IF (ICOD7) 107,112,107
  107 DO 108 N=1,NMODE
  108 PUNCH 126, N,W(N)
      DO 109 N=1,NMODE
      DO 109 M=1,NNODE
         KK=2*M-1
  109 PUNCH 127, M,AEIG(KK,N),AEIG(KK+1,N)
      GO TO 112
C
```

```
C     READ  FREQUENCIES  AND  MODE  SHAPES
C
  110 READ 121, (W(N),N=1,NMODE)
      DO 111 N=1,NMODE
      DO 111 M=1,NNODE
         KK=2*M-1
  111 READ 127, K,AEIG(KK,N),AEIG(KK+1,N)
      IF (ICOD8) 112,104,112
C
  112 IF (ICOD6) 120,113,120
C
C     INFLUENCE COEFFICIENT  MATRIX A(N,K)
C
  113 DO 114 N=1,NMODE
      DO 114 K=1,NODBC
  114 BINF(N,K)=0.
      DO 116 N=1,NMODE
      DO 116 K=1,NODBC
         TERM=0.
         UT=0.
         DO 115 L=1,NN
C
            UT=UT+AEIG(L,N)*STI(L,K)
C
  115    TPART=TPART+AEIG(L,N)*SMASS(L)*STI(L,K)
C
         UDM(N,K)=UT
C
  116 BINF(N,K)=TPART
      IF (ICOD3) 117,120,117
  117 PRINT 128
      DO 118 N=1,NMODE
  118 PRINT 130, (BINF(N,K),K=1,NODBC)
C
      DO 119 N=1,NMODE
  119 PRINT 130, (UDM(N,K),K=1,NODBC)
C
C     ---------------------------------------------------------
C
      CALL EIGUNCR (SMASS,AEIG,ST,OMEGAM,OMEGAK,W,KST,VE,UDEN,UW,NDGRFD,
     1NWDTHD,NNODED,NMODED,VALFA,VBETA,E,VOL,IDEBUG)
C
C     ----------------------------------------------------------
C
C
  120 CONTINUE
      RETURN
C
  121 FORMAT (12X,F15.8)
  122 FORMAT (2X, 29H           MODE NO    FREQUENCY)
  123 FORMAT (2X,1I12,1F15.5)
  124 FORMAT (2X, 29H THE FREQUENCY OF MODE NUMBER,I4,  7H  IS  =,F10.4/
     1)
  125 FORMAT (2X,1I12,2E15.6)
  126 FORMAT (1I12,1F15.8)
  127 FORMAT (1I12,2E15.6)
  128 FORMAT (2X, 40H  PARTICIPATION  COEFFICIENTS  A(K,N) S )
  129 FORMAT (2X, 43H NODAL POINT X-EIGEN  COORD  Y-EIGEN COORD )
  130 FORMAT (2X,8F15.6)
C
      END
      SUBROUTINE BEING (AEIG,A,R,W,SMASS,EV,NMODED,NDGRFD,NWDTHD,NEBC,NB
     1CD,IDEBUG)
C
C     ***********************************************************
C
C     EVALUATION  OF  THE  NATURAL  FREQUENCIES
C
      REAL SMASS(NDGRFD),AEIG(NDGRFD,NMODED),EV(NMODED),W(NDGRFD),R(NDGR
     1FD,NWDTHD),A(NDGRFD,NDGRFD)
C
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
```

```
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
C
      INTEGER NEBC(NBCD)
C
C     ----------------------------------------------------------------
C
C
C     INITIALIZE
C
C
      MM=NBAND
      IFLAG=0
      NEV=NMODE
C
C
C       EIGENVALUE  PROBLEM
C       --------------------------------------------------------------
C
      TRACE=0.
      DO 102 I=1,NN
         TRACE=TRACE+ABS(A(I,1))
         X=SMASS(I)
         IF (X.GT.0.) GO TO 101
         PRINT 116, I
         IFLAG=1
         GO TO 102
  101    SMASS(I)=1./SQRT(X)
  102 CONTINUE
      IF (IFLAG.NE.0) STOP
      DO 103 I=1,NN
         L=I-1
         MR=MIN0(MM,NN-I+1)
      DO 103 J=1,MR
         K=L+J
  103 A(I,J)=A(I,J)*SMASS(I)*SMASS(K)
C
C     IMPOSE  BOUNDARY  CONDITIONS  ON  A
C
      IF (NBCD.LE.0) GO TO 115
      DO 104 N=1,NBCD
         I=NEBC(N)
         A(I,1)=100.*TRACE
      DO 104 J=2,MM
         A(I,J)=0.
         L=I-J+1
         IF (L.LE.0) GO TO 104
         A(L,J)=0.
  104 CONTINUE
C
C     *******  DEBUG  ******
C
      IF (IDEBUG.EQ.1) GO TO 106
C
      DO 105 I=1,NN
         PRINT 117, (A(I,J),J=1,MM)
  105 CONTINUE
C
C     MATRIX  IN SYMETRIC  MODE
C
  106 DO 107 J=1,MM
         N1=0
      DO 107 I=MM-J+1,NN
         R(I,J)=A(1+N1,MM-J+1)
         N1=N1+1
  107 CONTINUE
C
C
C     ******  DEBUG  ******
C
      IF (IDEBUG.EQ.1) GO TO 109
C
      DO 108 I=1,NN
```

```
         PRINT 117, (R(I,J),J=1,MM)
  108 CONTINUE
  109 CONTINUE
C
      IND=2
      NM=NDGRFD
C
C     --------------------------------------
C
      CALL RSBEIG (NM,NN,MM,R,IND,W,A)
C
C     --------------------------------------
C
C
C ****** DEBUG ******
C
      IF (IDEBUG.EQ.1) GO TO 112
C
      DO 110 I=1,NN
  110 PRINT , ≠W=≠,W(I)
C
      DO 111 I=1,NN
  111 PRINT 117, (A(I,J),J=1,NN)
C
  112 CONTINUE
C
      DO 113 J=1,NEV
C
C       EV(J)  = W(J+NBC)
C
         EV(J)=W(J)
  113 CONTINUE
C
C
      DO 114 I=1,NN
         X=SMASS(I)
         SMASS(I)=1./X**2
      DO 114 J=1,NEV
  114 AEIG(I,J)=A(I,J)*X
C
  115 RETURN
C
  116 FORMAT (2X, 28H ONEG. OR ZERO MASS EQUATION,I5)
  117 FORMAT (2X,10(F10.3,2X))
C
      END
      SUBROUTINE DYNDIS (NPI,NPJ,NPK,POIS,COMM,E,STI,AEIG,W,DAMP,BINF,AC
     1C,NMODED,STRXI,STRYI,STRXYI,NELEMD,AJ,AK,BJ,BK,NNODED,MK,NTSTEPD,N
     2ODBCD,NGACD,NDGRFD,NWDTHD,DSX,DSY,VEL,C4,C5,F,ACCEL,DXZERO,V,DIS,Y
     3H,YV,R,VOL,VW,VD,VE,VPOIS,VDEN,VDM,VACD,VACW,VDD,VDW,VHOR,VVER,DSV
     4X,DSVY,LLKV,VCXX,VCYY)
C
C     ***************************************************************
C
C     EVALUATION  OF  DYNAMIC  DISPLACEMENTS
C
C
      COMMON /FLAG/ IFLAG1,IFLAG2,IFLAG3,IFLAG4,IFLAG5,IFLAG6
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
      COMMON /DYNA1/ NTSTEP,NDTC,LK,NC,TLIMIT
      COMMON /MXSTR/ SMAX(50),SMIN(50),IMAX(50),IMIN(50),SMAXD(50),SMIND
     1(50),IMAXD(50),IMIND(50)
C
      REAL AJ(NELEMD),AK(NELEMD),BJ(NELEMD),BK(NELEMD),E(NELEMD),POIS(NN
     1ODED),STRXI(NELEMD),STRYI(NELEMD),STRXYI(NELEMD),DSX(NNODED),DSY(N
     2NODED),ACC(NGACD),DAMP(NMODED),BINF(NMODED,NODBCD),AEIG(NDGRFD,NMO
     3DED),W(NMODED),VEL(NMODED),C4(NMODED),C5(NMODED),F(NMODED),ACCEL(N
     4MODED),DXZERO(NTSTEPD),V(NTSTEPD),DIS(NTSTEPD),STI(NDGRFD,NWDTHD),
     5YH(NNODED),YV(NNODED),R(LLKV,NMODED),VOL(NNODED),VDEN(NNODED),VPOI
     6S(NNODED),VE(NNODED),VW(NMODED),VD(NMODED),VDM(NMODED,NODBCD),VACD
     7(NMODED),VACW(NMODED),VDD(LLKV,NMODED),VDW(LLKV,NMODED),VHOR(NNODE
```

```
     8D),VVER(NNODED),DSVX(NNODED),DSVY(NNODED)
C
      DIMENSION VCXX(NNODED), VCYY(NNODED)
C
      INTEGER NPI(NELEMD),NPJ(NELEMD),NPK(NELEMD),MK(NMODED)
C
C
C     INTEGRATION OF GROUND DISPLACEMENT USING SIMPSON RULE
C     ******************************************************
C
      PRINT 150, DT
      PRINT 153, (ACC(I),I=1,NTSTEP)
      IF (IFLAG2) 105,101,105
  101 DT2=DT/2.
      LIM=NTSTEP+2
      V(1)=DT2*(ACC(1)+ACC(2))
      DO 102 I=2,LIM
  102 V(I)=V(I-1)+DT2*(ACC(I)+ACC(I+1))
      PRINT 154, DT
      PRINT 153, (V(I),I=1,NTSTEP)
      DT3=DT/3.
      DIS(1)=DT3*V(1)
      DO 103 I=3,LIM,2
         L=(I+1)/2
  103 DIS(L)=DIS(L-1)+DT3*(V(I-2)+4.*V(I-1)+V(I))
      LMAX=L-1
      DO 104 I=1,LMAX
         II=I*2-1
         DXZERO(II)=DIS(I)
  104 DXZERO(II+1)=(DIS(I)+DIS(I+1))/2.
      PRINT 155, DT
      PRINT 153, (DXZERO(I),I=1,NTSTEP)
  105 CONTINUE
C
      KOUNT=0
      KPRINT=0
C
C     CALCULATING  RESPONSES  OF  NORMAL  VIBRATIONAL  MODES
C     MATRIX  R
C     ******************************************************
C
C
      DO 106 I=1,LK
      DO 106 J=1,NMODE
  106 R(I,J)=0.
      IND=0
      C1=DT/2.
      BETA=1./6.
      C2=BETA*DT**2
      C3=(.5-BETA)*DT**2
C
C
C     CASE OF TRAVELING BOUNDARY CONDITIONS
C
      DO 108 N=1,NMODE
         C4(N)=W(N)**2
         C5(N)=2.*DAMP(N)*W(N)
         F(N)=1.+C1*C5(N)+C2*C4(N)
         VEL(N)=0.
         ACCEL(N)=-ACC(1)
         Y=0.
         DO 107 NN=1,LK
            AA=VEL(N)+C1*ACCEL(N)
            BB=Y+DT*VEL(N)+C3*ACCEL(N)
            ACCEL(N)=(-ACC(NN+1)-C5(N)*AA-C4(N)*BB)/F(N)
            VEL(N)=AA+C1*ACCEL(N)
C
            VACD(N)=-((C5(N)*AA)/DAMP(N))/F(N)**2
            VACW(N)=(-((C5(N)*AA)/W(N))-(2.*C4(N)/W(N))*BB)/F(N)**2
            VDD(NN,N)=C2*VACD(N)
            VDW(NN,N)=C2*VACW(N)
C
```

```
          Y=BB+C2*ACCEL(N)
  107     R(NN,N)=Y
  108 CONTINUE
C
C
  109 KOUNT=KOUNT+1
      KPRINT=KPRINT+1
C
      IF (KOUNT-NC) 113,113,110
C
C      CASE OF NON TRAVELING BOUDARY CONDITIONS
C
  110 DO 111 I=1,NC
      DO 111 J=1,NMODE
  111 R(I,J)=R(I+1,J)
      DO 112 N=1,NMODE
         AA=VEL(N)+C1*ACCEL(N)
         BB=R(NC,N)+DT*VEL(N)+C3*ACCEL(N)
         ACCEL(N)=(-ACC(KOUNT+1)-C5(N)*AA-C4(N)*BB)/F(N)
         VEL(N)=AA+C1*ACCEL(N)
  112 R(NC+1,N)=BB+C2*ACCEL(N)
      IND=IND+1
C
C     CALCULATION  TOTAL  DISPLACEMENT OF NODAL  POINTS
C
  113 IKOUNT=KOUNT-IND
C
      IF (KPRINT-NDTC) 139,114,114
  114 KPRINT=0
      DO 117 KK=1,NNODE
         N=2*KK-1
         L=N+1
         YH(KK)=0.
         YV(KK)=0.
C
         VHOR(KK)=0.
         VVER(KK)=0.
C
         DO 116 K=1,NODBC
C
C
            IF (KOUNT-MK(K)) 117,117,115
  115       MM=IKOUNT-MK(K)
C
         DO 116 NI=1,NMODE
C
            HM=VDM(NI,K)*AEIG(N,NI)*R(MM,NI)
            HW=BINF(NI,K)*AEIG(N,NI)*VDW(MM,NI)
            HD=BINF(NI,K)*AEIG(N,NI)*VDD(MM,NI)
C
            VRM=VDM(NI,K)*AEIG(L,NI)*R(MM,NI)
            VRW=BINF(NI,K)*AEIG(L,NI)*VDW(MM,NI)
            VRD=BINF(NI,K)*AEIG(L,NI)*VDD(MM,NI)
C
C
            VDX=HM**2*VOL(KK)*VDEN(KK)+HW**2*VW(NI)+HD**2*VD(NI)
            VDY=VRM**2*VOL(KK)*VDEN(KK)+VRW**2*VW(NI)+VRD**2*VD(NI)
C
C
            VHOR(KK)=VHOR(KK)+VDX
            VVER(KK)=VVER(KK)+VDY
            HT=BINF(NI,K)*AEIG(N,NI)*R(MM,NI)
            YH(KK)=YH(KK)+HT
            VT=BINF(NI,K)*AEIG(L,NI)*R(MM,NI)
  116    YV(KK)=YV(KK)+VT
  117 CONTINUE
      DO 118 N=1,NNODE
C
         DSVX(N)=VHOR(N)
         DSVY(N)=VVER(N)
C
         DSX(N)=YH(N)
```

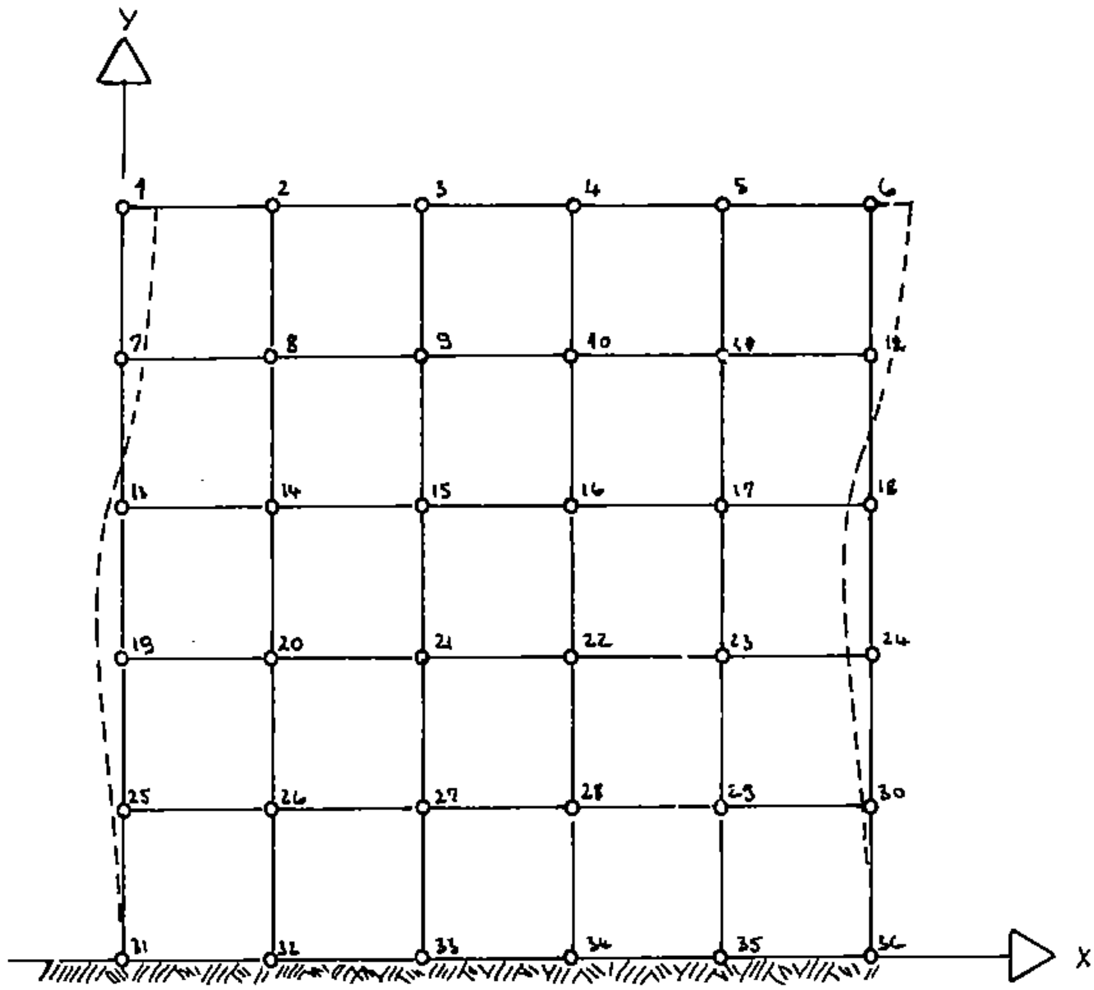
```
          DSY(N)=YV(N)
C
C
  118 CONTINUE
C
C
      FLAG=0
  119 IF (FLAG) 120,128,120
  120 IF (IFLAG3) 137,121,137
  121 IF (IFLAG4) 123,122,123
  122 PRINT 156
  123 DO 126 N=1,NNODE
          DO 125 K=1,NODBC
             IF (KOUNT-MK(K)) 126,126,124
  124        MI=KOUNT-MK(K)
C
             YH(N)=STI(2*N-1,K)*DXZERO(MI)
             YV(N)=STI(2*N,K)*DXZERO(MI)
C
             DSX(N)=DSX(N)+YH(N)
  125     DSY(N)=DSY(N)+YV(N)
  126 CONTINUE
C
      DO 127 I=1,NNODE
         VCXX(I)=SQRT(ABS(DSVX(I)))/DSX(I)
         VCYY(I)=SQRT(ABS(DSVY(I)))/DSY(I)
  127 CONTINUE
C
      GO TO 130
  128 EN=KOUNT
      TIME=EN*DT
      IF (TIME-TLIMIT) 129,129,137
  129 PRINT 157, TIME
C
      IF (IFLAG4) 137,130,137
  130 CONTINUE
      IF (FLAG) 142,131,133
C
  131 PRINT 143
      PRINT 144
      PRINT 159
      DO 132 I=1,NNODE
  132 PRINT 158, I,DSX(I),DSY(I)
C
  133 CONTINUE
      PRINT 145
      PRINT 144
      PRINT 159
      DO 134 I=1,NNODE
  134 PRINT 158, I,DSX(I),DSY(I)
C
      PRINT 146
      DO 135 I=1,NNODE
  135 PRINT 147, I,DSVX(I),DSVY(I)
      PRINT 148
      DO 136 J=1,NNODE
  136 PRINT 147, J,VCXX(J),VCYY(J)
C
      IF (FLAG) 137,138,137
C
C     ---------------------------------------------------------------
C
  137 CALL STRESS (NPI,NPJ,NPK,NELEMD,AJ,AK,BJ,BK,E,POIS,COMM,NNODED,STR
     1XI,STRYI,STRXYI,DSX,DSY,VE,VW,VPOIS,DSVX,DSVY,NMODED)
C
C     ---------------------------------------------------------------
C
      GO TO 139
  138 FLAG=1
      GO TO 119
  139 IF (KOUNT-NTSTEP) 109,140,140
C
```

```
C     PRINTING  ENVELOPE  OF  ELEMENT  STRESSES
C
  140 PRINT 149
      PRINT 151, (N,IMAX(N),SMAX(N),IMIN(N),SMIN(N),N=1,NELEM)
      IF (IFLAG4) 142,141,142
  141 PRINT 152
      PRINT 151, (N,IMAXD(N),SMAXD(N),IMIND(N),SMIND(N),N=1,NELEM)
  142 RETURN
C
  143 FORMAT (5X, 37HINERTIAL  COMPONENT OF  DISPLACEMENTS,/)
  144 FORMAT (2X,108H==================================================
     1==  ===================================================,/)
  145 FORMAT (5X, 36H TOTAL  DISPLACEMENTS  AND  STRESSES,/)
  146 FORMAT (5X, 52H  NODE         XVARIANCE         YVARIANCE    OF   DIS
     1P,/)
  147 FORMAT (2X,1I12,2E14)
  148 FORMAT (5X, 52H NODE          X-C.VAR.          Y-C.VAR.     OF   DIS
     1P,/)
  149 FORMAT (2X, 91HCYCLES OF TIME INTERVALS AT WHICH MAX  COEF. OF VAR
     1.    OCCUR    IN   X    AND  Y  DIRECTION,/11X, 39H EL.   CYCL  MAX
     2-CV.X     CYCL  MAX-CV.Y,/)
  150 FORMAT (2X, 46H GROUND  ACCELERATION  WITH  TIME  INTEPVAL = ,1F6.
     13/)
  151 FORMAT (2X,2I10,F11.3,I10,F11.3)
  152 FORMAT (2X, 99H CYCLES  OF TIME INTERVALS AT WHICH  MAX. AND MIN.
     1    STRESSES  OCCUR IN EACH INDIVIDUAL   ELEMENT,1X/, 43H EL.   CY
     2CL  MAX-STRESS   CYCLE MIN-STRESS )
  153 FORMAT (2X,8(F15.G,1X))
  154 FORMAT (2X, 41H GROUND  VELOCITY  WITH  TIME INTERVAL = ,1F6.3/)
  155 FORMAT (2X, 43H GROUND  DISPLACEMENT WITH TIME INTESVAL = ,1F6.3/)
  156 FORMAT (1H1)
  157 FORMAT (2X,  8H TIME = ,1F10.5/)
  158 FORMAT (2X,1I12,2F17.6)
  159 FORMAT (5X, 32H NODE           X-DISPL   Y-DISPL)
C
      END
      SUBROUTINE STRESS (NPI,NPJ,NPK,NELEMD,AJ,AK,BJ,BK,E,POIS,COMM,NNOD
     1ED,STRXI,STRYI,STRXYI,DSX,DSY,VE,VW,VPOIS,DSVX,DSVY,NNODED)
C
C     **************************************************************
C
C      EVALUATION  OF  STRESSES
C
C
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
      COMMON /DYNA1/ NTSTEP,NDTC,LK,NC,TLIMIT
      COMMON /VOLM/ AREA
C
      REAL AJ(NELEMD),AK(NELEMD),BJ(NELEMD),BK(NELEMD),E(NNODED),POIS(NN
     1ODED),STRXI(NELEMD),STRYI(NELEMD),STRXYI(NELEMD),DSX(NNODED),DSY(N
     2NODED),VE(NNODED),VW(NMODED),VPOIS(NNODED),DSVX(NNODED),DSVY(NNODE
     3D)
C
      COMMON /MXSTR/ SMAX(50),SMIN(50),IMAX(50),IMIN(50),SMAXD(50),SMIND
     1(50),IMAXD(50),IMIND(50)
C
C
      INTEGER NPI(NELEMD),NPJ(NELEMD),NPK(NELEMD)
C
C
C     ELEMENT  STRESSES FROM  NODAL POINT  DISPLACEMENT
C
      PRINT 113
C
C     INITIATING  TIME  RECORD  INDICES  FOR  STRESSES
C
      DO 101 N=1,NELEM
         CENT=(STRXI(N)+STRYI(N))/2.
         IF (CC.EO.0.) GO TO 101
C
         RAD=SQRT(((STRYI(N)-STRXI(N))/2.)**2+STRXYI(N)**2)
```

```
          SMAX(N)=CENT+RAD
          SMIN(N)=CENT-RAD
          SMAXD(N)=SMAX(N)
          SMIND(N)=SMIN(N)
  101 CONTINUE
C
      FVW=0.
      DO 102 I=1,NMODE
  102 FVW=FVW+VW(I)
C
C
      DO 111 N=1,NELEM
         I=NPI(N)
         J=NPJ(N)
         K=NPK(N)
C
         EMOD=(E(I)+E(J)+E(K))/3.
         POISR=(POIS(I)+POIS(J)+POIS(K))/3.
         FVE=(VE(I)+VE(J)+VE(K))/3.
         FVPOIS=(VPOIS(I)+VPOIS(J)+VPOIS(K))/3.
C
C
         EPSILX=(BJ(N)-BK(N))*DSX(I)+BK(N)*DSX(J)-BJ(N)*DSX(K)
         EPSILY=(AK(N)-AJ(N))*DSY(I)-AK(N)*DSY(J)+AJ(N)*DSY(K)
         GAMA=(AK(N)-AJ(N))*DSX(I)-AK(N)*DSX(J)+AJ(N)*DSX(K)+(BJ(N)-BK(N
     1   ))*DSY(I)+BK(N)*DSY(J)-BJ(N)*DSY(K)
         COMM=EMOD/((1.-POISR**2)*(AJ(N)*BK(N)-AK(N)*BJ(N)))
         STRX=COMM*(EPSILX+POISR*EPSILY)+STRXI(N)
         STRY=COMM*(EPSILY+POISR*EPSILX)+STRYI(N)
         STRXY=COMM*GAMA*(1.-POISR)*.5+STRXYI(N)
C
C       EVALUATION OF  STATISTICAL  CHARACTERISTICS OF STRESSES
C
C
         EXW=(BJ(N)-BK(N))*DSVX(I)+BK(N)*DSVX(J)-BJ(N)*DSVX(K)
         EYW=(AK(N)-AJ(N))*DSVY(I)-AK(N)*DSVY(J)+AJ(N)*DSVY(K)
         GW=(AK(N)-AJ(N))*DSVX(I)-AK(N)*DSVX(J)+AJ(N)*DSVX(K)+(BJ(N)-BK(
     1   N))*DSVY(I)+BK(N)*DSVY(J)-BJ(N)*DSVY(K)
C
C
         SXW=COMM*(EXW+POISR*EYW)
         SYW=COMM*(EYW+POISR*EXW)
         SXYW=COMM*GW*(1.-POISR)*.5
C
C
         SXE=COMM*(EPSILX+POISR*EPSILY)/EMOD
         SYE=COMM*(EPSILY+POISR*EPSILX)/EMOD
         SXYE=COMM*GAMA*(1.-POISR)*.5/EMOD
C
C
         DCOM=(1.-POISR)*2.*AREA
         SXN=COMM*EPSILY+(EPSILX+POISR*EPSILY)*(EMOD*2.*AREA*2.*POISR)/D
     1   COM**2
         SYN=COMM*EPSILX+(EPSILY+POISR*EPSILX)*(EMOD*2.*AREA*2.*POISR)/D
     1   COM**2
         SXYN=-COMM*GAMA*.5-GAMA*POISR*(EMOD*2.*AREA*2.*POISR)/DCOM**2
C
C
         VSTX=(FVW*SXW**2)+(FVE*SXE**2)+(FVPOIS*SXN**2)
         VSTY=(FVW*SYW**2)+(FVE*SYE**2)+(FVPOIS*SYN**2)
         VSTXY=(FVW*SXYW**2)+(FVE*SXYE**2)+(FVPOIS*SXYN**2)
C
C
         CENT=(STRX+STRY)/2.
         RAD=SQRT(((STRY-STRX)/2.)**2+STRXY**2)
         SIGMAX=CENT+RAD
         SIGMIN=CENT-RAD
         TAUMAX=(SIGMAX-SIGMIN)/2.
         IF (TIME-TLIMIT) 103,103,111
C
  103    CONTINUE
         COFSTX=SQRT(ABS(VSTX))/STRX
```

```
         COFSY=SQRT(ABS(VSTY))/STRY
C
         PRINT 114, N,STRX,STRY,STRXY,SIGMAX,SIGMIN,TAUMAX
         PRINT 112, VSTX,VSTY
         IF (FLAG) 104,111,104
  104    IF (SMAXD(N)-SIGMAX) 105,106,106
  105    SMAXD(N)=SIGMAX
         IMAXD(N)=KOUNT
  106    IF (SMIND(N)-SIGMIN) 111,111,107
  107    SMIND(N)=SIGMIN
         IMIND(N)=KOUNT
         IF (SMAX(N)-COFSTX) 108,109,109
  108    SMAX(N)=COFSTX
         IMAX(N)=KOUNT
  109    IF (SMIN(N)-COFSY) 110,111,111
  110    SMIN(N)=COFSY
         IMIN(N)=KOUNT
  111 CONTINUE
C
      RETURN
C
  112 FORMAT (2X, 10HVARIANCE  ,3E14)
  113 FORMAT (5X,103H  ELEMENT   X-STRESS   Y-STRESS   XY-STRESS
     1        MAX-STRESS   MIN-STRESS   MAX-SHEAR          )
  114 FORMAT (5X,1I10,3F15.4,5X,4F15.2)
C
      END
      SUBROUTINE EIGUNCR (SMASS,AEIG,ST,OMEGAM,OMEGAK,W,KST,VE,VDEN,VW,N
     1DGRFD,NWDTHD,NNODED,NMODED,VALFA,VBETA,E,VOL,IDEBUG)
C
C     ************************************************************
C
C     UNCERTAINTY  ANALYSIS  OF  NATURAL  FREQUENCIES
C
C
C
      COMMON /MESH/ NNODE,NELEM,NODBC,NN,NBAND
      COMMON /DYNA/ NMODE,KOUNT,FLAG,TIME,RMVEL,DT
C
      REAL SMASS(NDGRFD),AEIG(NDGRFD,NMODED),ST(NDGRFD,NWDTHD),W(NMODED)
     1,VE(NNODED),VDEN(NNODED),VW(NMODED),VALFA(NNODED),VBETA(NNODED),KS
     2T(NDGRFD),OMEGAM(NMODED,NMODED),OMEGAK(NMODED,NMODED),E(NNODED),VO
     3L(NNODED)
C
      REAL NUMERM,NUMERK
C
C     STIFNESS  +  MASS  TERMS
C
      REWIND 1
      READ (1) ((ST(I,J),I=1,NN),J=1,NBAND)
C
      DO 101 I=1,NNODED
         II=I*2-1
C
C
         KST(I)=ST(II,1)
  101 CONTINUE
C
      DO 102 J=1,NMODE
         L=2*J-1
         L2=2*J
C
C
         AA=2./(NMODE*SMASS(L)**2)
         A2=2./(NMODE*SMASS(L2)**2)
         VALFA(L)=AA*VDEN(J)*(VOL(J)**2)
         VALFA(L2)=A2*VDEN(J)*(VOL(J)**2)
C
         BB=2./(NMODE*KST(L)**2)
         B2=2./(NMODE*KST(L2)**2)
         VBETA(L)=BB*VE(J)*(KST(L)/E(J))**2
         VBETA(L2)=B2*VE(J)*(KST(L2)/E(J))**2*1000000.
  102 CONTINUE
```

```
C
      COEF=0.
      DO 103 I=1,NMODE
      DO 103 J=1,NMODE
         COEF=COEF+(AEIG(J,I)**2)*SMASS(J)
C
  103 CONTINUE
C
      K1=1
  104 IF (K1.GT.NMODE) GO TO 106
C
      DO 105 I=1,NMODE
C
C
         NUMERM=-(AEIG(I,K1)**2)*SMASS(K1)*W(K1)
         DENOMM=2.*COEF
C
         OMEGAM(K1,I)=NUMERM/DENOMM
C
         NUMERK=-(AEIG(I,K1)**2)*KST(K1)
         DENOMK=2.*W(K1)*COEF
C
         OMEGAK(K1,I)=NUMERK/DENOMK
C
  105 CONTINUE
C
      K1=K1+1
      GO TO 104
  106 CONTINUE
C
      VMASS=0.
      VSTIF=0.
      VWW=0.
      NMM=NMODE/2
C
      DO 108 II=1,NMM
         I=2*II-1
         DO 107 JJ=1,NMM
            J=2*JJ-1
            VWW=VWW+(OMEGAM(I,J)**2*VALFA(J)+OMEGAK(I,J)**2*VBETA(J))
C
            VMASS=VMASS+(OMEGAM(I,J)**2*VALFA(J))
            VSTIF=VSTIF+(OMEGAK(I,J)**2*VBETA(J))
C
  107    CONTINUE
C
         PRINT , ≠VMASS,VSTIF≠,VMASS,VSTIF
         VW(I)=VWW
  108 CONTINUE
C
C      ******DEBUG******
C
      IF (IDEBUG.EQ.1) GO TO 111
      PRINT , ≠OMEGAM≠
C
C
      DO 109 I=1,NMODE
  109 PRINT 112, (OMEGAM(I,J),J=1,NMODE)
      PRINT , ≠OMEGAK≠
      DO 110 I=1,NMODE
  110 PRINT 112, (OMEGAK(I,J),J=1,NMODE)
C
  111 CONTINUE
C
      PRINT , ≠VARIANCEOFEIGENVALUES≠
      PRINT 112, (VW(I),I=1,NMODE)
C
C     STOP
C
      RETURN
C
  112 FORMAT (2X,11F12.6)
```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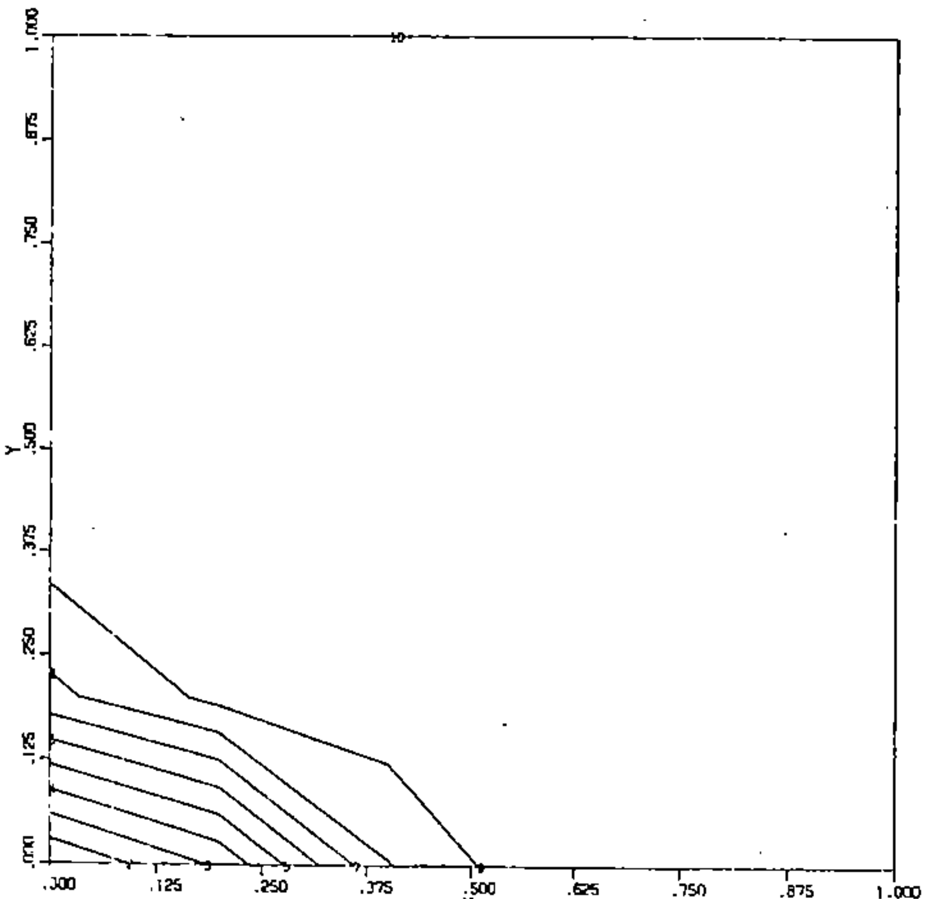
SPATIAL DISTRIBUTION OF THE DISPLACEMENTS

AT TIME 1.3 sec



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AT TIME 2.7 sec