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EXPANSION AND IMPROVEMENT OF THE FORMA SYSTEM FOR RESPONSE AND LOAD ANALYSIS

Volume IIC - Listings, Finite Element FORMA Subroutines

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This report presents results of the expansion and improvement of the FORMA system for response and load analysis. The acronym FORMA stands for FORTRAN Matrix Analysis. The study, performed from 16 May 1975 through 17 May 1976 was conducted by the Analytical Mechanics Department, Martin Marietta Corporation, Denver Division, under the contract NASA-31379. The program was administered by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama under the direction of Dr. John R. Admire, Structural Dynamics Division, Systems Dynamics Laboratory.

This report is published in seven volumes:

Volume I - Programming Manual,
Volume IIA - Listings, Dense FORMA Subroutines,
Volume IIB - Listings, Sparse FORMA Subroutines,
Volume IIC - Listings, Finite Element FORMA Subroutines,
Volume IIIA - Explanations, Dense FORMA Subroutines,
Volume IIIB - Explanations, Sparse FORMA Subroutines, and
Volume IIIC - Explanations, Finite Element FORMA Subroutines.
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ABSTRACT

This report presents techniques for the solution of structural dynamic systems on a electronic digital computer using FORMA (FORTRAN Matrix Analysis).

FORMA is a library of subroutines coded in FORTRAN IV for the efficient solution of structural dynamics problems. These subroutines are in the form of building blocks that can be put together to solve a large variety of structural dynamics problems. The obvious advantage of the building block approach is that programming and checkout time are limited to that required for putting the blocks together in the proper order.

The FORMA method has advantageous features such as:

1. subroutines in the library have been used extensively for many years and as a result are well checked out and debugged;
2. method will work on any computer with a FORTRAN IV compiler;
3. incorporation of new subroutines is no problem;
4. basic FORTRAN statements may be used to give extreme flexibility in writing a program.

Two programming techniques are used in FORMA: dense and sparse.
ACKNOWLEDGMENTS

The editor expresses his appreciation to those individuals whose assistance was necessary for the successful completion of this report. Dr. John R. Admire was instrumental in the definition of the program scope and contributed many valuable suggestions. Messrs. Carl Bodley, Wilcomb Benfield, Darrell Devers, Richard Hruda, Roger Philippus, and Herbert Wickenning, all of the Analytical Mechanics Department, Denver Division of Martin Marietta Corporation, have contributed ideas, as well as subroutines, in the formulation of the FORMA library.

The editor also expresses his appreciation to those persons who developed FORTRAN, particularly the subroutine concept of that programming tool.
I. INTRODUCTION

A listing of the source deck of each finite element FORMA subroutine is given in this volume to remove the "black box" aura of the subroutines so that the analyst may better understand the detailed operations of each subroutine.

The FORTRAN IV programming language is used in all finite element FORMA subroutines.
II. SUBROUTINE LISTINGS

The subroutines are given in alphabetical order with numbers coming before letters.
SUEROUTINE AXIAL (XYZ,JDOF,EUL,NUTL,NJ),
*    NUTMX,NUTXX,NUTLT,NUTST,
*    W1,T,S,KX,KJ,KE,KW)
DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KF,1),W(KW,1),T(KW,1),S(KW,1)
DIMENSION CJ(3,2), E(3,2), IVE(6)
DATA NAMEL/6MAXIAL /, NRW,NRLT/6,2/, IBLNK/6H /, KGCJ/3/.
DATA NIT,NCT/5,6/.

SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT...

    MASS MATRICES AND IVECS (ON NUTMX),
    STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
    AND IVECS (ON NUTXX)
    LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
    STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
    FOR AXIAL ROD ELEMENTS.
    MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
    GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
    (U,V,W) JOINT 1, THEN JOINT 2.
    WHERE U,V,W ARE TRANSLATIONS.
    IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
    IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
    IVEC(3)=0 OOMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINTS
    ELEMENT DOF 3 TO ZERO MOTION.
    GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL
    COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
    DIRECTIONS.
    ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
    (PU,PV,PW) JOINT 1, THEN JOINT 2.
    WHERE P IS FORCE.
    LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN LOCAL
    COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
    DIRECTIONS.
    ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
    PX1,PX2
    WHERE PX IS AXIAL FORCE.
    PX1(-), PX2(+) IS TENSION. PX2(+) IS COMPRESSION.
    STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
    COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
    ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
    SIGMA-X1, SIGMA-X2
    WHERE SIGMA IS NORMAL STRESS.
    SX1(-), SX2(+) IS TENSION. SX1(+) IS COMPRESSION.
    DATA ARRANGEMENT ON NUTMX, NUTXX, NUTLT, NUTST FOR EACH:FINITE
    ELEMENT IS (W,W,K,LT,ST)
    WRITE (NUTWX) NAMEN,NEL,NR,NC,NAMEN,(IBLNK,I=1,5),
       ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
    CALLS FORMA SUBROUTINES MASIA, PAGEHD, STFIA, ZZBOMB.
    LAST REVISION BY WA EENFIELD. MARCH 1976.

******************************************************************************

INPUT DATA READ IN THIS SUBROUTINE FROM NUTL. IF NUTL = 5, DATA IS
READ FROM CARDS.

NAMEK,NAMET,NAMEN,NAMST
RDE E

FORMAT (4(A6,4X))
FORMAT (2(5X,E10))
SUBROUTINE AXIAL -- 2/4

C 20 NEL,J1,J2,A1,A2
C IF (J1 .EQ. 0) RETURN
C GO TO 20
C
C DEFINITION OF INPUT VARIABLES.
C NAME = TYPE OF MASS MATRIX WANTED.
C = M1, DIAGONAL LUMPED.
C = M2, CONSISTENT.
C = 6H OR 6HNUMMASS, NO MASS MATRIX CALCULATED.
C NAMEKE = TYPE OF STIFFNESS MATRIX WANTED.
C = K1, CONSTANT AXIAL FORCE ASSUMED.
C = 6H OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C = 6H OR 6HNLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C = 6H OR 6HNSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C RD = MASS DENSITY.
C E = YOUNG'S MODULUS OF ELASTICITY.
C NEL = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C CALCULATIONS. WRITTEN ON NUTMX, ETC.
C J1 = JOINT NUMBER AT ROD END 1.
C J2 = JOINT NUMBER AT ROD END 2.
C A1 = CROSS-SECTION AREA AT ROD END 1.
C A2 = CROSS-SECTION AREA AT ROD END 2.
C
C EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C I = INTEGER DATA, RIGHT ADJUSTED.
C F = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C X = CARD COLUMNS SKIPPED.
C
C SUBROUTINE ARGUMENTS (ALL INPUT)
C XYZ = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C JDOF = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C ROTATION DOFS. SIZE(NJ,6).
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C MASS MATRICES AND IVFCS ARE OUTPUT.
C NUTM MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C MATRICES) AND IVFCS ARE OUTPUT.
C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NULT = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C W = MATRIX WORK SPACE. MIN SIZE(6,6).
C T = MATRIX WORK SPACE. MIN SIZE(6,6).
C S = MATRIX WORK SPACE. MIN SIZE(6,6).
C KK = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C KJ = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C KE = ROW DIMENSION OF FUL IN CALLING PROGRAM.
C
C NEPRCR EXPLANATION
C 1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C 2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C 3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C 4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
C 5 = ST MATRIX FORMED, NUTST .LE. ZERO.
C
1001 FORMAT (4(A6,4X))
1002 FORMAT (2(5X,E10.6))
1003 FORMAT (16F,4E10.0)
2001 FORMAT (/46X 29HINPUT DATA FOR AXIAL ELEMENTS)
2002 FORMAT (/40X 41HINPUT DATA FOR AXIAL ELEMENTS (CONTINUED))
2003 FORMAT (/ 16X7MASS = A6, 9X7STIF = A6, 9X13HLOAD TRANS = A6,
* 6X15HSTRESS TRANS = A6,
* / 18X4HRO = E10.3, 9X3HE = E10.3,
* /16X7HELELEMENT 13X7HJOINT 1 13X7HJOINT 2 15X4HAREA
* / 16X4HAREA / 16X6HNUMEER 55X7HJOINT 1 13X7HJOINT 2 /)
2004 FORMAT (1X 3120, 14X E10.3, 10X E10.3)
C
C READ AND WRITE FINITE ELEMENT DATA.
C NLINE = 0
C CALL PAGEBD
C WRITE (NUT,1001)
C READ (NUTEL,1001) NAMEM,NAMKE,NAMLT,NAMSTE
C READ (NUTEL,1002) RO,E
C WRITE (NUT,1003) NAMEM,NAMKE,NAMLT,NAMSTE,RO,E
C 20 READ (NUTEL,1003) NEL,J1,J2,A1,A2
C IF (J1 .LE. 0) RETURN
C NLINE = NLINE + 1
C IF (NLINE .LE. 42) GO TO 30
C CALL PAGEBD
C WRITE (NUT,1002)
C WRITE (NUT,1003) NAMEM,NAMKE,NAMLT,NAMSTE,RO,E
C NLINE = 0
C 30 WRITE (NUT,1004) NEL,J1,J2,A1,A2
C IF (J1 .GT. NJ .OR. J2 .GT. NJ ) GO TO 999
C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLE!. REVADD IVECS.
C DO 42 I=1,3
C CJ(I,1) = XYZ(J,1)
C CJ(I,2) = XYZ(J,2)
EJ(I,1) = FUL(J,1)
EJ(I,2) = FUL(J,2)
IV1(I) = JDIF(J,1)
IV1(I+3) = JDIF(J,2)

C FORM MASS MATRIX (W).
IF (NAMEM .EQ. 6H .AND. NAMEM .EQ. 6HNOUASS) GO TO 110
CALL MASIA (CJ, EJ, A1, A2, RO, NAMEM, W, KJ, KCJ, KW)

IF (NUTMX .LE. 0) GO TO 999
WRITE (NUTMX) NAMEM, NEL, NF, NR, NAMEL, (IBLNK, I=1, 3),
* ((W(I,J), I=1, NR), J=1, NR), (IV1(I), I=1, NR)

C FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C STRESS TRANSFORMATION MATRIX (S).
110 IF (NAMEK .EQ. 6H .AND. NAMEK .EQ. 6HNNOSTIF) GO TO 20
CALL STF1A (CJ, EJ, A1, A2, E, NAMEK, NAMEST, W, T, S, NRST,
* KJ, KCJ, KW, KW)

IF (NUTMX .LE. 0) GO TO 999
WRITE (NUTMX) NAMEK, NEL, NR, NR, NAMEL, (IBLNK, I=1, 5),
* ((W(I,J), I=1, NR), J=1, NR), (IV1(I), I=1, NR)
IF (NAMET .EQ. 6H .AND. NAME .EQ. 6HNOLOAD) GO TO 115

IF (NUTL .LE. 0) GO TO 999
WRITE (NUTL) NAMELT, NEL, NRTL, NR, NAMEL, (IBLNK, I=1, 5),
* ((T(I,J), I=1, NRTL), J=1, NR), (IV1(I), I=1, NR)
115 IF (NAMEST .EQ. 6H .AND. NAME .EQ. 6HNOSTRES) GO TO 20

IF (NUTST .LE. 0) GO TO 999
WRITE (NUTST) NAMEST, NEL, NRST, NR, NAMEL, (IBLNK, I=1, 5),
* ((S(I,J), I=1, NRST), J=1, NR), (IV1(I), I=1, NR)
GO TO 20

999 CALL ZZBOME (6HAXIAL, NERROR)
END
SUBROUTINE R1A1 (RL,Z,KZ)
DIMENSION Z(KZ,1)

C C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C C BUCKLING MATRIX
C C FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C C BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
C C BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
C C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE IN THE X-Z PLANE
C C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C DZ1,DZ2
C WHERE DZ IS TRANSATION.
C DEVELOPED BY RL WOHLEN. AUGUST 1973.
C LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
C SUBROUTINE ARGUMENTS
C RL = INPUT ROD LENGTH.
C Z = OUTPUT BUCKLING MATRIX. SIZE(2,2).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
C C = 1./RL
Z(1,1) = C
Z(1,2) = -C
Z(2,1) = -C
Z(2,2) = C

RETURN
END
SUBROUTINE B1A2 (RL, Z, K2)
DIMENSION Z(K2,1)

SUBROUTINE TO CALCULATE FINITE ELEMENT...
BUCKLING MATRIX
FOR A BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE.
WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
LOCAL COORDINATE ORDER IS
DZ1, DZZ, TY1, TY2
WHERE DZ IS TRANSLATION AND TY IS ROTATION.
DEVELOPED BY RL WOHLEN. AUGUST 1973.
LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.

SUBROUTINE ARGUMENTS
RL = INPUT ROD LENGTH.
Z = OUTPUT BUCKLING MATRIX. SIZE(4,4).
K2 = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.

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SUBROUTINE BAR (XYZ, JDREF, EUL, NUTEL, NJ,
* NUTMX, NUTKX, NUTRX, NULT, NUTST,
* W, T, S, KJ, KE, KX)
DIMENSION XYZ(KR, 1), JDREF(KJ, 1), EUL(KE, 1), W(KW, 1), T(KW, 1), S(KW, 1)
DIMENSION CJ(3, 3), EJ(3, 2), IV1(12), TR(12, 12), TD(24, 24)
DIMENSION KODEK(4), KODEK(2), IFPN(4), IV2(4)
DATA NAMEL / 6HEAP /
DATA NROW, NPLT/12, 12/, IBLNK/6H /*, KJ/3/*, KTR/12/*, KTD/24/
DATA NIT, NCT/5, 6/
C C SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C MASS MATRICES AND IVECS (ON NUTMX),
C STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C AND IVECS (ON NUTKX),
C UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTRX),
C LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NULT),
C STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
C FOR COMBINED AXIAL-TORSION-ENDIING BAR ELEMENTS.
C MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C DIRECTIONS.
C GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
C (U, V, W, P, O, R) JOINT 1, THEN JOINT 2
C WHERE U, V, W ARE TRANSLATIONS AND P, O, R ARE ROTATIONS.
C IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES ...
C IVEC(6) = 834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C IVEC(3) = 0 OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINTS
C ELEMENT DOF 3 TO ZERO MOTION.
C GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL
C COORDINATE SYSTEM TO DEFORMATIONS IN THE GLOBAL COORDINATE
C DIRECTIONS.
C ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C (PU, PV, PW, MP, MO, MR) JOINT 1, THEN JOINT 2
C WHERE P IS FORCE AND M IS MOMENT.
C LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS LOCAL
C COORDINATE SYSTEM TO DEFORMATIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C PX1, PX2, MX1, M1X2, FY1, FY2, M21, M22, PZ1, PZ2, MY1, MY2
C WHERE P IS FORCE AND M IS MOMENT.
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS LOCAL
C COORDINATE SYSTEM TO DEFORMATIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C PX1/A1, PX2/A2, MX1/R1/TJ1, MX2/R2/TJ2,
C PY1/A1, PY2/A2, M21/CY1/B121, M22/CY1/B122,
C PZ1/A1, PZ2/A2, MY1/CZ1/E1Y1, MY2/CZ2/E1Y2
C WHERE P IS FORCE AND M IS MOMENT.
C DATA ARRANGEMENT ON NUTMX, NUTKX, NUTRX, NULT, NUTST FOR EACH
C FINITE ELEMENT IS (N, M, KE, E, L, ST)
C WRITE (NUTMX) NAME, NEL, NR, NC, NAMEL, (IBLNK, I = 1, 5),
C ((W(I, J), I = 1, NR), J = 1, NC), (IVEC(1), I = 1, NC)
C CALLS FORM SUBROUTINES EUCB, MASLE, PAGE80, STFB, TZBOME.
C LAST REVISION BY RL WOHLEN. APRIL 1976.
C
C**********************************************************************************************************
C INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
READ FROM CARDS.
NAMEN,NAMES1,NAMES2,NAMES3,NAMES4
KODEK(1),I=1,4),KODEB(1),I=1,2
R0,E,C
20 MEL,J1,J2,J3,REF,A1,P11,TJ1,61Z1,B1Y1,SF1
IFPY1,IFPZ1,IFPY2,IFPZ2,IFAPR
IF (J1.EQ.0) RETURN
IF (IFAPR .EQ. 1) A2,P12,TJ2,61Z2,B1Y2 FORMAT (415,5E10,E5,5A1)
30 IF (NAMEST .EQ. 6) .OR. NAMEST .EQ. 6HNCSTRS) GO TO 20
R1,CY1,CZ,R2,CY2,CZ
GO TO 20

INPUT DATA REQUIREMENTS

AXIAL TORSION BENDING BENDING
ALONG ABOUT ABOUT
LOCAL X LOCAL X LOCAL Z LOCAL Y

MASS A,RO PI,RO A,RO
STIFF, LOAD TRANS A,EF TJ,G E1Z1,A,SF,E,G E1Y1,A,SF,E,G
BUCKLING NONE NONE NONE
STRESS TRANS SEE STIF STIF+R STIF-CY STIF+CZ

FOR NO SHEAR DEFORMATION IN BENDING, SET ANY OF A (NOT IF AXIAL USED),
SF, OR GINCT IF TORSION IS USED) TO ZERO. IF BENDING STRESS
TRANSFORMATION IS WANTED, A MUST NOT BE ZERO.

DEFINITION OF INPUT VARIABLES.
NAMEN = TYPE OF MASS MATRIX WANTED.
= M1, DIAGONAL LUMPED.
= M2, CONSISTENT.
= 6H, CR 6H-NOMASS, NO MASS MATRIX CALCULATED.

NAMES1 = TYPE OF STIFFNESS MATRIX WANTED.
= K1, CONSTANT FORCE FOR AXIAL, CONSTANT TORQUE FOR TORSION,
CONSTANT SHEAR AND LINEAR MOMENT FOR BENDING.
= 6H, CR 6H-NOSTIF, NO STIFFNESS MATRIX CALCULATED.

NAMEST = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
= 6H, CR 6H-NCLOAD, DC LOAD TRANSFORMATIONS CALCULATED.

NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
= 6H, CR 6H-NCSTRS, NO STRESS TRANSFORMATIONS CALCULATED.

NAMEB = TYPE OF BUCKLING MATRIX WANTED.
= E1, AXIAL RCO.
= E2, BEAM.
= 6H, CR 6H-NCBUCK, NO BUCKLING MATRIX CALCULATED.

KODEK = OPTION CODE FOR AXIAL, TORSION, BENDING Z, BENDING Y LOCAL
STIFFNESS. IF BLANK, ALL FOUR ARE CALCULATED. SIZE(4).
KODEK(1)=A, LOCAL STIF MTRIX IS CALCULATED FOR AXIAL
(AMEPT LOCAL X-AXIS).
KODEK(2)=T, LOCAL STIF MTRIX IS CALCULATED FOR TORSION
(AMEPT LOCAL X-AXIS).
KODEK(3)=E2, LOCAL STIF MTRIX IS CALCULATED FOR BENDING
(AMEPT LOCAL X-AXIS).
KODEK(4)=EY, LOCAL STIF MTRIX IS CALCULATED FOR BENDING
(AMEPT LOCAL Y-AXIS).

KODEB = OPTION CODE FOR BUCKLING IN LOCAL Y OR Z DIRECTION.
IF BLANK, BOTH ARE CALCULATED. SIZE(2).
KODEB(1)=EY, LOCAL BUCKLING MATRIX IS CALCULATED FOR
DEFLECTION IN LOCAL Y DIRECTION.

KODEE(2)=6, LOCAL BUCKLING MATRIX IS CALCULATED FOR
DEFLECTION IN LOCAL Z DIRECTION.

RO = MASS DENSITY.
E = YOUNG'S MODULUS OF ELASTICITY.
G = SHEAR MODULUS OF ELASTICITY.
NEL = FINITE ELEMENT NUMBER, FOR REFERENCE ONLY, NOT USED IN
CALCULATIONS, WRITTEN ON NUTMX, ETC.
J1 = JOINT NUMBER AT BAR END 1. LOCAL X-AXIS ORIGI-NATES AT J1.
J2 = JOINT NUMBER AT BAR END 2. LOCAL X-AXIS GOES FROM J1 TO J2.
JREF = REFERENCE POINT. LOCAL Z-AXIS IS DEFINED BY VECTOR (J1,J2)
CROSSED INTO VECTOR (J1,JREF). LOCAL Y-AXIS LIES IN XY PLANE
DEFINED BY J1,J2,JREF.
A1 = CROSS-SECTION AREA AT BAR END 1.
A2 = SAME AS A1 AT BAR END 2.
PI1 = CROSS-SECTION POLAR AREA MOMENT OF INERTIA FOR MASS
CALCULATIONS AT BAR END 1.
PI2 = SAME AS PI1 AT BAR END 2.
TJ1 = CROSS-SECTION SPAN VENANTS TOR-SION CONSTANT (J) IN JG FOR
TORSION STIFFNESS AT BAR END 1.
TJ2 = SAME AS TJ1 AT BAR END 2.
BIZ1 = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Z-AXIS
(FOR BENDING) AT BAR END 1.
BIZ2 = SAME AS BIZ1 AT BAR END 2.
BIY1 = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Y-AXIS
(FOR BENDING) AT BAR END 1.
BIY2 = SAME AS BIY1 AT BAR END 2.
SF = SHAPE FACTOR (K) FOR SHEAR IN KAG.
USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
IFPY1 = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Y AT BAR END 1.
= 1H, MOMENT JOINT.
= 1HP, PIN JOINT.
IFPY2 = SAME AS IFPY1 AT BAR END 2.
IFPZ1 = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Z AT BAR END 1.
= 1H, MOMENT JOINT.
= 1Hp, PIN JOINT.
IFPZ2 = SAME AS IFPZ1 AT BAR END 2.
IFTAPR = OPTION FOR TAPERED END.
= 1H, CONSTANT SECTION PROPERTIES.
= 1HT, LINEAR TAPER SECTION PROPERTIES.
R1 = DISTANCE FROM LOCAL X-AXIS TO OUTER FIBER FOR TORSION
STIFFNESS CALCULATION AT BAR END 1.
R2 = SAME AS R1 AT BAR END 2.
CY1 = DISTANCE FROM LOCAL XZ PLANE TO OUTER FIBER FOR BENDING
STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.
CY2 = SAME AS CY1 AT BAR END 2.
CZ1 = DISTANCE FROM LOCAL XY PLANE TO OUTER FIBER FOR BENDING
STRESS CALCULATION AT BAR END 1. LOCAL Z DIRECTION.
CZ2 = SAME AS CZ1 AT BAR END 2.

EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
I = INTEGER DATA, RIGHT ADJUSTED.
E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
**SUBROUTINE ARGUMENTS (ALL INPUT)**

- **XYZ**: Matrix of joint global X, Y, Z locations. Rows correspond to joint numbers. Columns 1, 2, 3 correspond to the joint X, Y, Z locations respectively. Size(NJ, 3).
- **JDOF**: Matrix of joint global degrees of freedom. Rows correspond to joint numbers. Columns 1, 2, 3 correspond to the joint translation DOFs and columns 4, 5, 6 correspond to the joint rotation DOFs. Size(NJ, 6).
- **EUL**: Matrix of joint Euler angles (degrees). Rows correspond to joint numbers. Columns 1, 2, 3 correspond to the joint global X, Y, Z permutation. Size(NJ, 3).
- **NJ**: Logical number of tape containing element input data for this subroutine. If NJT = 5, data is read from cards.
- **NUTEL**: Number of joints in lines in matrices (XYZ), (JDOF), (EUL).
- **NUTMX**: Logical number of utility tape on which element mass matrices and IVECs are output. NUTMX may be zero if mass matrix is not formed. Uses FORTRAN READ, WRITE.
- **NUTMX**: Logical number of utility tape on which element stiffness matrices (same as global loads transformation matrices) and IVECs are output. NUTMX may be zero if stiffness matrix is not formed. Uses FORTRAN READ, WRITE.
- **NUTBX**: Logical number of utility tape on which element unit load buckling matrices and IVECs are output. NUTBX may be zero if buckling matrix is not formed. Uses FORTRAN READ, WRITE.
- **NUTLT**: Logical number of utility tape on which element local load transformation matrices and IVECs are output. NUTLT may be zero if local load transformations are not formed. Uses FORTRAN READ, WRITE.
- **NUTST**: Logical number of utility tape on which element stress transformation matrices and IVECs are output. NUTST may be zero if stress transformations are not formed. Uses FORTRAN READ, WRITE.
- **W**: Matrix work space. Min size(12, 12).
- **T**: Matrix work space. Min size(12, 12).
- **S**: Matrix work space. Min size(17, 12).
- **KX**: Row dimension of XYZ in calling program.
- **KJ**: Row dimension of JDOF in calling program.
- **KE**: Row dimension of EUL in calling program.
- **KW**: Row dimension of W, T, and S in calling program. Min=12.

**NEPREF EXPLANATION**

1. Joint number greater than number of joints.
2. Stiffness matrix formed, NUTMX .LE. ZERO.
3. Load transformation matrix formed, NUTLT .LE. ZERO.
4. Stress transformation matrix formed, NUTST .LE. ZERO.
5. Mass matrix formed, NUTMX .LE. ZERO.
6. Buckling matrix formed, NUTBX .LE. ZERO.

1001 FORMAT (5(A6,4X),A1,A1,2(A2,4X),A2)
1002 FORMAT (3(5X,E10.0))
1003 FORMAT (4(5X,E10.0),E5.0,5A1)
1004 FORMAT (20X,6E1C.0)
2001 FORMAT (//46X 27INPUT DATA FOR BAR ELEMENTS)
2002 FORMAT (//46X 39INPUT DATA FOR BAR ELEMENTS (CONTINUED))
2003 FORMAT (45X,8HKODEK = A1,A1,A2,A2, 4X 8HKODEB = A2,A2,
*              10X7HMASS = A6, 6X7HSTIF = A6, 6X13HLOAD TRANS = A6,
*              3X15HSTRESS TRANS = A6, 3X11HEUCKLING = A6,
*              12X4HRC = E10.3, 6X3HE = E10.3, 80X7H1 I I I,
*              32X3HG = E10.3, 80X7HF F F F,
*              125X7HP P P P,
*              1X7HELEMENT 2X5HJOINT 2X5HJOINT 3X3HREF 5X4HAREA
*              7X5HPOLAR 5X7HTORSION 3X9H2 BENDING 2X9HY BENDING
*              2X5HSHEAP 3X6HSTRESS 5X6HSTRESS 5X6HSTRESS 3X7HY Z Y Z
*              1X6HNUMBER 5X1H1 6X1H2 4X5HPOINT
*              14X 7HINEPTIA 5X5HCONST 5X7HINEPTIA
*              4X7HINEPTIA 3X6HFACTOR 5X1HR 9X2HCY 9X2HCZ 5X7H1 I 2 2)
2004 FORMAT (1X I5, 18, 2I7, 1X 5E11.3, F7.3, 3E11.3, 4(I1A1))
2005 FORMAT (29X,5E11.3,7X,3E11.3)
C
C READ AND WRITE FINITE ELEMENT DATA.
R1 = 0.0
CY1 = 0.0
CZ1 = 0.0
NLINE = 0
CALL PAGEHD
WRITE (NOT,2001)
READ (NUTEL,1001) NAMEK,NAMEL,NAMEST,NAMESB,
*                  (KODEK(I),I=1,4),(KODEB(I),I=1,2),
READ (NUTEL,1002) RO,E,G
WRITE (NOT,2003) (KODEK(I),I=1,4),(KODEB(I),I=1,2),
*                  NAMEK,NAMEL,NAMEST,NAMESB,RO,E,G
20 READ (NUTEL,1003) NEL,J1,J2,REF,A1,P11,TJ1,BI1,VI1,SI,
*                  IPF,IN,IFTAPR
IF (J1 .LE. 0) RETURN
IF (IFTAPR .EQ. 1HT) READ (NUTEL,1004) A2,P12,TJ2,BI2,VI2
IF (NAMESF .EQ. 6H)  
  OR NAMEST .EQ. 6HNOSTRO) GO TO 25
READ (NUTFL,1004) R1,CY1,CZ1,R2,CY2,CZ2
25 NLINE = NLINE + 1
IF (IFTAPR .EQ. 1HT) NLINE=NLINE+1
IF (NLINE .LE. 42) GO TO 30
CALL PAGEHD
WRITE (NOT,2002)
WRITE (NOT,2003) (KODEK(I),I=1,4),(KODEB(I),I=1,2),
*                  NAMEK,NAMEL,NAMEST,NAMESB,RO,E,G
NLINE = C
30 WRITE (NOT,2004) NEL,J1,J2,REF,A1,P11,TJ1,BI1,VI1,SI,
*                  R1,CY1,CZ1,IPF
ERROR = 1
IF (J1 .GT. NJ .CR. J2 .GT. NJ .CR. JREF .GT. NJ) GO TO 999
IF (IFTAPR .EQ. 1HT) WRITE (NOT,2005) A2,P12,TJ2,BI2,VI2,R2,
*                  CY2,CZ2
C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
DC 42 I=1,3
C FORM DATA FOR UNIFORM ELEMENT.
IF (IFTAPER .EQ. 1HT) GO TO 50
A2 = A1
PI2 = PI1
TJ2 = TJ1
RI2 = RI1
BI2 = BI1
BI2 = BI1
R2 = R1
CY2 = CY1
CZ2 = CZ1
C FORM PINING IVEC.
50 NPIN = 0
DO 55 I=1,N
IF (IFPIN(I) .NE. 1HP) GO TO 55
NPIN = NPIN + 1
IF (I .EQ. 1) IV2(NPIN) = 11
IF (I .EQ. 2) IV2(NPIN) = 7
IF (I .EQ. 3) IV2(NPIN) = 12
IF (I .EQ. 4) IV2(NPIN) = 8
55 CONTINUE
C FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C STRESS TRANSFORMATION MATRIX (S).
100 IF (NAMEK .EQ. 6H) OR NAMEK .EQ. 6HNOSTIF) GO TO 110
   CALL STF1B (CJ,EJ,KODEK,A1,A2,TJ1,TJ2,BI2,8,IV2,R1,R2,
                     CY1,CY2,CZ1,CZ2,SE,G,NAMEK,NAMEST,W,T,S,NRST,
                     KC1,KCJ,KW,KW)
C PIN STIFFNESS MATRIX.
IF (NPIN .EQ. 0) GO TO 105
C CALL DCON1B (CJ,EJ,W,KCJ,KCW)
CALL TRANS (V,TR,WRW,WRW,KW,KTR)
CALL MULTA (TD,TR,WRW,WRW,KW,KTR)
CALL MULTA (TD,TD,WRW,WRW,KTR,KT)
CALL MULTA (TD,TD,WRW,WRW,KTR,KT)
CALL MULTA (TD,TD,WRW,WRW,KW,KTR)
IF (NAMEST .EQ. 6H) OR NAMEST .EQ. 6HNODLS) GO TO 105
CALL MULTA (S,TR,NRST,WRW,WRW,KW,KTR)
105 IF (NUTKX .LE. 0) GO TO 999
WRITE (NUTKX) NAMEK,NEL,NRW,NAMEL,(IRLNK,I=1,5),
(*) ((I,J),I=1,NRW),J=1,NRW),(IV(I,J),I=1,NRW)
IF (NAMELT .EQ. 6H) OR NAMELT .EQ. 6HNOLDL) GO TO 115
IF (NUTLT .LE. 0) GO TO 999
WRITE (NUTLT) NAMELT,NFL,NRLT,NRW,NAMEL,(IBLNK,I=1,5),
* ((T(I,J),I=1,NRLT),J=1,NRW),(IVI(I),I=1,NRW)
115 IF (NAMEST .EQ. 6H OR NAMEST .EQ. 6HNOSTRS) GO TO 110
NERROR=4

IF (NUTST .LE. C) GO TO 999
WRITE (NUTST) NAMEST,NEL,NEST,NRW,NAMEL,(IBLNK,I=1,5),
* ((S(I,J),I=1,NEST),J=1,NRW),(IVI(I),I=1,NRW)
C
C FORM MASS MATRIX (W).
110 IF (NAMEM .EQ. 6H OR NAMEM .EQ. 6HNOBMASS) GO TO 140
CALL MAS1B (CJ,EJ,A1,A2,PI1,PI2,RO,NAMEM,W,T,JCJ,KCJ,KW)
C
C PIN MASS MATRIX.
   IF (NPIN .GT. 0) CALL BTABA (W,TR,NRW,NRW,KW,KTR)
NERROR=5

IF (NUTMX .LE. 0) GO TO 999
WRITE (NUTMX) NAMEM,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
* ((W(I,J),I=1,NRW),J=1,NRW),(IVI(I),I=1,NRW)
C
C FORM UNIT LOAD BUCKLING MATRIX (W).
140 IF (NAMEB .EQ. 6H OR NAMEB .EQ. 6HNOBUCK) GO TO 20
CALL BUCIB (CJ,EJ,KODEF,NAMEM,W,S,KCJ,KCJ,KW)
NERROR=6

IF (NUTFX .LE. 0) GO TO 999
WRITE (NUTFX) NAMEB,NEL,NRW,NRW,NAMEL,(IBLNK,I=1,5),
* ((W(I,J),I=1,NRW),J=1,NRW),(IVI(I),I=1,NRW)
GO TO 20
C
999 CALL ZZBOMM (6HBAR ,NERROR)
END
SUBROUTINE RUCIB, (CJ, EJ, KODEB, NAMEB, Z, W, KCJ, KEJ, KZ, KW)
DIMENSION CJ(KCJ, 1), EJ(KEJ, 1), KODEB(1), Z(KZ, 1), W(KW, 1)

SUBROUTINE TO CALCULATE FINITE ELEMENT...
BUCKLING MATRIX
FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED BOUNDARIES.
BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
BUCKLING MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
GLOBAL COORDINATE ORDER IS
(U, V, W, P, Q, R) JOINT 1, THEN JOINT 2
WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS.
EULER ANGLE CONVENTION IS GLOBAL X, Y, Z PERMUTATION.
CALLS FORMA SUBROUTINES B1A1, B1A2, BTAB, DCOS1B, Z2BOMB.
DEVELOPED BY RL WOLEN. AUGUST 1973.
LAST REVISION BY WA BENFIELD. MARCH 1976.

SUBROUTINE ARGUMENTS
CJ = INPUT MATRIX OF GLOBAL X, Y, Z COORDINATES AT BAR JOINTS.
ROWS 1, 2, 3 CORRESPOND TO X, Y, Z COORDINATES.
COLS 1, 2 CORRESPOND TO JOINTS 1, 2. COL 3 CORRESPONDS TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3, 3).
EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
ROWS 1, 2, 3 CORRESPOND TO GLOBAL X, Y, Z PERMUTATION.
COLS 1, 2 CORRESPOND TO JOINTS 1, 2. SIZE(3, 2).
KODEB = INPUT OPTION CODE FOR LOCAL Y, LOCAL Z BUCKLING.
IF BLANK, BOTH ARE CALCULATED. SIZE(2).
KODEB(1) = BY, LOCAL BUCKLING MATRIX IS CALCULATED FOR LOCAL Y DIRECTION.
KODEB(2) = BZ, LOCAL BUCKLING MATRIX IS CALCULATED FOR LOCAL Z DIRECTION.
NAMEB = INPUT TYPE OF BUCKLING MATRIX WANTED.
= P1, AXIAL RCD.
= P2, BEAM.
Z = OUTPUT BUCKLING MATRIX. SIZE(12, 12).
W = INPUT WORK SPACE MATRIX. SIZE(12, 12).
KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
KW = INPUT ROW Dimensions OF W IN CALLING PROGRAM. MIN=12.

NERROR EXPLANATION
1 = DIMENSION SIZE EXCEEDED.
2 = IMPROPERLY DEFINED NAMEB.

IF (KZ .LT. 12 OR. KW .LT. 12) GO TO 999
DO 5 J = 1, 12
DO 5 I = 1, 12
5 Z(I, J) = 0.0
RL = SQRT((CJ(1, 2) - CJ(1, 1))**2 + (CJ(2, 2) - CJ(2, 1))**2 + (CJ(3, 2) - CJ(3, 1))**2)
KODEBY = 1
KODEBZ = 1
IF (KODEB(1) .EQ. 2) AMD. KODEB(2) .EQ. 2 ) GO TO 10
IF (KODEP(1) .NE. 2HBY) KODEBY = 0
IF (KODEB(2) .NE. 2HBZ) KODEFBZ = 0
10 IF (NAMEB .EQ. 6HB1 ) GO TO 110
   IF (NAMEB .EQ. 6HB2 ) GO TO 120
   GO TO 999
C
110 IF (KODERY .EQ. 1) CALL B1A1 (RL,Z(5,5),KZ)
   IF (KODEBZ .EQ. 1) CALL B1A1 (RL,Z(9,9),KZ)
   GO TO 300
C
120 IF (KODERY .EQ. 1) CALL B1A2 (RL,Z(5,5),KZ)
   DO 125 J=7,8
   DO 125 I=5,6
      Z(I,J) =-Z(I,J)
   125
   IF (KODEBZ .EQ. 1) CALL B1A2 (RL,Z(9,9),KZ)
C
300 CALL DCOSIB (CJ,EJ,W,KCJ,KEJ,KW)
   CALL PTABA (Z,W,12,12,KZ,KW)
   RETURN
C
999 CALL ZZBOMB (6HBUC1B,NERROR)
END
SUBROUTINE DCOSIA (CJ,EJ,Z,KCJ,KEJ,KZ)
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
DIMENSION P(3), T(3,3)

C
SUBROUTINE TO CALCULATE FINITE ELEMENT...
C DIRECTION COSINE MATRIX
C FOR AN AXIAL ROD ELEMENT.
C THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C TO GLOBAL COORDINATE DISPLACEMENTS.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C DX1,DX2
C WHERE DX IS TRANSLATION.
C COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C (U,V,W) JOINT 1, THEN JOINT 2.
C WHERE U,V,W ARE TRANSLATIONS.
C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C CALLS FORMA SUBROUTINES EULER,MULTR,ZIBOMB.
C DEVELOPED BY RL WOHLLEN. SEPTEMBER 1972.
C LAST REVISION BY WA BENFIELD. MARCH 1976.

C
SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C Z = OUTPUT DIRECTION COSINE MATRIX. SIZE(2,6).
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
C NEPROR EXPLANATION
C 1 = DIMENSION SIZE LESS THAN 2.
C
NEPROR = 1

IF (KZ .LT. 2) GO TO 999
PX = CJ(1,2)-CJ(1,1)
PY = CJ(2,2)-CJ(2,1)
PZ = CJ(3,2)-CJ(3,1)
P1 = (PX**2 + PY**2 + PZ**2)
P(1) = PX/P1
P(2) = PY/P1
P(3) = PZ/P1
DO 10 I=1,2
DO 10 J=1,6
10 Z(I,J) = 0.0
CALL EULEP (EJ(1,1),T,3)
CALL MULTR (P,T,1,3,3,1,3)
DO 22 J=1,3
22 Z(I,J) = T(I,J)
CALL EULEP (EJ(1,2),T,3)
CALL MULTR (P,T,1,3,3,1,3)

999 RETURN
DO 24 J = 1, 3
  24 Z(2, J+3) = T(1, J)
RETURN
C
999 CALL ZZBOMB (6HDCOS1A, NERROR)
END
SUBROUTINE DCOS18 (CJ,EJ,Z,KCJ,KEJ,KZ)
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
DIMENSION W(3,3), T(3,3)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C DIRECTION COSINE MATRIX
C FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT.
C THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C TO GLOBAL COORDINATE DISPLACEMENTS.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE BAR TO LIE IN THE X-Y PLANE
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS,
C REFERENCE POINT 3 (TO DEFINE THE LOCAL X-Y PLANE) IS IN THE
C POSITIVE Y DIRECTION.
C ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C DX1,DX2, TX1,TX2, DY1,DY2, T12, T22, DZ1,DZ2, TY1,TY2
C WHERE DX, DY, DZ ARE TRANSLATIONS AND TX, TY, TZ ARE ROTATIONS.
C COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
C WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS.
C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C CALLS FORMA SUBROUTINES EULEP,MULTB,ZZBOMB.
C DEVELOPED BY RL WOHLN. FEBRUARY 1973.
C LAST REVISION BY WA BENFIELD. MARCH 1976.

C SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C Z = OUTPUT DIRECTION COSINE MATRIX. SIZE(12,12).
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C NERROR EXPLANATION
C 1 = DIMENSION SIZE LESS THAN 12.

IF (KZ .LT. 12) GO TO 999
PX = CJ(1,2)-CJ(1,1)
PY = CJ(2,2)-CJ(2,1)
PZ = CJ(3,2)-CJ(3,1)
PL = SQRT(PX**2 + PY**2 + PZ**2)
RX = PY*(CJ(3,3)-CJ(3,1)) - PZ*(CJ(2,3)-CJ(2,1))
RY = PZ*(CJ(1,3)-CJ(1,1)) - PX*(CJ(3,3)-CJ(3,1))
RZ = PX*(CJ(2,3)-CJ(2,1)) - PY*(CJ(1,3)-CJ(1,1))
RL = SQRT(PX**2 + RY**2 + RZ**2)
QX = RY*RZ - RZ*PY
QY = RZ*PX - RX*PZ
QZ = RX*PY - RY*PX
QL = SQRT(QX**2 + QY**2 + QZ**2)
W(1,1) = PX/PL
W(1,2) = PY/PL
W(1,3) = PZ/PL
W(2,1) = QX/OQ
W(2,2) = QY/OQ
W(2,5) = QZ/OQ
W(3,1) = RX/RQ
W(3,2) = PY/RQ
W(3,3) = PZ/RQ
DO 10 J=1,12
DO 10 I=1,12
10 : (I,J) = G*0
   CALL EULER (EH1(I,1),T,3)
   CALL MULTR (W,T, 3,3, 3,3)
   DC 22 J=1,3
   Z(E,1) = T(1,J)
   Z(E,2) = T(2,J)
   Z(E,3) = T(3,J)
   JP3 = J+3
   Z(3,JP3) = T(1,J)
   Z(7,JP3) = T(2,J)
   Z(11,JP3) = T(3,J)
22 Z(11,JP3) = T(3,J)
   CALL EULER (EH1(I,1),T,3)
   CALL MULTR (W,T, 3,3, 3,3)
   DO 24 J=1,3
   JP6 = J+6
   Z(2,JP6) = T(1,J)
   Z(6,JP6) = T(2,J)
   Z(10,JP6) = T(3,J)
   JP9 = J+9
   Z(4,JP9) = T(1,J)
   Z(8,JP9) = T(3,J)
24 Z(12,JP9) = T(2,J)
   RETURN
999 CALL ZELETR (6HDCOSB,NERROR)
END
SUBROUTINE DCOS2 (CJ,EJ,Z,KCJ,KEJ,KZ)
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
DIMENSION W(3,3), T(3,3)

SUBROUTINE TO CALCULATE FINITE ELEMENT...
DIRECTION COSINE MATRIX
FOR A COMBINED MEMBRANE-PENDING TRIANGLE PLATE ELEMENT.
THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
TO GLOBAL COORDINATE DISPLACEMENTS.
THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
WITH JOINT 1 AT THE ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
(PX,PY,PZ) JOINT 1, THEN JOINT 2, 3, NEXT
(QZ,TX,TY) JOINT 1, THEN JOINT 2, 3
WHERE PX,PY,PZ ARE TRANSLATIONS AND TX,TY,TZ ARE ROTATIONS.
COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
(U,V,W) JOINT 1, THEN JOINT 2, 3.
WHERE U,V,W ARE TRANSLATIONS AND P,C,K ARE ROTATIONS.
EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
CALLS FORM SUBROUTINES EULER,MULTB,ZZBOMB.
DEVELOPED BY WA BENDFIELD. FEBRUARY 1973.
LAST REVISION BY WA BENDFIELD. MARCH 1976.

SUBROUTINE ARGUMENTS
CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.
ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
COLUMNS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
COLUMNS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
Z = OUTPUT DIRECTION COSINE MATRIX. SIZE(18,18).
KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=18.

ERROR EXPLANATION
1 = DIMENSION SIZE LESS THAN 18.
DCOS2 -- 2/2

W(1,3) = PZ/PL
W(2,1) = QX/QL
W(2,2) = QY/QL
W(2,3) = QZ/QL
W(3,1) = RX/RL
W(3,2) = RY/RL
W(3,3) = RZ/RL
DO 10 J=1,18
DO 10 I=1,18
10 Z(I,J) = 0.0
DO 50 NW=1,3
    CALL EULER (EJ{I,NW,T,3})
    CALL MULTE (W,T,3,3,3,3)
    IZZ = 3*(NW-1)
    JZZ = 6*(NW-1)
    DO 50 JW=1,3
    JZ = JZZ+JW
    Z(IZZ+1,JZ) = T(1,JW)
    Z(IZZ+2,JZ) = T(2,JW)
    Z(IZZ+1C,JZ) = T(3,JW)
    JZ = JZ+2
    Z(IZZ+3,JZ) = T(3,JW)
    Z(IZZ+11,JZ) = T(1,JW)
50    Z(IZZ+12,JZ) = T(2,JW)
    RETURN
C
999 CALL ZZSOME (6:DCOS2,NERROR)
END
SUBROUTINE DCOS3C (CJ,EJ,Z,KCJ,KEJ,KZ)
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1)
DIMENSION W(2,3), T(3,3)

C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C DIRECTION COSINE MATRIX
C FOR A RECTANGULAR SHEET PANEL ELEMENT.
C THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
C TO GLOBAL COORDINATE DISPLACEMENTS.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, JOINT 3 IS IN THE POSITIVE X, Y DIRECTION, AND JOINT 4 LIES
C ALONG THE POSITIVE Y AXIS.
C ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C DX1,DX2,DX3,DX4, DY1,DY2,DY3,DY4
C WHERE DX, DY ARE TRANSLATIONS.
C COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
C (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C WHERE U,V,W ARE TRANSLATIONS.
C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C CALLS FORMA SUBROUTINES EULER, MULTIEZ, ZEBOMB.
C DEVELOPED BY RL WOHLA. APRIL 1974.
C LAST REVISION BY WA RENFIELD. MARCH 1976.
C
C SUBROUTINE: ARGUMENTS
C
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C Z = OUTPUT DIRECTION COSINE MATRIX. SIZE(3,3).
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C NEPROG EXPLANARTION
C 1 = DIMENSION SIZE TOO SMALL.
C
C IF (KZ.LT. E) CC TO 999
Py = CJ(1,2)-CJ(1,1)
Pz = CJ(2,2)-CJ(2,1)
Pl = SQRT(Py**2 + Pz**2 + Py**2)
Cy = CJ(1,4)-CJ(1,1)
Cz = CJ(3,4)-CJ(3,1)
Gl = SQRT(Cy**2 + Cz**2 + Gl**2)
W(1,1) = Py/Pl
W(1,2) = Py/Pl
W(1,3) = Pz/Pl
W(2,1) = Cy/Cz
W(2,2) = Cy/Cz
W(2,3) = Gl/Cz

CERROR=1
DO 10 J=1,12
DO 10 I=1,8
10 Z(I,J) = 0.0
DO 50 IJNT=1,4
    CALL EULEF (EJ(I,IJNT),T,3)
    CALL MULTF (W,T, 2,3,3, 2,3)
    JZ2 = 3*(IJNT-1)
DO 50 JW=1,3
    JZ = JZ2+JW
    Z(IJNT,JZ) = T(1,JW)
50 Z(IJNT+4,JZ) = T(2,JW)
RETURN

C 999 CALL Z26OMB (6,DCOS3C,NERROR)
C END
SUBROUTINE EULER (E, R, KR)
DIMENSION E(1), R(KR, 1)

C C CALCULATE EULER ANGLE ROTATION TRANSFORMATION MATRIX.
C EULER ANGLE CONVENTION IS GLOBAL X, Y, Z PERMUTATION.
C DEVELOPED BY C. BODLEY, MARCH 1973.

C C SUBROUTINE ARGUMENTS
C E = INPUT VECTOR OF JOINT EULER ANGLES (DEGREES).
C     LOCATIONS 1, 2, 3 CORRESPOND TO THE GLOBAL X, Y, Z
C     PERMUTATION. SIZE(3).
C R = OUTPUT EULER ROTATION TRANSFORMATION MATRIX. SIZE(3, 3).
C KR = INPUT ROW DIMENSION OF R IN CALLING PROGRAM.

C D1OR = ATAN2(1., 1.)/45.

C C1 = COS(E(1)*D1OR)
C C2 = COS(E(2)*D1OR)
C C3 = COS(E(3)*D1OR)
C S1 = SIN(E(1)*D1OR)
C S2 = SIN(E(2)*D1OR)
C S3 = SIN(E(3)*D1OR)

C F(1, 1) = C2*C3
F(1, 2) = -C2*S3
F(1, 3) = S2
R(2, 1) = C1*S3 + S1*S2*C3
R(2, 2) = C1*C3 - S1*S2*S3
F(2, 3) = -S1*C2
R(3, 1) = S1*S3 - C1*S2*C3
R(3, 2) = S1*C3 + C1*S2*S3
R(3, 3) = C1*C2

C RETURN
END
SUBROUTINE FINEL (XYZ, JDFF, EUL, NUTEL, NJ, *
  MOTH, NUTK, NULT, NUST, NUTC, V, LV, KV, *
  KRX, KRE, KTE, NUTX, NUTY, NUTZ, NUT1, NUT2, NUT3)
DIMENSION XYZ(KRX, 1), JDFF(KRX, 1), EUL(KRE, 1), V(1), LV(1)
DIMENSION W(24, 24), W2(24, 24), W3(24, 24)
DATA KW/24/, IBLANK/64/, 1, 11/1
DATA NUT, NOT/5, 6/
C SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT...  
C ASSEMBLED MASS MATRIX (ON NUTM),
C ASSEMBLED STIFFNESS MATRIX (ON NUTK),
C ELEMENT LOCAL LOAD TRANSFORMATION MATRICES, IVECS (ON NULTL),
C ELEMENT GLOBAL LOAD TRANSFORMATION MATRICES, IVECS (ON NUTX),
C ELEMENT STRESS TRANSFORMATION MATRICES, IVECS (ON NUST1),
C ELEMENT UNIT LOAD BUCKLING MATRICES, IVECS (ON NUTC).
C IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C IVEC(3)=6 OMITS ELEMENT DOF 2 FROM GLOBAL DOF. THIS CONSTRAINTS
C ELEMENT DOF 3 TO ZERO MOTION.
C DATA ARRANGEMENT ON NUTH, NUTK FOR THE ASSEMBLED MATRICES IS IN
C SPARSE (Y) FORMA SUBROUTINE FORMAT.
C DATA ARRANGEMENT ON NULTL, NUTX, NUST, NUTC FOR EACH FINITE
C ELEMENT (WRITTEN IN SUBROUTINE AXIAL, BAR, ETC) IS
C WRITE (NUTH) NAMEW, NEL, NNC, NAMEL (IBLANK, I=1, 5),
C (W(I), J, I=1, N, J=1, NC), (IVEC(I), I=1, NC)
C NAMEW = NAMEEL, NAMEXX, NAMEST, OR NAMEB.
C NAMEEL = AXIAL, PAP, ETC.
C LAST RECORD TO DENOTE TERMINATION IS,
C WRITE (NUTH) IBLANK(11, I=1, 36)
C THE FOLLOWING UTILITY TAPES USE RASIX FORTRAN READ, WRITE. DO NOT
C USE THESE TAPES IN SPARSE (Y) FORMA SUBROUTINES WHICH USE FORMA
C SUBROUTINES YIN, YOUT (BECAUSE THEY USE BUFFER IN, BUFFER OUT).
C NUTL, NUST, NUTC, NUTX, NUTC.
C THE FOLLOWING UTILITY TAPES USE FORMA YIN, YOUT.
C NUTM, NUTK, NUTC, NUTC3.
C CALLS FORMA SUBROUTINES AXIAL, BAR, FLUID, GRAVITY, PAGEHDO, QUAD,
C RECTSP, TANG, YRVAD2, ZIZEMB.
C LAST REVISION FD BY RL WOHLNE. MAY 1976.
C
C**************************************************************
C INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C READ FROM CARDS.
C 50 NAMEL FORMAT (A6)
C IF (NAMEL = 'EQ', 6mRETURN) RETURN
C IF (NAMEL = 'EQ', 6AXIAL ) CALL AXIAL (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HPAR ) CALL PAR (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HFLUID ) CALL FLUID (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HGRAVITY ) CALL GRAVITY (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HQUAD ) CALL QUAD (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HRECTSP ) CALL RECTSP (SEE SUBRT FOR INPUT)
C IF (NAMEL = 'EQ', 6HTRNSL ) CALL TRANS (SEE SUBRT FOR INPUT)
C GO TO 50
C
C DEFINITION OF INPUT VARIABLES.
**FINEL -- 2/5**

C NAMEL = AXIAL, BAR, ETC AS SHOWN ABOVE. GIVES SUBROUTINE CALLED.
C
C EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C A = ANY KEYPUNCH SYMBOL.
C X = CARD COLUMNS SKIPPED.
C
************************************************************
C
C SUBROUTINE ARGUMENTS (ALL INPUT)
C XYZ = MATRIX OF JOINT GLOBAL X, Y, Z LOCATIONS. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C MAY BE EQUIVALENCED TO VIII IN CALLING PROGRAM.
C JDOF = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C ROTATION DOFS. SIZE(NJ,6).
C MAY BE EQUIVALENCED TO LV(1) IN CALLING PROGRAM.
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C LOCAL X,Y,Z PERMUTATION. SIZE(NJ,3). MAY BE
C EQUIVALENCED TO VKRX*(XYZ COL DIM)+1) IN CALLING PROGRAM.
C NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C THIS SUBROUTINE AND SUBROUTINES AXIAL, ETC GIVEN BY NAMEL.
C IF NUTEL = 5, DATA WILL BE READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C NUTM = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
C MASS MATRIX IS OUTPUT IN SPARSE NOTATION.
C NUTM MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTK = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
C STIFFNESS MATRIX IS OUTPUT IN SPARSE NOTATION.
C NUTK MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NULT = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOAD
C TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NULT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTS = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTS MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTB = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C BUCKLING MATRICES AND IVECS ARE OUTPUT.
C NUTB MAY BE ZERO IF BUCKLING MATRICES ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C V = VECTOR WORK SPACE.
C LV = VECTOR WORK SPACE.
C KV = DIMENSION SIZE OF VX, LV IN CALLING PROGRAM.
C KRX = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C KRI = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C KRE = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C MASS MATRICES AND IVECS ARE STORED.
C NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
FINEL -- 3/5

C NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C MATRICES) AND INVECS ARE STORED.
C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORMAT READ, WRITE.
C NUT1 = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C NUT2 = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C NUT3 = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C NERROR EXPLANATION
C 1 = NAMEL IMPROPERLY DEFINED.
C
1001 FORMAT (A6)
2001 FORMAT (/*41X I5HJOINT DATA USED IN SUBROUTINE FINEL)
2002 FORMAT (/*35X 47HJOINT DATA USED IN SUBROUTINE FINEL (CONTINUED))
2003 FORMAT (/*16X 8HDEGREES OF FREEDOM
 * 1PX 2HGLOBAL CARTESIAN COORDINATES
 * 12X 22HEULER ANGLES (DEGREES)
 * /14X 11HTRANSLATION 8X 8HROTATION
 * / 2XSHJOINT 6X1IHU 5X1IHV 5X1IHW 'X1HP 5X1IHQ 5X1HR
 * II1IHX II1IHY 111IHZ 141IHX 101IHY 101IHZ /
2004 FORMAT (I1 15, 3X 616, 3X 3912.4, 4X 3911.4)
C
IF (NUTMX .GT. 0) REWIND NUTMX
IF (NUTKX .GT. 0) REWIND NUTKX
IF (NUT1  .GT. 0) REWIND NUT1
IF (NUT2  .GT. 0) REWIND NUT2
IF (NUT3  .GT. 0) REWIND NUT3
C
C DETERMINE SIZE OF FINAL MASS-STIFFNESS MATRIX FROM THE MAXIMUM DOF
C NUMBER IN JD9F.
C
NDOF = JDOF(1,1)
DO 35 I=1,NJ
DO 35 J=1,6
IF (JDOF(I,J) .GT. NDOF) NDOF=JDOF(I,J)
35 CONTINUE
C
C PRINT JOINT DOF, XYZ COORDINATES, EULER ANGLES.
C CALL PAGEHD
C WRITE (NCT,2001)
C WRITE (NCT,2003)
C NLINE = 0
DO 40 IJ=1,NJ
NLINE = NLINE+1
IF (NLINE .LE. 42) GO TO 40
CALL PAGEHD
WRITE (NCT,2002)
WRITE (NCT,2003)
NLINE = 1
40 WRITE (NCT,2004) IJ, (JDOF(IJ,J), J=1,6), (XYZ(IJ,J), J=1,3),
      *(EUL(IJ,J), J=1,3)
C
C READ FINITE ELEMENT TYPE.
C 50 READ (NUTEL,1001) NAMEL
C IF (NAMEL .EQ. 6HRETURN) GO TO 50C
IF NERROR=1  
GO TO 999  

C BAR FINITE ELEMENT (AXIAL ONLY)
110 CALL AXIAL (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C BAR FINITE ELEMENT (COMBINED AXIAL, TORSION, BENDING)
140 CALL BAR (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTB,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C TRIANGULAR PLATE ELEMENT
150 CALL TRKGL (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C FLUID ELEMENT
151 CALL FLUID (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C QUADRILATERAL PLATE ELEMENT
160 CALL QUAD (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTP,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C RECTANGULAR SHEAR PANEL
162 CALL RECTSP (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTMX,NUTKX,NUTLT,NUTST,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C GRAVITY ELEMENT
171 CALL GRAVITY (XYZ,JDCF,EUL,NUTEL,NJ,  
* NUTKX,  
* W1,W2,W3,KRX,KRJ,KRE,KW)
GO TO 50  

C TERMINATE FINITE ELEMENT DATA ON STORAGE DISKS.
500 IF (NUTMX .GT. 0) WRITE (NUTMX) IBLANK, (II,I=1,30)  
IF (NUTKX .GT. 0) WRITE (NUTKX) IBLANK, (II,I=1,30)  
IF (NUTB .GT. 0) WRITE (NUTB) IBLANK, (II,I=1,30)  
IF (NUTLT .GT. 0) WRITE (NUTLT) IBLANK, (II,I=1,30)  
IF (NUTST .GT. 0) WRITE (NUTST) IBLANK, (II,I=1,30)  

C SUM FINITE ELEMENT MATRICES.
IF (NUTMX.GT.C) CALL YZERO (NUTM,NDCF,NDCF)  
IF (NUTKX.GT.C) CALL YZERO (NUTK,NDCF,NDCF)
IF (NUTMX .GT. 0) CALL YRVAD2 (NUTMX, NUTH, NDOF, W1, KW, V, LV, KV, NUT1, NUT2, NUT3)
*    IF (NUTKX .GT. 0) CALL YRVAD2 (NUTKX, NUTK, NDOF, W1, KW, V, LV, KV, NUT1, NUT2, NUT3)
    RETURN
C
999 CALL ZEBOMB (6HFINEL, NERROR)
END
SUBROUTINE FLUID (XYZ, JDCE, EUL, NUTEL, NJ,
* NUTMX, NUTKX, NULT, NUST,
* W, T, S, KX, KJ, KE, KW
DIMENSION XYZ(KX,1), JDCE(KJ,1), EUL(KE,1), W(KW,1),
* TK(W,1), SK(W,1)
DIMENSION CJ(3,8), EJ(3,8), IV(24), IVTE(12), JM(4,16), VL(10),
* DV(12), DIST(12,12), TV(24)
DATA NRW,NRST/24,1/, IBLNK/6H
DATA NIT,NUT/5,6/
DATA NAMEL/6HFLUID/
DATA KCI/2/, KJM/4/
DATA KDIST/12/, IFBAD/1/
DATA JM/1,2,3,4, 3,6,4,2, 2,6,4,5, 3,5,1,2,
* 1,3,6,5, 1,6,4,5, 2,7,4,5, 1,2,4,5,
* 4,7,8,5, 5,2,7,6, 4,2,3,7, 1,3,9,6,
* 1,6,8,5, 1,3,4,8, 1,2,3,6, 8,3,7,6 /
C
C SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C MASS MATRICES AND IVECS (ON NUTMX),
C STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C AND IVECS (ON NUTKX),
C PRESSURE TRANSFORMATION MATRICES AND IVECS (ON NUST),
C FOR FLUID ELEMENTS.
C ELEMENT SHAPE MAY BE TETRAHEDRON, PENTAHEDRON, OR HEXAHEDRON.
C MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C GLOBAL COORDINATE ORDER IS
C (U,V,W) JOINT 1, THEN JOINT 2,3,4,(5,6,7,8).
C WHERE U,V,W ARE TRANSLATIONS.
C IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C IVEC(3)=0 Omits ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINT
C ELEMENT DOF 3 TO ZERO MOTION.
C PRESSURE TRANSFORMATION MATRICES RELATE CHANGE IN PRESSURE (DUE TO
C COMRESSIBILITY) TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C PRESSURE CHANGE WITHIN THE FLUID ELEMENT IS CONSTANT. STATIC PRESSURE
C DUE TO GRAVITY AND FLUID HEIGHT IS NOT INCLUDED.
C DATA ARRANGEMENT ON NUTMX, NUTKX, NUST FOR EACH FINITE ELEMENT IS
C (W=M,K,ST)
C WHERE NAMENAMELNAME M=NUTMX,Naml NC,NAMEL, (IBLNK,I=1,5),
C (((W(I,J),I=1,MR),J=1,NC),(IVEC(I),I=1,NC)
C CALLED FORMA SUBROUTINES TEGFM, VCROSS, VDOT, ZIBOMB.
C DEVELOPED BY C S EDDLEY. FEBRUARY 1974.
C LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C READ FROM CARDS.
C NAMENAMENAMELNAME NAMEST FORMAT (4(A6,4X)
C NC,EK FORMAT (2(5X,E10))
C ZC NEL,J1,J2,J3,J4,J5,J6,J7,J8 FORMAT (915)
C IF (J1,EC, 0) RETURN
C GC TO 20
C
C DEFINITION OF INPUT VARIABLES.
C NAMEM = TYPE OF MASS MATRIX WANTED,
C = M1, LUMPED MASS MATRIX.
C = M2, QUASI-IRRATIONAL CONSISTENT MASS MATRIX.
C = M3, IRRATIONAL MASS MATRIX.
C = 6P or 6H, MASS MATRIX CALCULATED.
C NAMEK = TYPE OF STIFFNESS MATRIX WANTED.
C = K1, LINEAR DISPLACEMENT ASSUMED.
C = 6H or 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C NAMEPT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES. (NOT YET).
C NAMEST = IDENTIFICATION NAME FOR PRESSURE TRANSFORMATION MATRICES.
C = 6P or 6HNOSTIF, NO PRESSURE TRANSFORMATIONS CALCULATED.
C RO = MASS DENSITY.
C BKM = BULK MODULUS.
C NEL = FINITE ELEMENT NUMBER, FOR REFERENCE ONLY, NOT USED IN CALCULATIONS. WRITTEN ON NUTMX, ETC.
C J1 = JOINT NUMBER AT ELEMENT VERTEX 1.
C J2 = JOINT NUMBER AT ELEMENT VERTEX 2.
C J3 = JOINT NUMBER AT ELEMENT VERTEX 3.
C J4 = JOINT NUMBER AT ELEMENT VERTEX 4.
C FOR A TETRAHEDRON, FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS VIEWED FROM OUTSIDE THE ELEMENT.
C J5 = JOINT NUMBER AT ELEMENT VERTEX 5. (USED FOR PENTAHEDRON AND HEXAHEDRON).
C J6 = JOINT NUMBER AT ELEMENT VERTEX 6. (USED FOR PENTAHEDRON AND HEXAHEDRON).
C FOR A PENTAHEDRON, FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS VIEWED FROM OUTSIDE THE ELEMENT. FACE 4,5,6 IS NUMBERED IN THE SAME ORDER AS FACE 1,2,3. A LINE JOINING JOINTS 1 AND 4 MUST FORM AN EDGE OF THE PENTAHEDRON.
C J7 = JOINT NUMBER AT ELEMENT VERTEX 7. (USED FOR HEXAHEDRON).
C J8 = JOINT NUMBER AT ELEMENT VERTEX 8. (USED FOR HEXAHEDRON).
C FOR A HEXAHEDRON, FACE 1,2,3,4 MUST BE NUMBERED CLOCKWISE AS VIEWED FROM OUTSIDE THE ELEMENT. FACE 5,6,7,8 IS NUMBERED IN THE SAME ORDER AS FACE 1,2,3,4. A LINE JOINING JOINTS 1 AND 5 MUST FORM AN EDGE OF THE HEXAHEDRON.
C EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C I = INTEGER DATA, RIGHT ADJUSTED.
C E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C X = CARD COLUMNS SKIPPED.
C SUBROUTINE ARGUMENTS (ALL INPUT)
C XYZ = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C JDOF = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT ROTATION DOFS. SIZE(NJ,6).
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR THIS SUBROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT MASS MATRICES AND IVFCS ARE OUTPUT.
NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.
NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
MATRICES) AND IVECS ARE OUTPUT.
NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
USES FORTRAN READ, WRITE.
NULTL = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOAD
TRANSFORMATION MATRICES AND IVECS ARE OUTPUT. (NOT YET).
NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
PRESSURE TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
NUTST MAY BE ZERO IF PRESSURE TRANSFORMATIONS ARE NOT FORMED.
USES FORTRAN READ, WRITE.
W = MATRIX WORK SPACE. MIN SIZE(24,24).
T = MATRIX WORK SPACE. MIN SIZE(24,24).
S = MATRIX WORK SPACE. MIN SIZE(24,24).
KX = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
KJ = ROW DIMENSION OF JOEF IN CALLING PROGRAM.
KE = ROW DIMENSION OF EUL IN CALLING PROGRAM.

ERROR EXPLANATION
1 = INCORRECT TETRAHEDRON GEOMETRY.
2 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
3 = NUTMX NOT POSITIVE.
4 = NUTKX NOT POSITIVE.
5 = NUTST NOT POSITIVE.

1001 FORMAT (5(A6,4X))
1002 FORMAT (3(15X,E10.0))
1003 FORMAT (9I5)
2001 FORMAT (//25X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
 * 21H HEXAHEDRON) ELEMENTS)
2002 FORMAT (//20X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
 * 33H HEXAHEDRON) ELEMENTS (CONTINUED))
2003 FORMAT (/12X7HMASS = A6,13X7HSTIF = A6,6X13HLOAD TRANS = A5,
 * 3X15HSTRESS TRANS = A6, 3X
 * / 15X4HRC = E10.3, 13X7HULKM = E10.3,
 * // 9X7HELEMENT 6 HJOINT 1 6X7HJOINT 2 6X7HJOINT 3 6X7HJOINT 4
 * 6X7HJOINT 5 6X7HJOINT 6 6X7HJOINT 7 6X7HJOINT 8
 * / 9X6HNUMBER)
2004 FORMAT (3X,9(8X,15))
3601 FORMAT (51H * * * * * UNCONVENTIONAL JOINT NUMBERING * * * * * , /
 * 915)

IF (I1ST .EQ. 1) GO TO 3
I1ST = 1
DO 4 I=1,4
  I1 = 3*I - 2
DO 4 J=1,4
  J1 = 3*J - 2
4 CALL UNITY (DIST(I1,J1),3,KU1ST)

3 NLINIE = 0
NERROR = 1
IF (J1 .LE. 0) RETURN
NLIT = NLINE + 1
CALL PAGEHD
WRITE (NCT,2002)
WRITE (NCT,2003) NAMEK,NAMEL,NAMEST,* RO, BKM
NLITE = 0
30 WRITE (NCT,2004) NEL,J1,J2,J3,J4,J5,J6,J7,J8
NERROR = 2
IF (J5 .GE. NJ) DO 30
IF (J5 .GE. NJ) DO 31
IF (J5 .GE. NJ) DO 32
IF (J5 .GE. NJ) DO 33
IF (J5 .GE. NJ) DO 34
IF (J5 .GE. NJ) DO 35
IF (J5 .GE. NJ) DO 36
IF (J5 .GE. NJ) DO 37
IF (J5 .GE. NJ) DO 38
IF (J5 .GE. NJ) DO 39
IF (J5 .GE. NJ) DO 40

CALL PAGEHD
WRITE (NCT,2001)
READ (NUTEL,1001) NAMEK,NAMEL,NAMEST
READ (NUTEL,1002) RO, BKM
WRITE (NCT,2003) NAMEK,NAMEL,NAMEST,* RO, BKM
IF ('YAMFM NE. 6HM3 ) GO TO 20
DO 2 I=1,12
2 DIST(I,I) = 2.
C
DO 26 READ (NUTEL,1003) NEL,J1,J2,J3,J4,J5,J6,J7,J8
NERROR = 1
IF (J1 .LE. 0) AND. IFRAD .EQ. -1) GO TO 999
IF (J1 .LE. 0) RETURN
NLITE = NLINE + 1
IF (NLINE .LE. 42) GO TO 30
CALL PAGEHD
WRITE (NCT,2002)
WRITE (NCT,2003) NAMEK,NAMEL,NAMEST,* RO, BKM
NLITE = 0
30 WRITE (NCT,2004) NEL,J1,J2,J3,J4,J5,J6,J7,J8
NERROR = 2
IF (J5 .GE. NJ) DO 30
IF (J5 .GE. NJ) DO 31
IF (J5 .GE. NJ) DO 32
IF (J5 .GE. NJ) DO 33
IF (J5 .GE. NJ) DO 34
IF (J5 .GE. NJ) DO 35
IF (J5 .GE. NJ) DO 36
IF (J5 .GE. NJ) DO 37
IF (J5 .GE. NJ) DO 38
IF (J5 .GE. NJ) DO 39
IF (J5 .GE. NJ) DO 40

C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
C
LR = 10
NJJ = 8
IF (J7 .NE. 0) GO TO 38
LR = 6
NJJ = 6
IF (J5 .NE. 0) GO TO 38
LR = 1
NJJ = 4
C
DO 38 I=1,NCOL
DO 35 J=1,NCOL
WI(I,J) = 0.
SI(I,J) = 0.
T(I,J) = 0.
38 NCOL = 2*NJJ
DO 40 I=1,3
CJ(I,1) = XYZ(J1,I)
CJ(I,2) = XYZ(J2,I)
CJ(I,3) = XYZ(J3,I)
CJ(I,4) = XYZ(J4,I)
EJ(I,1) = EUL(J1,I)
EJ(I,2) = EUL(J2,I)
EJ(I,3) = EUL(J3,I)
EJ(I,4) = EUL(J4,I)
IV1(I ) = JDIF(J1,I)
IV1(I+3) = JDIF(J2,I)
IV1(I+6) = JDCF(J3, I)
40 IV1(I+9) = JDCF(J4, I)
    IF (LR .EQ. 1) GO TO 50
C
   DO 42 J=1,3
   CJ(I,5) = XYZ(J5, I)
   CJ(I,6) = XYZ(J6, I)
   EJ(I,5) = EU(J5, I)
   EJ(I,6) = EU(J6, I)
IV1(I+12) = JDCF(J5, I)
42 IV1(I+15) = JDCF(J6, I)
    IF (LP .EQ. 6) GO TO 50
C
   DO 44 J=1,3
   CJ(I,7) = XYZ(J7, I)
   CJ(I,8) = XYZ(J8, I)
   EJ(I,7) = EU(J7, I)
   EJ(I,8) = EU(J8, I)
IV1(I+18) = JDCF(J7, I)
44 IV1(I+21) = JDCF(J8, I)

C
   50 DO 52 L=1,LR
   LA = L
   IF (LR .EQ. 10) LA=L+6
   DO 52 I=1,4
   JNO = JMJ(I,LA)
   LI = 3*I - 2
   IVTFT(L1) = 5*XNC - 2
   IVTET(L1+1) = 3*XNC - 1
   53 IVTET(L1+2) = 3*XNC

C
   CALL TEGEOF (CMJ, JMJ, LA ), VL(L), DV, KCJ, IFED)
   IF (IFBAD .NE. 0) GO TO 51
   WRITE (NQ1,3001) NEL, J1, J2, J3, J4, J5, J6, J7, J8
   IFBAD = -1
   51 SM = RO*VL(L)/16.0
   IF (NAMEM .EQ. 6HM3 ) SM=RO*VL(L)/20.0
   IF (LR .GT. 1) SM = SM/2.
   CALL REVADD (1,5, DV, JIVTET, T, 12, LR, NCOL, I, KW)
   CALL REVADD (SM, DIST, IVTET, IVTET, W, 12, 12, NCOL, NCOL, KDIST, KW)

C
   IF (NAMEM .NE. 6HM1 ) GO TO 220
   DO 210 I=1,NCOL
   SAVE = 0.0
   DO 215 J=1,NCOL
   SAVE = SAVE + W(I,J)
   215 W(I,J) = 0.0
   210 W(I,I) = SAVE

C
   220 IF (LR .EQ. 1) GO TO 60
   DO 55 I=2,LR
   VL(I) = VL(I) + VL(I)
   DO 55 J=1,NCOL
   55 T(I,J) = T(I,J) + T(I,J)
   VL(I) = VL(I)/2.
56 T(I,J) = T(I,J)/2.

60 DO 61 J=1,NCOL
61 TV(J) = T(I,J)
   DC 65 J=1,NJN
   J1 = 3*J - 2
65 CALL EULEM (EJ(I,J),S(J1,J1),KW)
   IF (NAMEST .EQ. 6H .OR. NAMEST .EQ. 6HNYEOST) GO TO 90
   CALL PRESS (CJ,T,KJN,NCOL,KCJ,KW)
   CALL MULTA (T,S,KN,NCOL,NCOL,KW,KW)
90 CALL RTAPA (W,S,NCOL,NCOL,KW,KW)
   CALL MULTA (TV,S,1,NCOL,NCOL,1,KW)
   BOV = EKM/VL(I)
   DO 70 I=1,NCOL
   DO 70 J=1,NCOL
   S(I,J) = BOV*TV(I)*TV(J)
70 S(J,I) = S(I,J)

   C
   IF (NAMEM .EQ. 6H .OR. NAMEM .EQ. 6HNYCMASS) GO TO 110
      NERROR=3
   IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM,NEL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
      * (W(J,J),I=1,J,NCOL), (IV1(I),I=1,NCOL)
   C
110 IF (NAMEK .EQ. 6H .OR. NAMEK .EQ. 6HNYOSTIF) GO TO 120
      NERROR=4
   IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NEL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
      * (S(I,J),J=1,J,NCOL), (IV1(I),I=1,NCOL)
   C
120 IF (NAMEST .EQ. 6H .OR. NAMEST .EQ. 6HNYEOST) GO TO 20
      NERROR=5
   IF (NUTST .LE. 0) GO TO 999
      NNP1 = NJN + 1
      CALL MULTA (T,S,T(NJNP1,1),NJN,NCOL,NCOL,KW,KW)
      CALL MULTA (T,W,NJN,NCOL,NCOL,KW,KW)
      NRST = 2*NJN
      WRITE (NUTST) NAMEST,NEL,NRST,NCOL,NAMEL,(IV1(I),I=1,4),
      * (T(I,J),I=1,NRST), (IV1(I),I=1,NCOL)
      GO TO 26
   C
999 CALL ZZBOMF (6HFLUID ,NERROR)
END
SUBROUTINE GRAVITY (XYZ, JDOF, EUL, NUTEL, NJ,
  * NUTKX, * W, T, S, RX, KJ, KE, KW)
DIMENSION XYZ(KJ,1), JDOF(KJ,1), EUL(KE,1), W(KW,1),
  *(KW,1), S(KW,1)
DIMENSION CJ(3,4), EJ(3,4), IV(12), IVTRI(9), JM(3,4), GV(3), EV(3)
DATA IBLNK/6H /
DATA NIT, NMT/ 5, 6 /
DATA NAMEL / 6HGRAVITY /
DATA NCJM / 3 /
DATA JM / 1,2,3, 1,3,4, 1,2,4, 4,2,3 /

C SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C AND IVECS (ON NUTKX),
C FOR GRAVITY ELEMENTS.
C STIFFNESS MATRICES ARE 9- GL021-. 30OR49-IT 4IR 090-S8
C GLOBAL COORDINATE ORDER IS
C (U,V,W) JOINT 1, THEN JOINT 2,3,(4).
C WHERE U,V,W ARE TRANSLATIONS.
C IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C IVEC(3)=0 OMPITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINTS
C ELEMENT DOF 3 TO ZERO MOTION.
C DATA ARRANGEMENT ON NUTKX FOR EACH FINITE ELEMENT IS
C (W=K)
C WRITE (NUTWX) NAMEW,NEL, NR, NC, NAMEL,(IBLNK, I=1,5),
C ((W[I,J], I=1, NFW), J=1, NC), (IVEC(I), I=1, NC)
C CALLS FORMA SUBROUTINES KGRAV, MULTA, MULTB, VGROSS, ZZBOMB.
C DEVELOPED BY C S BODELEY. FEBRUARY 1974.
C LAST REVISION BY W A BENFIELD. MARCH 1976.
C
C**************************************************************************************************
C INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C READ FROM CARDS.
C NAMEM,NAMESK FORMATT (2(A6,4X)
C RO FORMATT (5X,E10)
C (C(VII), I=1, 3) FORMATT (3(5X,E10))
C 20 NEL, J1, J2, J3, J4 FORMATT (515)
C IF (J1, =E0, 0) RETURN
C GO TO 20
C
C DEFINITION OF INPUT VARIABLES.
C NAMEM = TYPE OF MASS MATRIX WANTED.
C = 6H OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C NAMEK = TYPE OF STIFFNESS MATRIX WANTED.
C = K1, LINEAR DISPLACEMENT ASSUMED.
C = 6H OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C RO = MASS DENSITY.
C GV = GRAVITY VECTOR.
C NEL = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C CALCULATIONS, WRITTEN ON NUTKX.
C J1 = JOINT NUMBER AT ELEMENT VERTEX 1.
C J2 = JOINT NUMBER AT ELEMENT VERTEX 2.
C J3 = JOINT NUMBER AT ELEMENT VERTEX 3.
GRAVITY-- 2/4

C J4 = JOINT NUMBER AT ELEMENT VERTEX 4. (USED FOR QUADRILATERAL).
C THE ELEMENT MUST BE NUMBERED CLOCKWISE AS VIEWED FROM THE FLUID SIDE
C OF THE ELEMENT.
C
C EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C I = INTEGER DATA, RIGHT ADJUSTED.
C F = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C X = CARD COLUMNS SKIPPED.
C
C******************************************************************************
C
C SUBROUTINE ARGUMENTS (ALL INPUT)
C XYZ = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C JDOF = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C ROTATION DOFS. SIZE(NJ,6).
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C THIS SUBROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C MATRICES) AND IVECS ARE OUTPUT.
C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C W = MATRIX WORK SPACE. MIN SIZE(12,12).
C T = MATRIX WORK SPACE. MIN SIZE(12,12).
C S = MATRIX WORK SPACE. MIN SIZE(12,12).
C XX = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C KJ = ROW DIMENSION OF JDOF IN CALLING PROGRAM.
C KE = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C KW = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=12.
C
C NERPOE EXPLANATION
C 1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
C 2 = NUTKX NOT POSITIVE.
C
1001 FORMAT (S(6,4X))
1002 FORMAT (3(5X,E10.0))
1003 FORMAT (5(15))
2001 FORMAT (/25X 45SHINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
* 24T QUADRILATERAL) ELEMENTS)
2002 FORMAT (/20X 45SHINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
* 36T QUADRILATERAL) ELEMENTS (CONTINUED))
2003 FORMAT (/12X7HMAXS = A6,13X7HSTIF = A6,6X
* /15X,4HRC = E10.3, 13X5HGXX = E10.3, 13X5HGYY = E10.3,
* 13X5HGZ = E10.3,
* /15X7HELEMENT 13X7HJOINT 1 13X7HJOINT 2 13X7HJOINT 3
* 13X7HJOINT 4
* /15X6HNUMPR)
2004 FORMAT (18X,9(15,15X))
C
C NLINE = 0
CALL PAGEHD
WRITE (NOT,2001)
READ (NUTEL,1001) NAMEM,NAMEK
READ (NUTEL,10C2) RD
READ (NUTEL,1002) (GVI(I),I=1,3)
WRITE (NOT,2003) NAMEM,NAMEK,
* RC, (GVI(I),I=1,3)
C
20 READ (NUTEL,1003) NEL,J1,J2,J3,J4
IF (J1 .LE. 0) RETURN
NLINE = NLINE + 1
IF (NLINE .LE. 42) GO TO 30
CALL PAGEHD
WRITE (NOT,2002)
WRITE (NOT,2003) NAMEM,NAMEK,
* RC, (GVI(I),I=1,3)
NLINE = 0
30 WRITE (NOT,2004) NEL,J1,J2,J3,J4
C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
C
LP = 4
NJN = 4
IF (J4 .NE. 0) GO TO 38
LP = 1
NJN = 3
38 NCOL = 3*NJN
DO 5 I=1,NCOL
DO 5 J=1,NCOL
W(I,J) = C
5 S(I,J) = 0.
5 T(I,J) = 0.
C
DO 40 I=1,3
CJ(I,1) = XYZ(J1,I)
CJ(I,2) = XYZ(J2,I)
CJ(I,3) = XYZ(J3,I)
EJ(I,1) = FUL(J1,I)
EJ(I,2) = FUL(J2,I)
EJ(I,3) = FUL(J3,I)
IVI(I) = JDCF(J1,I)
IVI(I+3) = JDCF(J2,I)
40 IVI(I+6) = JDCF(J3,I)
IF (LP .LE. 1) GO TO 50
C
DO 42 I=1,3
CJ(I,4) = XYZ(J4,I)
EJ(I,4) = FUL(J4,I)
42 IVI(I+9) = JDCF(J4,I)
C
50 G = SQRT(GV(1)**2 + GV(2)**2 + GV(3)**2)
   DO 51 I=1,3
51  EV(I) = -GV(I)/G
   DO 52 I=-1,LR
      CALL KGRAV (CJ,JM(I,L),EV,A,W,KW,KCJM)
C
     DO 53 I=1,3
        JN0 = JM(I,L)
        L1 = 3*I - 2
        IVTRI(L1+1) = 3*JN0 - 2
        IVTRI(L1+1) = 3*JN0 - 1
53  IVTRI(L1+2) = 3*JNC
        SS = RO*G*A/24.*
        IF (LR .GT. 1) SS = SS/2.
   52  CALL REVADD (SS,W,IVTRI,IVTRI,S,9,9,NCOL,NCOL,KW,KW)
C
     DO 65 J=1,NJN
        J1 = 3*J - 2
65  CALL EULCP (FJ(I,J),T(J1,J1),KW)
      CALL ETABA (S,T,NCOL,NCOL,KW,KW)
C
     IF (NAMEK .EQ. 6H .OR. NAMEK .EQ. 6HNDSTIF) GO TO 20
        NERROR=2
     IF (NUTKY .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK,NFL,NCOL,NCOL,NAMEL,(IBLNK,I=1,5),
      * (S(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
     GO TO 20
C
999 CALL ZEROMP (6HGRAVY,NERROR)
END
SUBROUTINE K1A1 (A1,A2,RL,E,Z,TS,KZ,KTS)
DIMENSION Z(K2,1), TS(KTS,1)
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C CONSTANT FORCE ASSUMED.
C STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C COORDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C SIGMA-X1, SIGMA-X2
C WHERE SIGMA 1 IS NORMAL STRESS.
C SX1(-), SX2(+) IS TENSION, SX1(+), SX2(-) IS COMPRESSION.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C DX1,DX2
C WHERE DX IS TRANSLATION.
C DEVELOPED BY RL WOHLFELD, SEPTEMBER 1972.
C
C SUBROUTINE ARGUMENTS
C A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
C RL = INPUT ROD LENGTH.
C E = INPUT YOUNG'S MODULUS OF ELASTICITY.
C Z = OUTPUT STIFFNESS MATRIX, SIZE(2,2).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX, SIZE(2,2).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
S = A1*E/RL
R = A2/A1
IF (A1*FRZ-1.0 .GT. .01) S = (A2-A1)*E / (RL*ALOG(R))
C STIFFNESS MATRIX.
Z(1,1) = S
Z(1,2) = -S
Z(2,1) = -S
Z(2,2) = S
C
C STRESS TRANSFORMATION MATRIX.
TS(1,1) = Z(1,1)/A1
TS(1,2) = Z(1,2)/A1
TS(2,1) = Z(2,1)/A2
TS(2,2) = Z(2,2)/A2
C
RETURN
END

K1A1
SUBROUTINE KIP1 (B11,B12,C1,C2,A1,A2,SF,RL,E,G,Z,TS,KZ,KTS)
DIMENSION Z(2),TS(KTS,1)
DATA EPS/3.E-15/
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR A BENDING (PLUS SHEAR) BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
C UNIFORM SHEAR AND LINEAR BENDING MOMENT VARIATION IS ASSUMED.
C SHEAR STIFFNESS USES SF*A1*G AND SF*A2*E. IF ANY OF THESE VARIABLES
C ARE ZERO, THERE IS NO SHEAR DEFORMATION IN BENDING.
C STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT BEAM ENDS IN LOCAL
C COORDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C TAU-X1,TAU-X2,SIGMA-X1,SIGMA-X2
C WHERE SIGMA IS NORMAL STRESS ((ML/I) AND TAU IS SHEAR STRESS (P/A).
C THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C DZ1,DZ2,TY1,TY2
C WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C LAST REVISION BY RL WOHLEN. APRIL 1976.
C
C SUBROUTINE ARGUMENTS
C B11 = INPUT CROSS-SECTION AREA MOMENT OF INERTIA AT BEAM END 1.
C B12 = INPUT SAME AS B11 AT BEAM END 2.
C C1 = INPUT DISTANCE FROM BENDING NEUTRAL AXIS TO OUTER FIBER
C AT BEAM END 1.
C C2 = INPUT SAME AS C1 AT BEAM END 2.
C A1 = INPUT CROSS-SECTION AREA AT BEAM END 1. CAN BE ZERO FOR NO
C SHEAR DEFORMATION IN BENDING. SHEAR STRESS IN STRESS
C TRANSFORMATION WILL BE SET TO ZERO.
C A2 = INPUT SAME AS A1 AT BEAM END 2.
C SF = INPUT SHAPE FACTOR (K) FOR SHEAR IN KAG.
C USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C SF=2.5 FOR A THIN WALLED CIRCULAR CYLINDER.
C RL = INPUT ROD LENGTH.
C E = INPUT YOUNG'S MODULUS OF ELASTICITY.
C G = INPUT SHEAR MODULUS OF ELASTICITY. CAN BE ZERO FOR NO SHEAR
C DEFORMATION IN BENDING.
C Z = OUTPUT STIFFNESS MATRIX. SIZE(4,4).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(4,4).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=4.
C
C BENDING FLEXIBILITY.
RP = FI2/F11
RI = P1-1.
IF (AR(P1*RI) .LT. .01) GO TO 15
ERR = F*RI*P1*RI
REILN = ALOG(RP)
F11 = (.5 - 1.*RBIM1 + RBILN/RBIM1**2) * (RL**3) / EBR
F12 = (1. - RBILN/RBIM1) * (RL**2) / EBR
F22 = RL* RBILN / EER
GO TO 20
15 F11 = RL**3 / (3.*E*BII)
    F12 = RL**2 / (2.*E*BII)
    F22 = RL / (E*BII)
C SHEAR FLEXIBILITY.
20 IF (SF*LT.EPS .OR. A1*LT.EPS .OR. A2*LT.EPS .OR. G*LT.EPS)GO TO 30
    RA = A2/A1
    IF (ABS(RA-1.) .LT. .01) GO TO 25
    F11 = F11 + RL * ALOG(RA) / (SF*G*(A2-A1))
    GO TO 30
C
C BENDING + SHEAR STIFFNESS MATRIX.
30 D = F11+F22 - F12**2
    Z(1,1) = F22/D
    Z(1,2) =-Z(1,1)
    Z(1,3) =-F12/D
    Z(1,4) = (-RL*F22 + F12)/D
    Z(2,1) = Z(1,1)
    Z(2,3) =-Z(1,3)
    Z(2,4) =-Z(1,4)
    Z(3,3) = F11/D
    Z(3,4) = (RL*F12 - F11)/D
    Z(4,4) = (F22*RL**2 - 2.*RL*F12 + F11)/D
C SYMMETRIZE LOWER HALF.
    DO 40 J=1,4
    DO 40 I=J,4
40    Z(I,J) = Z(J,I)
C
C STRESS TRANSFORMATION MATRIX.
    DO 55 J=1,4
    TS(1,J) = 0.*0
    TS(2,J) = C.*0
    IF (A1 .GT. 0.0) TS(1,J) = Z(1,J)/A1
    IF (A2 .GT. 0.0) TS(2,J) = Z(2,J)/A2
    TS(3,J) = Z(3,J)*C1/BII
55    TS(4,J) = Z(4,J)*C2/E12
C
RETURN
END
SUBROUTINE KIC1 (TJ1, TJ2, R1, R2, RL, G, Z, TS, KZ, KTS)
DIMENSION Z(KZ,1), TS(KTS,1)
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES,
C ROD MAY BE LINEARLY TAPERED OR UNIFORM,
C CONSTANT TORQUE ASSUMED,
C STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM,
C STRESS TRANSFORMATION MATRIX PELATES STRESS AT ROD ENDS IN LOCAL
C COORDINATE SYSTEM TO ROTATIONS IN LOCAL COORDINATE SYSTEM,
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C TAU-X1, TAU-X2
C WHERE TAU IS SHEAR STRESS.
C STRESS IS + CR AS RIGHT HAND AXIS BETWEEN END F. INTS 1 AND 2,
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS
C LOCAL COORDINATE ORDER IS
C TX1, TX2
C WHERE TX IS ROTATION.
C LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
C SUBROUTINE ARGUMENTS
C TJ1 = INPUT CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
C AT ROD END 1. E.G., TJ1=.5*PI*PI**4 FOR A SOLID CIRCULAR
C CYLINDER. TJ1=2.*PI*T*RI**3 FOR A THIN WALLED CIRCULAR
C CYLINDER.
C TJ2 = INPUT CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
C AT ROD END 2.
C R1 = INPUT DISTANCE FROM TORSION AXIS TO CUTER FIBER AT ROD END 1.
C R2 = INPUT DISTANCE FROM TORSION AXIS TO CUTER FIBER AT ROD END 2.
C RL = INPUT ROD LENGTH.
C G = INPUT SHEAR MODULUS OF ELASTICITY.
C Z = OUTPUT STIFFNESS MATRIX. SIZE(2,2).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(2,2).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
S = TJ1*G/RL
R = TJ2/TJ1
IF (ABS(R-.01) .GT. .01) S = (TJ2-TJ1)*G / (RL*ALOG(R))
C STIFFNESS MATRIX.
Z(1,1) = S
Z(1,2) = -S
Z(2,1) = -S
Z(2,2) = S
C
C STRESS TRANSFORMATION MATRIX.
TS(1,1) = Z(1,1)*R1/TJ1
TS(1,2) = Z(1,2)*R1/TJ1
TS(2,1) = Z(2,1)*R2/TJ2
TS(2,2) = Z(2,2)*R2/TJ2
C
RETURN
END
DIMENSION Z(KZ,1), T(KT,1), R(KR,1)
DIMENSION XE(3), ET(I)

SUBROUTINE TO CALCULATE FINITE ELEMENT...

STIFFNESS MATRIX,
STRESS TRANSFORMATION MATRIX,
FOR A MEMBRANE TRIANGULAR PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED.
STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRIANGLE VERTICES
IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
(SIGMA-X, SIGMA-Y, TAU-XY) JOINT 1, THEN JOINT 2, 3.
WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
The local coordinate system assumes the plate to lie in an X-Y plane
WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
LOCAL COORDINATE ORDER IS
(DX, DY, TZ) JOINT 1, THEN JOINT 2, 3.
WHERE DX, DY ARE TRANSLATION, AND TZ IS ROTATION.
CALLS FDMAS SUBROUTINES ETAE A AND MULTA.
DEVELOPED BY CS ECDLEY, WA EEFIELD, MARCH 1973.
LAST REVISION BY CS ECDLEY, SEPTEMBER 1973.

SUBROUTINE ARGUMENTS
X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
X3 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 3.
Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
TH = INPUT PLATE THICKNESS.
E = INPUT YOUNG'S MODULUS OF ELASTICITY.
ANU = INPUT POISSON'S RATIO. (E/2G)-1.
Z = OUTPUT STIFFNESS MATRIX. SIZE(9,9).
T = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(9,9).
R = INPUT MATRIX WORK SPACE. SIZE(8,9).
KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
KT = INPUT ROW DIMENSION OF T IN CALLING PROGRAM. MIN=9.
KR = INPUT ROW DIMENSION OF R IN CALLING PROGRAM. MIN=8.

DO 5 I=1,9
DO 5 J=1,9
5 T(I,J) = 0.0
DO 10 I=1,9
DO 10 J=1,9
10 Z(I,J) = 0.0
IF (TH .LE. 0.0) RETURN
X22 = X2*X2
Y32 = Y3*Y3
X2Y3 = X2*Y3
SE1 = X3/X2
G = E/(2.0 + 2.*ANU)
DD = E*TH/(1.0 - ANU*2)
DNU = DD*ANU
DG = G*TH
DO 15 I=1,8  
DC 15 J=1,9  
15 R(I,J) = 0.  
C  
F00 = X2Y3/2.  
F10 = X2Y3*(1. + SE1)/6.  
F01 = X2Y3/6.  
F20 = X2Y3*(1. + SE1 + SE1**2)/12.  
F11 = X2Y3*(1. + 2.*SE1)/24.  
F02 = X2Y3/12.  
C  
Z(1,1) = DD*F00/X22  
Z(1,3) = DD*F01/X22  
Z(1,6) = DNU*F00/X2Y3  
Z(1,8) = DNU*F10/X2Y3  
Z(2,2) = DG*F00/Y32  
Z(2,3) = DG*F10/Y32  
Z(2,4) = 2.*DG*F01/Y32  
Z(2,5) = DG*F00/X2Y3  
Z(2,7) = 2.*DG*F10/X2Y3  
Z(2,8) = DG*F01/X2Y3  
Z(3,3) = DD*F02/X22 + DG*F20/Y32  
Z(3,4) = 2.*DG*F11/Y32  
Z(3,5) = DG*F10/X2Y3  
Z(3,6) = DNU*F01/X2Y3  
Z(3,7) = 2.*DG*F20/X2Y3  
Z(3,8) = DNU*F11/X2Y3 + DG*F11/X2Y3  
Z(4,4) = 4.*DG*F02/Y32  
Z(4,5) = 2.*DG*F01/X2Y3  
Z(4,7) = 4.*DG*F11/X2Y3  
Z(4,8) = 2.*DG*F02/X2Y3  
Z(5,5) = DG*F00/X22  
Z(5,7) = 2.*DG*F10/X22  
Z(5,8) = DG*F01/X22  
Z(6,6) = DD*F00/Y32  
Z(6,8) = DD*F10/Y32  
Z(7,7) = 4.*DG*F20/X22  
Z(7,8) = 2.*DG*F11/X22  
Z(8,8) = DD*F20/Y32 + DG*F02/X22  
DC 20 I=1,8  
DO 20 J=1,8  
20 Z(I,J) = Z(I,J)  
C  
R(1,1) = -1.  
R(1,..) = 1.  
R(2,1) = SE1 - 1.  
R(2,3) = -Y3  
R(2,4) = -SE1  
R(2,7) = 1.  
R(2,9) = Y3  
R(3,2) = Y2  
R(3,6) = -Y3  
R(4,3) = Y3*(1. - S11)  
R(4,6) = Y3*SE1  
R(4,9) = -Y3
\( R(5,2) = -1 \cdot \)

\( R(5,3) = x_2 \)

\( R(5,5) = 1 \cdot \)

\( R(5,6) = -x_2 \)

\( R(6,2) = 5 \varepsilon_1 - 1 \cdot \)

\( R(6,5) = -5 \varepsilon_1 \)

\( R(6,6) = x_3 \)

\( R(6,8) = 1 \cdot \)

\( R(6,9) = -x_3 \)

\( R(7,3) = -x_2 \)

\( R(7,6) = x_2 \)

\( P(8,3) = x_2*(5 \varepsilon_1 - 1) \)

\( R(5,10) = -x_3 \)

\( R(8,9) = x_2 \)

**C**

\text{CALL BTA8A} (Z,R,8,9,KZ,KR)

**C**

\( D11 = D0/TH \)

\( D12 = ANU*D11 \)

\( D33 = 6 \)

\( XE(1) = 0 \cdot \)

\( XE(2) = 1 \cdot \)

\( XF(3) = 5 \varepsilon_1 \)

\( ET(1) = 0 \cdot \)

\( ET(2) = 0 \cdot \)

\( ET(3) = 1 \cdot \)

\( DC = 10 \cdot I = 1 + 3 \)

\( K1 = 3*I - 2 \)

\( K2 = K1 + 1 \)

\( K3 = K1 + 2 \)

\( T(K1,1) = D11/X2 \)

\( T(K1,5) = D11*ET(1)/X2 \)

\( T(K1,6) = D12/Y3 \)

\( T(K1,6) = D12*XF(1)/Y3 \)

\( T(K2,11) = D12/X2 \)

\( T(K2,3) = D12*ET(1)/X2 \)

\( T(K2,6) = D11/Y3 \)

\( T(K2,6) = D11*XF(1)/Y3 \)

\( T(K3,2) = D33/Y2 \)

\( T(K3,3) = D33*XF(1)/Y3 \)

\( T(K3,4) = 2*D33*ET(1)/Y3 \)

\( T(K3,5) = D33/X2 \)

\( T(K3,7) = 2*D33*XE(1)/X2 \)

50 \( T(K3,9) = 2*ET(1)/X2 \)

**C**

\text{CALL MULT.} (T,R,8,9,KT,KR)

**C**

\text{RETURN}

END
SUBROUTINE K261 (X2, X3, Y3, TH, E, ANU, I, TS, T, KZ, KTS, KT)
DIMENSION Z(KZ,1), TS(KTS,1), T(KT,1)
DIMENSION R(I,1,1), IVEC(I,1), CCEF(9), XE(3), ET(3)
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR A FENDING TRIANGLE PLATE ELEMENT WITH UNPRESERVED BOUNDARIES.
C CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
C STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT JOINTS IN LOCAL
C COORDINATE SYSTEM TO DEFORMATIONS IN THE LOCAL SYSTEM.
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C (SIGMA-, SIGMA-, TAU-XY) FOR (Z-TH/2) AT JOINT 1, THEN JOINT 2, 3,
C (SIGMA-, SIGMA-, TAU-YY) FOR (Z-TH/2) AT JOINT 1, THEN JOINT 2, 3,
C WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C LOCAL COORDINATE ORDER IS
C (DZ, TX, TY) JOINT 1, THEN JOINT 2, 3.
C WHERE DZ IS TRANSLATION AND TX, TY ARE ROTATIONS.
C CALLS FORMA SUBROUTINES ETREE AND MULTA.
C DEVELOPED BY CS ECHLEY. MARCH 1973.
C LAST REVISION BY CS ECHLEY. SEPTEMBER 1973.
C
C SUBROUTINE ARGUMENTS
C X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C X3 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 3.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PLATE THICKNESS.
C E = INPUT YOUNG'S MODULUS OF ELASTICITY.
C ANU = INPUT POISSON RATIO. (E/2G)-1.
C Z = OUTPUT STIFFNESS MATRIX. SIZE(9,9).
C TS = OUTPUT LOCAL STRESS TRANSFORMATION MATRIX. SIZE(18,9).
C T = OUTPUT MATRIX NERV SP. CE. SIZE(10,10).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=18.
C KT = INPUT ROW DIMENSION OF T IN CALLING PROGRAM. MIN=10.
C
DC 16 I=1,9
DC 16 J=1,9
10 Z(I,J) = 0.0
DC 11 I=1,10
DC 11 J=1,9
11 TS(I,J) = 0.0
IF (TH < LF) 0.0)
C
DC 12 I=1,10
DC 12 J=1,10
12 T(I,J) = 0.0
X22 = X2*X2
Y24 = Y24*Y24
Y32 = Y3*Y3
Y34 = Y34*Y34
SE1 = X3/X2
SE2 = SE1*SE1
SE3 = SE2*SE1
SE4 = SE3*SE1
SECl = (1. + SE1)/3.
SEc2 = SECl**2
SEc3 = SECl**3
G = E/(2. + 2.*ANU)
DD = (E*71)**3/112.*((1. - ANU)**2)
DNu = DD*ANU
DG = (G*TH)**3/12.
AL = DD/Y:
AE = DNu/(X22+Y32)
GA = CD/Y34
DE = 4.*DG/(X22+Y32)

T(1,1) = 1.
T(2,2) = 1.
T(3,2) = 1.
T(4,1) = 1.
T(4,2) = 1.
T(4,4) = 1.
T(4,7) = 1.
T(5,3) = 1.
T(5,5) = 1.
T(5,6) = 1.
T(6,2) = 1.
T(6,4) = 2.
T(6,7) = 3.
T(7,1) = 1.
T(7,2) = SE1
T(7,3) = 1.
T(7,4) = SE2
T(7,5) = SE1
T(7,6) = 1.
T(7,7) = SE2
T(7,8) = SE1
T(7,9) = SE1
T(7,10) = 1.
T(8,1) = 1.
T(8,5) = SE1
T(8,8) = SE2
T(8,9) = 2.*SE1
T(8,10) = ?.
T(9,2) = 1.
T(9,4) = 2.*SE1
T(9,5) = 1.
T(9,7) = 3.*SE2
T(9,8) = 2.*SE1
T(9,9) = 1.
T(10,1) = 1.
T(10,2) = SE1
T(10,3) = 1.*C.
T(10,4) = SE2
\[ T(10,5) = \frac{\text{SEC1}/3}{ } \]
\[ T(10,6) = \frac{1}{9} \]
\[ T(10,7) = \text{SEC2} \]
\[ T(10,8) = \text{SEC2}/3 \]
\[ T(10,9) = \text{SEC1}/9 \]
\[ T(10,10) = 1/27 \]

C

DO 5 I=1,10
DO 7 J=1,10
7 R(I,J) = 0.
5 R(I,I) = 1.

C

DO 160 L=1,10
JEIG = 1
ALJEG = T(L,L)
DO 15 J=2,10
ALJEG = ABS(T(L,J))
IF (ALJEG .LT. A1) GO TO 15
ALJEG = A2
JEIG = J
15 CONTINUE
IVEC(L) = JEIG
ALJPIG = T(L,JEIG)
DO 17 J=1,10
T(L,J) = T(L,J)/ALJPIG
17 R(L,J) = F(L,J)/ALJPIG
DO 25 I=1,10
ALJPIG = T(I,JEIG)
IF (ALJPIG .LT. L) GO TO 25
ALJPIG = A2
DO 25 J=1,10
T(I,J) = T(I,J) - ALJPIG*ALJPIG
25 CONTINUE
CONTINUE

C

DO 40 I=1,10
IP = IVEC(I)
DO 40 J=1,10
40 T(IF,J) = R(I,J)
DO 50 I=1,10
DO 50 J=1,10
50 R(I,J) = T(I,J)

C

DO 26 I=1,10
R(I,1) = Y2*F(1,I)
R(I,2) = -Y2*F(1,2)
R(I,3) = Y2*F(1,3)
R(I,4) = -Y2*F(1,4)
R(I,5) = Y2*F(1,5)
R(I,6) = -Y2*F(1,6)
R(I,7) = Y2*F(1,7)
R(I,8) = -Y2*F(1,8)
R(I,9) = -Y2*F(1,9)
R(I,10) = -Y2*F(1,10)

C

COEFF(1) = 1. / 2.
COEFF(2) = Y2 / 1.
COEFF(3) = -(Y2 + X2) / 1E-
COEFF(4) = 1. / 3.
CCOF(5) = Y3/18.
CCOF(6) = (2.*X2 - X3)/18.
CCOF(7) = 1./2.
CCOF(8) = -Y3/6.
CCOF(9) = (2.*X3 - X2)/18.
DO 80 I=1,10
DO 80 J=1,9
80 R(I,J) = R(I,J) + R(I,10)*CCOF(J).
C
DC 55 I=1,10
DO 55 J=1,10
55 T(I,J) = 0.
C
F00 = X2*Y3/2.
F10 = X2*Y3*(1. + SE1)/6.
F01 = X2*Y3/6.
F20 = X2*Y3*(1. + SE1 + SE2)/12.
F11 = X2*Y3*(1. + 2.*SE1)/24.
F02 = X2*Y3/12.
C
T(4,4) = 4.*AF*F00
T(4,6) = 4.*EE*F00
T(4,7) = 12.*AL*F10
T(4,8) = 4.*AL*F01
T(4,9) = 4.*EE*F10
T(4,10) = 12.*EE*F01
T(5,5) = DF*F00
T(5,7) = 2.*DE*F10
T(5,9) = 2.*DE*F11
T(6,6) = 4.*GA*F00
T(6,7) = 12.*EE*F10
T(6,8) = 4.*EE*F01
T(6,9) = 4.*GA*F10
T(6,10) = 12.*GA*F01
T(7,7) = 36.*AL*F20
T(7,8) = 12.*AL*F11
T(7,9) = 12.*EE*F20
T(7,10) = 36.*EE*F11
T(8,8) = 4.*AL*F02 + 4.*DE*F20
T(8,9) = 4.*EE*F11 + 4.*DE*F11
T(8,10) = 12.*EE*F02
T(9,9) = 4.*GA*F20 + 4.*DE*F02
T(9,10) = 12.*GA*F11
T(10,10) = 36.*GA*F02
C
DC 60 I=1,10
DC 60 J=1,10
60 T(J,1) = T(I,J)
CALL ETAFA (T,J,10,9,KT,10)
DC 85 I=1,6
DC 85 J=1,6
85 Z(I,J) = T(I,J)
C
DC 73 I=1,6
DC 73 J=1,10
73 T(I,J) = C \cdot C
D11 = -6.*DD/((X2*TH)**2)
D21 = ANU*DI1
D22 = -6.*DD/((Y3*TH)**2)
D12 = ANU*DI2
D33 = -12.*DG/((X2*Y3)*TH**2)
XE(1) = C.*
XE(2) = 1.*
XE(3) = SE1
ET(1) = 0.*
ET(2) = 0.*
ET(3) = 1.*
DO 75 I=1,3
K1 = 3*I - 2
K2 = K1 + 1
K3 = K1 + 2
T(K1,4) = 2.*D11
T(K1,6) = 2.*D12
T(K1,7) = 6.*D11*XE(I)
T(K1,8) = 2.*D11*ET(I)
T(K1,9) = 2.*D12*XE(I)
T(K1,10) = 6.*D12*ET(I)
T(K2,4) = 2.*D21
T(K2,6) = 2.*D22
T(K2,7) = 6.*D21*XE(I)
T(K2,8) = 2.*D21*ET(I)
T(K2,9) = 2.*D22*XE(I)
T(K2,10) = 6.*D22*ET(I)
T(K3,5) = D33
T(K3,8) = 2.*D33*XE(I)
75 T(K3,9) = 2.*D33*ET(I)
CALL MULTA(T,K,9,10,K,T,10)
DO 77 I=1,9
IP9 = I + 9
DO 77 J=1,9
T(I,J) = T(I,J)
77 T(I,IP9,J) = -T(I,J)

C
RETURN
END
SUBROUTINE K3C1 (X3,Y3,TH,G,Z,T,KZ,KT)
DIMENSION Z(KZ,1), T(KT,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C LINEAR DISPLACEMENT (CONSTANT STRAIN) FIELD IS USED.
C STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C STRESS TRANSFORMATION MATRIX RELATES PANEL SHEAR STRESS (CONSTANT)
C IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
C ALONG THE POSITIVE Y AXIS.
C LOCAL COORDINATE ORDER IS
C DX1,DX2,DX3,DX4, DY1,DY2, DY3,DY4
C WHERE DX, DY ARE TRANSLATIONS.
C DEVELOPED BY RL WOHLEN. APRIL 1974.
C
C SUBROUTINE ARGUMENTS
C X3 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 3.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PANEL THICKNESS.
C G = INPUT SHEAR MODULUS OF ELASTICITY.
C Z = OUTPUT STIFFNESS MATRIX. SIZE(R,6).
C T = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,8).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C KT = INPUT ROW DIMENSION OF T IN CALLING PROGRAM. MIN=1.
C
C STIFFNESS MATRIX.
C
C = 12*G/4,
A = C*X3/Y3
B = C*Y2/X2
Z(1,1) = A
Z(1,2) = A
Z(1,3) = -A
Z(1,4) = -A
Z(1,5) = C
Z(1,6) = -C
Z(1,7) = -C
Z(1,8) = C
Z(2,1) = A
Z(2,2) = -A
Z(2,3) = -A
Z(2,4) = -A
Z(2,5) = C
Z(2,6) = -C
Z(2,7) = -C
Z(2,8) = C
Z(3,1) = A
Z(3,2) = A
Z(3,3) = -C
Z(3,4) = C
Z(3,5) = C
Z(3,6) = C
Z(3,7) = C
Z(3,8) = C
Z(4,4) = A
Z(4,5) = -C
Z(4,6) = C
Z(4,7) = C
Z(4,8) = -C
Z(5,5) = F
Z(5,6) = -F
Z(5,7) = -F
Z(5,8) = F
Z(6,6) = B
Z(6,7) = B
Z(6,8) = -E
Z(7,7) = B
Z(7,8) = -F
Z(8,8) = F

C. SYMMETRIZE LOWER HALF.
   DO 10 J=1,8
   DO 10 I=J,F
   10 Z(I,J) = Z(J,I)

C. STRESS TRANSFORMATION MATRIX.
   DO 20 J=1,6
   20 T(1,J) = 2.*Z(3,J)/(TH*X3)

C
RETURN
FIND
SUBROUTINE KGRAV (CJ, JM, EV, A, W, KW, KCJ)
DIMENSION CJ(KCJ,1), JM(1), EV(1), W(KW,1)
DIMENSION F(3,4), R12(3), R13(3), VN(3), F(3,3)
DATA KEF / 3 /

C SUBROUTINE TO DERIVE STIFFNESS MATRIX FOR A TRIANGULAR GRAVITY ELEMENT.
C CALLS FORMA SUBROUTINES MULTA, MULTB, VCRoss.
C DEVELOPED BY C S EDDLEY. FEBRUARY 1974.
C LAST REVISION BY C S EDDLEY. NOVEMBER 1974.
C SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF JOINT COORDINATES. SIZE (3,4).
C JM = INPUT VECTOR OF JOINTS DEFINING A TRIANGLE. SIZE (3).
C EV = INPUT VECTOR NORMALIZED GRAVITY. SIZE = 3.
C A = OUTPUT AREA.
C W = OUTPUT STIFFNESS MATRIX.
C KW = INPUT ROW DIMENSION SIZE OF W IN CALLING PROGRAM. MIN=9.
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
J1 = JM(1)
J2 = JM(2)
J3 = JM(3)
DO 5 I=1,9
DO 5 J=1,3
W(I,J) = 0.
5 E(J,I) = 0.
DO 7 I=1,3
F12(I) = CJ(I,J2) - CJ(I,J1)
F13(I) = CJ(I,J3) - CJ(I,J1)
7 F(I,J) = 1.
F(1,1) = 2.
DO 10 I=1,3
10 VN(I) = VN(I)/A
ACUM = 0.0
DO 15 I=1,3
11 = 3*I - 3
ACUM = ACUM + VN(I)*EV(I)
DO 15 J=1,2
E(I,11+J) = VN(I)
15 W(I1+J,1) = VN(I)
CALL MULTB (F, E, 3, 2, 0, KEF, KEF)
CALL MULTA (W, E, 3, 2, 9, KW, KEF)
A = A*ACUM*ACUM*ACUM
C RETURN
END
SUBROUTINE M1A1 (A1,A2,RL,RO,Z,KZ)
DIMENSION Z(KZ,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C LUMPED MASS MATRIX
C FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C DX1,DX2
C WHERE DX IS TRANSLATION.
C
C SUBROUTINE ARGUMENTS
C A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
C RL = INPUT ROD LENGTH.
C RO = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(2,2).
C KZ = INPUT FLOW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
W1 = A1*RL*RO/6.
W2 = A2*RL*RO/6.
Z(1,1) = 2.*W1 + W2
Z(1,2) = 0.
Z(2,1) = 0.
Z(2,2) = W1 + 2.*W2

RETURN
END
SUBROUTINE M1A2 (A1,A2,RL,RC,Z,KZ)
DIMENSION Z(KZ,1)
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C CONSISTENT MASS MATRIX
C FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C ROD MAY BE LINEARLY TAPEPED OR UNIFORM.
C LINEAR DISPLACEMENT FUNCTION ASSUMED.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C DX1,DX2
C WHERE DX IS TRANSLATION.
C DEVELOPED BY RL WOHLLEN. SEPTEMBER 1972.
C
C SUBROUTINE ARGUMENTS
C A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
C RL = INPUT ROD LENGTH.
C RC = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(2,2).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
W1 = A1*RL*RC/12.
W2 = A2*RL*RC/12.
Z(1,1) = 3.*W1 + W2
Z(1,2) = W1 + W2
Z(2,1) = Z(1,2)
Z(2,2) = W1 + 3.*W2
C
RETURN
END
SUBROUTINE M1P1 (A1,A2,RL,RO,Z,KZ)
DIMENSION Z(KZ,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C LUMPED MASS MATRIX
C FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
C BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C D21,D22,TY1,TY2
C WHERE D2 IS TRANSLATION AND TY IS ROTATION.
C DEVELOPED BY RL WCHL'N. FEBRUARY 1973.
C
C SUBROUTINE ARGUMENTS
C A1 = INPUT CROSS-SECTION AREA AT BEAM END 1.
C A2 = INPUT CROSS-SECTION AREA AT BEAM END 2.
C RL = INPUT BEAM LENGTH.
C RO = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(4,4).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
C
W1 = A1*RL*RO/6.
W2 = A2*RL*RO/6.
DO 10 J=1,4
   DO 10 I=1,4
10 Z(1,J) = 0.0
   Z(1,1) = 2.*W1 + W2
   Z(2,2) = W1 + 2.*W2
   Z(4,4) = (A2*RO*RL*3)/24.

RETURN
END
SUBROUTINE M182 (A1, A2, RL, KO, Z, KZ)
DIMENSION Z(K2, I)

SUBROUTINE TO CALCULATE FINITE ELEMENT...

CONSISTENT MASS MATRIX

FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.

BEAM MAY BE LINEARLY TAPERED OR UNIFORM.

CUBIC DISPLACEMENT FUNCTION ASSUMED.

MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.

THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE.

WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.

LOCAL COORDINATE ORDER IS

DZ1, DZ2, TY1, TY2

WHERE DZ IS TRANSLATION AND TY IS ROTATION.

DEVELOPED BY RL WOHLLEN. FEBRUARY 1973.


SUBROUTINE ARGUMENTS

A1 = INPUT CROSS-SECTION AREA AT BEAM END 1.
A2 = INPUT CROSS-SECTION AREA AT BEAM END 2.
RL = INPUT BEAM LENGTH.
KO = INPUT MASS DENSITY.
Z = OUTPUT MASS MATRIX, SIZE(4,4).

KZ = INPUT RICE DIMENSION OF Z IN CALLING PROGRAM. MIN=4.

W1 = A1*RL*RO/E40.
W2 = A2*RL*KO/E40.
RL2 = RL**2
Z(1,1) = 72.0*W1 + 72.0*W2
Z(1,2) = 72.0*W1 + 72.0*W2
Z(2,2) = 72.0*W2 + 240.0*W2
Z(1,3) = 14.0*W1 + 14.0*W2 + 36.0*RL
Z(1,4) = 14.0*W1 + 14.0*W2 + 36.0*RL
Z(2,3) = 12.0*W2 + 30.0*W2 + 36.0*RL
Z(2,4) = 12.0*W2 + 30.0*W2 + 36.0*RL
Z(3,3) = 5.0*W1 + 5.0*W1 + 15.0*W2 + 36.0*RL2
Z(3,4) = 3.0*W1 + 5.0*W1 + 15.0*W2 + 36.0*RL2
Z(4,4) = 3.0*W1 + 5.0*W1 + 15.0*W2 + 36.0*RL2

DO 10 J=1,4
   DO 10 I=J,4
10   Z(I,J) = Z(J,I)

RETURN
END
SUBROUTINE M1C1 (PI1, PI2, RL, RO, Z, KZ)

DIMENSION Z(KZ, 1)

SUBROUTINE TO CALCULATE FINITE ELEMENT...

LUMPED MASS MATRIX

FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.

ROD MAY BE LINEARLY TAPERED OR UNIFORM.

MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.

THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS

WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.

LOCAL COORDINATE ORDER IS

TX1, TX2

WHERE TX IS NOTATION.


LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.

SUBROUTINE ARGUMENTS

PI1 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.

PI2 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.

RL = INPUT ROD LENGTH.

RO = INPUT ROD DENSITY.

Z = OUTPUT TORSION ELEMENT SIZE(2x2).

KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.

W1 = PI1*RL*RO/6.

W2 = PI2*RL*RO/6.

Z(1,1) = Z*w1 + W2

Z(1,2) = 0.

Z(2,1) = 0.

Z(2,2) = .W1 + 2.*W2

RETURN

END
SUBROUTINE MIC2 (PI1, PI2, RL, RO, z, KZ)
DIMENSION Z(KZ, 1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C CONSTANTS MASS MATRIX
C FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C LINEAR DISPLACEMENT FUNCTION ASSUMED.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C LOCAL COORDINATE ORDER IS
C TX, TY
C WHERE TY IS ROTATION.
C LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.

C SUBROUTINE ARGUMENTS
C PI1 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.
C PI2 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.
C RL = INPUT ROD LENGTH.
C RO = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(2,2).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.

W1 = PI1*RO*RL**2/12.
W2 = PI2*RO*RL**2/12.
Z(1,1) = 3.*W1 + W2
Z(1,2) = W1 + W2
Z(2,1) = Z(1,2)
Z(2,2) = W1 + 3.*W2

RETURN
END
SUBROUTINE M2A1 (X2, Y3, TH, RC, Z, KZ)
DIMENSION Z(KZ, 1)

C
C SUBROUTINE M: CALCULATE FINITE ELEMENT...
C LUMPED MASS PR.
C FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C LOCAL COORDINATE ORIGIN IS
C (EX, EY, T2) JOINT 1, THEN JOINT 2, 3.
C WHERE EX, EY ARE TRANSLATIONS AND T2 IS ROTATION.
C DEVELOPED BY W2 BENFIELD. FEBRUARY 1972.
C LAST REVISION BY RL KOHLER. SEPTEMBER 1973.
C
C SUBROUTINE ARGUMENTS
C X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PLATE THICKNESS.
C RC = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(5, 9).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C
AREA = 0.5*X2*Y2
CM = (RC*TH*AREA)/3.0
DO 10 I=1, 6
DO 10 J=1, 6
10 Z(I, J) = CM
DO 20 L=1, 9
20 Z(L, 1) = CM
RETURN
END

M2A1
SUBROUTINE M2A2 (X2, X3, Y3, Tm, TNC, Z, T, R, KZ, KT, KR)
DIMENSION Z(KZ,1), T(KT,1), F(KR,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C CONSISTENT MASS MATRIX,
C FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLAN.
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C LOCAL COORDINATE ORDER IS
C (MX, DY, TZ) JOINT 1, THEN JOINT 2, 3.
C WHERE DX, DY ARE TRANSLATIONS AND TZ IS ROTATION.
C CALLS FORM SUBROUTINES E11RA.
C DEVELOPED BY CF SCDLEY. MARCH 1973.
C LAST REVISION BY WA BENFIELD. SEPTEMBER 1973.

C SUBROUTINE ARGUMENTS
C X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C X3 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 3.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PLATE THICKNESS.
C TNC = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX SIZE(9,9).
C T = OUTPUT MATRIX WORK SPACE SIZE(10,10).
C R = INPUT MATRIX WORK SPACE SIZE(10,10).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM, MIN=9.
C KT = INPUT ROW DIMENSION OF T IN CALLING PROGRAM, MIN=10.
C KR = INPUT ROW DIMENSION OF R IN CALLING PROGRAM, MIN=10.

C SEI = X2/2.
C SE2 = SE1*SE1
C SE3 = SE2*SE1
C SE4 = SE3*SE1
C X2Y3 = X2*Y3*TH:

C DO 10 J=1,10
C DO 10 I=1,10
C 10 R(I,J) = 0.

C F00 = Z2Y3/2.
C F10 = Z2Y3*(1. + SE1)/6.
C F11 = X2Y3*6.
C F20 = X2Y3*(1. + SE1 + SE2)/12.
C F11 = X2Y3*(1. + 2.*SE1/24.
C F20 = X2Y3/12.
C F20 = X2Y3*(1. + SE1 + SE2 + SE3)/20.
C F21 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3/60.
C F12 = X2Y3*(1. + 3.*SE1/120.
C F22 = X2Y3*(1. + 3.*SE1 + 6.*SE2/180.
\[ F_{13} = \frac{X2Y3*(1.4 + 47.5S1)}{120}, \]

\[ F_{04} = \frac{X2Y3}{30}. \]

\[ T(1,1) = F_{06} \]
\[ T(1,2) = F_{10} \]
\[ T(1,3) = F_{31} \]
\[ T(1,4) = F_{11} \]
\[ T(1,5) = F_{02} \]
\[ T(2,2) = F_{21} \]
\[ T(2,3) = F_{11} \]
\[ T(2,4) = F_{21} \]
\[ T(2,5) = F_{11} \]
\[ T(3,2) = F_{02} \]
\[ T(3,3) = F_{21} \]
\[ T(3,4) = F_{21} \]
\[ T(3,5) = F_{31} \]
\[ T(4,4) = F_{22} \]
\[ T(4,5) = F_{03} \]
\[ T(5,5) = F_{44} \]
\[ T(6,6) = F_{10} \]
\[ T(6,7) = F_{10} \]
\[ T(6,8) = F_{01} \]
\[ T(6,9) = F_{20} \]
\[ T(6,10) = F_{11} \]
\[ T(7,7) = F_{20} \]
\[ T(7,8) = F_{11} \]
\[ T(7,9) = F_{02} \]
\[ T(7,10) = F_{21} \]
\[ T(8,8) = F_{02} \]
\[ T(8,9) = F_{21} \]
\[ T(8,10) = F_{12} \]
\[ T(9,9) = F_{44} \]
\[ T(9,10) = F_{21} \]
\[ T(10,10) = F_{22} \]

\[ DC = 20 \]

\[ DJ = 1,10 \]

\[ 30 \quad T(j+1) = T(j,J) \]

\[
\begin{align*}
F(1,1) & = 1. \\
R(2,1) & = -1. \\
R(2,4) & = 1. \\
P(3,1) & = 571 - 1. \\
S(3,3) & = -Y3 \\
P(3,4) & = -SE1 \\
R(3,6) & = Y3 \\
P(4,3) & = Y3 \\
P(4,6) & = -Y3 \\
R(5,2) & = Y3*(T. - SE1) \\
P(5,6) & = Y3*SE1 \\
R(5,9) & = -Y3 \\
R(6,2) & = 1. \\
P(7,2) & = -1. \\
F(7,3) & = Y2 \\
P(7,4) & = 1. \\
P(7,6) & = -Y2 \\
P(8,2) & = SE1 - 1. 
\end{align*}
\]
R(1,5) = -5e1
R(1,6) = X3
R(1,8) = 1.
R(2,4) = -Y2
R(4,3) = -X2
R(5,6) = X2
R(10,2) = Y2*(SE1 - 1.)
R(11,6) = -X3
R(10,9) = X2

CALL PTAEA (T,F,10,9,KT,KP)
DC -6 I=1,6
DC 40 J=1,6
40 Z(I,J) = T(I,J)

RETURN
END
SUBROUTINE M261 (X2,Y3,TH,R0,Z,KZ)
DIMENSION Z(KZ,1)
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C LUMPED MASS MATRIX.
C FOR A PENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C LOCAL COORDINATE ORDER IS
C (DZ,DX,DY) JOINT 1, THEN JOINT 2, 3.
C WHERE DZ IS TRANSLATION AND DX,DY ARE ROTATIONS.
C LAST REVISION BY KL WOHLFEND. SEPTEMBER 1973.
C
SUBROUTINE ARGUMENTS
C X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PLATE THICKNESS.
C R0 = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(9,9).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C
AREA = 0.5*X2*Y3
CM = (R0*TH*AREA)/3.0
DO 10 I=1,9
DO 10 J=1,9
10 Z(I,J) = 0.0
DO 20 I=1,9
20 Z(I,I) = CM
RETURN
END
SUBROUTINE M2F2 (X2, Y3, Y3, TH, FH0, Z, T, P, KZ, KT, KR)
DIMENSION 2(KZ, 1), I(KT, 1), K(KR, 1)
DIMENSION IVEC(10), CCEF(19)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C CONSISTENT MASS MATRIX.
C FOR A BENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
C CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
C THIS IS NOT THE SQUARED STRICKLAND ELEMENT.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C LOCAL COORDINATE CHECK IS
C (OZ, TX, TY) JOINT 1, THEN JOINT 2, 3.
C WHERE OZ IS TRANSLATION AND TX, TY ARE ROTATIONS.
C CALLS FROM SUBROUTINES GFAEA2.
C DEVELOPED BY CAFF POOLEY MARCH 1973.
C LAST REVISION BY WA BENFIELD. SEPTEMBER 1973.

C SUBROUTINE ARGUMENTS
C X2 = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C X3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C Y3 = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT PLATE THICKNESS.
C FH0 = INPUT MASS DENSITY.
C Z = OUTPUT MASS MATRIX. SIZE(9,9).
C T = OUTPUT MATIX WORK SPACE. SIZE(10,10).
C P = OUTPUT MATTIX WORK SPACE. SIZE(10,10).
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C KT = INPUT ROW DIMENSION OF T IN CALLING PROGRAM. MIN=10.
C KR = INPUT ROW DIMENSION OF R IN CALLING PROGRAM. MIN=10.

SE1 = X2/Y3
SE2 = SE1*SE1
SE3 = SE2*SE1
SE4 = SE3*SE1
SE5 = SE4*SE1
SE6 = SE5*SE1
SE1 = (1. + SE1)/3.
SE2 = SE1*SE2
SE3 = SE1*SE3

CP 10 J=1,10
DP 10 J=1,10
10 T(1,J) = 0.

T(1,1) = 1.
T(2,2) = 1.
T(2,3) = 1.
T(4,1) = 1.
T(4,2) = 1.
T(4,4) = 1.
T(4,7) = 1.
T(5,3) = 1.
C
T(5,5) = 1.
T(5,8) = 1.
T(6,2) = 1.
T(6,4) = 2.
T(6,7) = 3.
T(7,1) = 1.
T(7,2) = SE1
T(7,3) = 1.
T(7,4) = SE2
T(7,5) = SE1
T(7,6) = 1.
T(7,7) = SE2
T(7,8) = SE2
T(7,9) = SE1
T(7,10) = 1.
T(8,2) = 1.
T(8,5) = SE1
T(8,6) = 2.
T(8,8) = SE2
T(8,9) = 2.*SE1
T(8,10) = 3.
T(9,2) = 1.
T(9,4) = 2.*SE1
T(9,5) = 1.
T(9,7) = 2.*SE2
T(9,8) = 2.*SE1
T(9,9) = 1.
T(10,1) = 1.
T(10,2) = SEC1
T(10,3) = 1./3.
T(10,4) = SEC2
T(10,5) = SEC1/3.
T(10,6) = 1./9.
T(10,7) = SEC2
T(10,8) = SEC2/3.
T(10,9) = SEC1/9.
T(16,10) = 1./27.

C
DO 5 J=1,10
5 R(I,J) = 0.
R(I,1) = 1.
C
DO 100 L=1,16
JPEIG = 1
A1 = AES(T(L,1))
DO 15 J=2,16
A2 = AES(T(L,J))
IF (A2 .LT. A1) GO TO 15
A1 = A2
JPEIG = J
15 CONTINUE
IVEC(L) = JPEIG
ALJEIG = T(L,JPEIG)
DC 17 J=1,10
T(L,J) = T(L,J)/A12F1G
17 R(L,J) = R(L,J)/A12F1G
DC 25 I=1,10
Al2F1G = T(I,J)/A12F1G
IF (I+12F1G < L) GC TC 25
DO 30 J=1,10
T(I,J) = T(I,J) - A12F1G*T(I,J)
30 R(I,J) = R(I,J) - A12F1G*R(I,J)
25 CONTINUE
100 CONTINUE

C
DO 40 I=1,10
IF = IVEC(I)
DC 40 J=1,10
40 T(R,J) = R(I,J)
DC 50 I=1,10
CC 50 J=1,10
50 R(I,J) = T(I,J)

C
DO 20 I=1,10
R(I,2) = Y3*R(I,2)
R(I,3) = -X2*R(I,3)
R(I,5) = Y3*R(I,5)
R(I,6) = -Y3*R(I,6)
R(I,8) = Y3*R(I,8)
20 R(I,9) = -X2*R(I,9)

C
CCEF(1) = 1.5/3.
CCEF(2) = Y3/18.
CCEF(3) = -(X2+X3)/18.
CCEF(4) = 1.5/3.
CCEF(5) = Y3/18.
CCEF(6) = (2.*X2 - X3)/18.
CCEF(7) = 1.5/3.
CCEF(9) = (2.*X3 - X2)/18.
DO 60 I=1,10
DO 60 J=1,9
60 R(I,J) = R(I,J) + R(I,10)*CCEF(J)

C
DC 55 I=1,10
DC 55 J=1,10
55 T(1,J) = 0.

C
X2Y3 = Y2*Y3*TH*RHO
FG0 = X2Y3/2.
FG1 = X2Y3*1. + SE1/6.
FG1 = X2Y3/6.
FG3 = Y2*Y3*1. + SE1 + SE2/12.
F11 = X2Y3*1. + 2.*SE1/24.
FG2 = X2Y3/12.
FG5 = X2Y3*1. + SE1 + SE2 + SE3/24.
F21 = X2Y3*1. + 2.*SE1 + 3.*SE2/6.
F12 = X2Y3*1. + 3.*SE1/6.
FG3 = X2Y3/20.
F40 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4)/30.
F31 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3)/120.
F22 = X2Y3*(1. + 3.*SE1 + 6.*SE2)/180.
F13 = X2Y3*(1. + 4.*SE1)/120.
F04 = X2Y2/30.
F05 = X2Y2*(1. + SE1 + SE2 + SE3 + SE4 + SE5)/42.
F32 = X2Y2*(1. + 3.*SE1 + 6.*SE2 + 10.*SE3)/420.
F23 = X2Y2*(1. + 4.*SE1 + 10.*SE2)/420.
F14 = X2Y2*(1. + 5.*SE1)/210.
F06 = X2Y2/56.

T(1,1) = F00
T(1,2) = F10
T(1,3) = F01
T(1,4) = F20
T(1,5) = F11
T(1,6) = F02
T(1,7) = F30
T(1,8) = F21
T(1,9) = F12
T(1,10) = F03
T(2,2) = F20
T(2,3) = F11
T(2,4) = F20
T(2,5) = F21
T(2,6) = F12
T(2,7) = F30
T(2,8) = F51
T(2,9) = F22
T(2,10) = F13
T(3,3) = F02
T(3,4) = F21
T(3,5) = F12
T(3,6) = F03
T(3,7) = F31
T(3,8) = F22
T(3,9) = F13
T(3,10) = F04
T(4,4) = F40
T(4,5) = F31
T(4,6) = F22
T(4,7) = F50
T(4,8) = F41
T(4,9) = F23
T(4,10) = F23
T(5,5) = F22
T(5,6) = F13
T(5,7) = F41
T(5,8) = F32
T(5,9) = F23
T(5,10) = F14
T(6,6) = F64
T(6,7) = F22
T(6,8) = F19
T(6,9) = F14
T(6,10) = F65
T(7,7) = F66
T(7,8) = F51
T(7,9) = F42
T(7,10) = F33
T(8,8) = F47
T(8,9) = F33
T(8,10) = F24
T(9,9) = F33
T(9,10) = F15
T(10,10) = F66

C
DO 60 I=1,10
DO 60 J=1,10
60 T(I,J) = T(I,J)
CALL RTARA (T,R,10,9,KT,KR)
DO 85 I=1,9
DO 85 J=1,9
85 Z(I,J) = T(I,J)

C
RETURN
END
SUBROUTINE M3CI (X3, Y3, TH, RD, Z, KZ)
DIMENSION Z(2,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C LUMPED MASS MATRIX
C FOR A RECTANGULAR SHEET PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE.
C WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
C ALONG THE POSITIVE Y AXIS.
C LOCAL COORDINATE ORDER IS
C DX1,DX2,DX4, DY1,DY2,DY3,DY4
C WHERE DX, DY ARE TRANSLATIONS.
C DEVELOPED BY RL WOHLER. APRIL 1974.
C
C SUBROUTINE ARGUMENTS
C X3 = INPUT: LOCAL X COORDINATE LOCATION OF JOINT 3.
C Y3 = INPUT: LOCAL Y COORDINATE LOCATION OF JOINT 3.
C TH = INPUT: PANEL THICKNESS.
C RD = INPUT: MASS DENSITY.
C Z = OUTPUT: MASS MATRIX. SIZE(8,8).
C KZ = INPUT: ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C
CM = RD*TH*X3*Y3/4.0
DC 16 J=1,8
DC 10 I=1,8
10 Z(I,J) = 0.0
DC 26 I=1,8
20 Z(I,I) = CM

RETURN
END
SUBROUTINE MASIA (CJ,EJ,A1,A2,RU,YMEM,Z,KCJ,KEJ,KZ)

DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(1), R(1), RU
DIMENSION E1(3,3), E2(3,3), W(2,2)

C

SUBROUTINE TO CALCULATE FINITE ELEMENT...

C

MASS MATRIX
C

FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
C

ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C

MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C

GLOBAL COORDINATE ORDER IS
C

(U*,V,W) JOINT 1, THEN JOINT 2.
C

WHERE U*,V,W ARE TRANSLATIONS.
C

EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C

CALLS FORMAS SUBROUTINES EULER,M1A1,M1A2,ZZBOMB.
C

DEVELOPED BY RL WOHLEN. SEPTEMBER 1972.
C

LAST REVISION BY WA BENFIELD. MARCH 1976.
C

C

SUBROUTINE ARGUMENTS
C

CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C
ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
COLUMNS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C

EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
C
ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
COLUMNS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C

A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C
A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
C

RO = INPUT MASS DENSITY.
C

NAME = INPUT TYPE OF MASS MATRIX WANTED.
C

= M1, LUMPED.
C

= M2, CONSISTENT.
C

Z = OUTPUT MASS MATRIX. SIZE(6,6).
C

KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C

KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C

KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=6.
C

C

ERROR EXPLANATION
C

1 = DIMENSION SIZE EXCEEDED (KZ).
C

2 = NAME IMPROPERLY DEFINED.
C

IF (KZ .LT. 6) GO TO 999
DC 5 J=1,6
DO 5 I=1,6
5 Z(I,J) = 0.0
RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
* + (CJ(3,2)-CJ(3,1))**2)
IF (NAMEF EQ. 6MM1 ) GO TO 110
IF (NAMEF EQ. 6MM2 ) GO TO 126

GO TO 999

C

LUMPED.

110 CALL M1A1 (A1,A2,RL,RO,CJ)
DC 112 I=1,5
112 Z(I,1) = W(I,1)

NERRDR=1

NERRDR=2
DO 114 I=4,6
  114 Z(I,I) = W(2,2)  -
  RETURN

C CONSISTENT.
   120 CALL MIA2 (A1,A2,RL,RO,W,2)
   DO 122 I1=1,3
   122 Z(I,1) = W(1,1)
      CALL EULER (E1(1,1),E1,3)
      CALL EULER (E1(1,2),E2,3)
      CALL ATXRB (E1,E2,3,3,3,3,3)
      DO 124 I=1,3
      DO 124 J=4,6
         Z(I,J) = W(1,2)*E2(I,J-3)
   124 Z(J,1) = Z(I,J)
   DO 126 I=4,6
   126 Z(I,1) = W(2,2)
   RETURN

C 999 CALL ?ZBUMB (6HMASIA ,NERROR)
END.
MAS16 -- 1/2

SUBROUTINE MAS16 (CJ, EJ, A1, A2, PI1, PI2, RO, NAMEM, Z, W, KCJ, KEJ, KZ, KW)
DIMENSION CJ(KCJ, 1), EJ(KEJ, 1), Z(KZ, 1), W(KW, 1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C MASS MATRIX
C FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
C BOUNDARIES.
C BAR MAY BE LINEARLY TAPERED OR UNIFORM.
C MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C GLOBAL COORDINATE ORDER 1;
C (U, V, W, P, Q, R) JOINT 1, THEN JOINT 2
C WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS.
C EULER ANGLE CONVENTION IS GLOBAL X, Y, Z PERMUTATION.
C CALLS FORMA SUBROUTINES BTAB, DCS16, M1A1, M1A2, MIB1, MIB2, M1C1, M1C2.
C DEVELOPED BY RL WOHLER, FEBRUARY 1973.
C LAST REVISION BY WA BENFIELD, MARCH 1976.

C SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF GLOBAL X, Y, Z COORDINATES AT BAR JOINTS.
C ROWS 1, 2, 3 CORRESPOND TO X, Y, Z COORDINATES.
C COLS 1, 2 CORRESPOND TO JOINTS 1, 2. COL 3 CORRESPONDS
C TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3, 3).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
C ROWS 1, 2, 3 CORRESPOND TO GLOBAL X, Y, Z PERMUTATION.
C COLS 1, 2 CORRESPOND TO JOINTS 1, 2. SIZE(3, 2).
C A1 = INPUT CROSS-SECTION AREA AT BAR END 1.
C A2 = INPUT CROSS-SECTION AREA AT BAR END 2.
C PI1 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 1.
C PI2 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 2.
C RO = INPUT MASS DENSITY.
C NAMEM = INPUT TYPE OF MASS MATRIX WANTED.
C = M1, LUMPED.
C = M2, CONSISTENT.
C Z = OUTPUT MASS MATRIX. SIZE(12, 12).
C W = INPUT WORK SPACE MATRIX. SIZE(12, 12).
C KCJ = INPUT PCW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C KEJ = INPUT PCW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C KW = INPUT ROW DIMENSION OF W IN CALLING PROGRAM. MIN=12.

C PROGRAM EXPLANATION
C 1 = DIMENSION SIZE EXCEEDED KZ, KW).
C 2 = NAMEM IMPROPERLY DEFINED.

IF (KZ .LT. 12 .OR. KW .LT. 12) GO TO 999
DC = J=1, 12
DO 5 J=1, 12
5 Z(I, J) = 0.0
RL = .5*sqrt((CJ(1, 1) - CJ(1, 1))**2 + (CJ(1, 2) - CJ(2, 1))**2
     + (CJ(3, 2) - CJ(3, 1))**2)
IF (NAMEM .EQ. 'LUMP') GO TO 110
IF (NAMEM .EQ. 'CONS') TC TO 120
NERRCR=1

NERRCR=2
GO TO 009

C AXIAL=M1A1 (LUMPED), TORSION=M1C1 (LUMPED), BENDING=M1B1 (LUMPED).

110 CALL M1A1 (A1, A2, PL, KC, Z, KZ)
   CALL M1C1 (P11, P12, PL, PO, Z(3,3), KZ)
   CALL M1B1 (A1, A2, PL, RC, Z(5,5), KZ)
   CALL M1B1 (A1, A2, PL, RC, Z(9,9), KZ)
   GO TO 300

C AXIAL=M1A2 (LINEAR DISP), TORSION=M1C2 (LINEAR DISP),
C BENDING=M1F2 (CURVIC DISP).

120 CALL M1A2 (A1, A2, PL, PC, Z, KZ)
   CALL M1C2 (P11, P12, RL, RC, Z(3,3), KZ)
   CALL M1F2 (A1, A2, RL, PO, Z(5,5), KZ)
   DO 125 J=7,8
   DO 125 I=5,6
   Z(I,J) = Z(I,J)
125 Z(J,I) = Z(J,I)
   CALL M1F2 (A1, A2, PL, PO, Z(9,9), KZ)

C

300 CALL DCS1F (CJ, EJ, K, KCJ, KEJ, KW)
   CALL HTAFA (Z, W, 12, 12, KZ, KW)
   RETURN

C

999 CALL ZFOMF (6, MAS1E, NERPOP)
   END
SUBROUTINE MAS2 (CJ, EJ, TMAS, RO, NAMEM, Z, W1, W2, KCJ, KEJ, KZ, KW1, KW2)
DIMENSION CJ(KCJ, 1), EJ(KEJ, 1), Z(KZ, 1), W1(KW1, 1), W2(KW2, 1)
DIMENSION IVFCC(1)
DATA IVFC/1, 2, 6, 7, 8, 12, 13, 14, 18, 3, 4, 5, 9, 10, 11, 15, 16, 17/
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C MASS MATRIX
C FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH
C UNRESTRAINED BOUNDARIES.
C MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C GLOBAL COORDINATE ORDER IS
C (U, V, W, P, C, R) JOINT 1, THEN JOINT 2, 3.
C WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS.
C FULL ANGLE CONVENTION IS GLOBAL X, Y, Z PERMUTATION.
C CALLS FOR SUBROUTINES ETA, DCCS2, M2A1, M2A2, M2B1, M2B2, Z2BOMP.
C DEVELOPED BY WA FENZIELD, FL WOHLLEN. FEBRUARY 1973.
C LAST REVISION BY KS BENFIELD. MARCH 1976.
C
C SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF GLOBAL X, Y, Z COORDINATES AT TRIANGLE JOINTS.
C FOWS 1, 2, 3 CORRESPOND TO X, Y, Z COORDINATES.
C COLS 1, 2, 3 CORRESPOND TO JOINTS 1, 2, 3. SIZE(3,3).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
C FOWS 1, 2, 3 CORRESPOND TO GLOBAL X, Y, Z PERMUTATION.
C COLS 1, 2, 3 CORRESPOND TO JOINTS 1, 2, 3. SIZE(3,3).
C TMAS = INPUT EFFECTIVE MASS THICKNESS.
C RO = INPUT MASS DENSITY.
C NAMEM = INPUT TYPE OF MASS MATRIX WANTED.
C = 1, LUMPED.
C = 2, CONSISTENT.
C Z = OUTPUT MASS MATRIX. SIZE(18,18).
C W1 = INPUT WORK SPACE MATRIX. SIZE(18,18).
C W2 = INPUT WORK SPACE MATRIX. SIZE(10,10).
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=18.
C KW1 = INPUT ROW DIMENSION OF W1 IN CALLING PROGRAM. MIN=18.
C KW2 = INPUT ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN=10.
C
C NEPROP EXPLANATION
C 1 = DIMENSION SIZE EXCEEDED (KZ, KW1, KW2).
C 2 = NAMEM IMPROPERLY DEFINED.
C
IF (KZ .LT. 16 .OR. KW1 .LT. 16 .OR. KW2 .LT. 10) GO TO 999
DC 5, J=1, 18
DC 5, I=1, 18
5 Z(I,J) = CJ(I,J)
5 SL12 = SQRT((CJ(1,1) - CJ(1,1))**2 + (CJ(2,2) - CJ(2,1))**2
* + (CJ(3,3) - CJ(3,1))**2)
5 SL23 = SQRT((CJ(1,1) - CJ(1,2))**2 + (CJ(3,3) - CJ(3,2))**2
* + (CJ(3,3) - CJ(3,2))**2)
5 SL13 = SQRT((CJ(1,1) - CJ(1,3))**2 + (CJ(2,3) - CJ(2,1))**2
* + (CJ(3,3) - CJ(3,1))**2)
5 X3 = (SL13**2 + SL12**2 - SL23**2)/(2.0*SL12)
Y3 = SQRT(SL13**2-X3**2)

IF (NAME2 .EQ. 6HM1 ) GO TO 110
IF (NAME2 .EQ. 6HM2 ) GO TO 120

GO TO 999

C
C MEMBRANE = M2A1 (LUMPED), BENDING = M2F1 (LUMPED).
110 CALL M2A1 (SL12,X3,Y3,MTMAS,PO,W1,KW1)
   CALL M2F1 (SL12,X3,MTMAS,PS,W1(10,10),KW1)
   DC 115 IW=1,18
   IZ = IVEC(IW)
115 Z(IZ,IZ) = W1(IW,IW)
   RETURN

C
C MEMBRANE = M2A2 (CONSISTENT), BENDING = M2E2 (CONSISTENT).
120 CALL M2A2 (SL12,X3,Y3,MTMAS,RC,Z,W1,W2,KZ,KW1,KW2)
   CALL M2E2 (SL12,X3,Y3,MTMAS,PO,Z(10,10),W1,W2,KZ,KW1,KW2)
   CALL DCOS2 (CJ,EJ,W1,KCJ,KEJ,KW1)
   CALL RTABA (Z,W1,18,1F,KZ,KW1)
   RETURN

C
999 CALL Z2LOMB (*THMAS2 ,NEROR)
END
SUBROUTINE MAS3 (CJ, EJ, TMAS, RC, NAMEM, Z, WI, K, KCJ, KEJ, KZ, KW1, KW2)
DIMENSION (J, EJ, KEJ, 1, 1, 1, W1(KW1, 1), W2(KW2, 1),
* W3(16, 16))
DATA IV1/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
* 20, 21, 22, 23, 24, 25,
* 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41,
* 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57,
* 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73,
* 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89,
* 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104,
* 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130,
* 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143,
* 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156,
* 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169,
* 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182,
* 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195,
* 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208,
* 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221,
* 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234,
* 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247,
* 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260,
* 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273,
* 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286,
* 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299,
* 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312,
* 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325,
* 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338,
* 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351,
* 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364,
* 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377,
* 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390,
* 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403,
* 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416,
* 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429,
* 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442,
GO TO 999

C

110 DO 112 I=1,3
    CW(I,1) = CJ(I,1)
    EW(I,1) = EJ(I,1)
    CW(I,2) = CJ(I,2)
    EW(I,2) = EJ(I,2)
    CW(I,3) = CJ(I,3)
112 EW(I,3) = EJ(I,3)
    CALL MAS2 (CW,EW,TMAS,RO,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
    CALL REVADD (.5,W1,IV1,IV1,2, 18,18,24,24, KM1,KZ)

DC 113 I=1,3
    CW(I,1) = CJ(I,1)
    EW(I,1) = EJ(I,1)
    CW(I,2) = CJ(I,2)
    EW(I,2) = EJ(I,2)
    CW(I,3) = CJ(I,3)
113 EW(I,3) = EJ(I,3)
    CALL MAS2 (CW,EW,TMAS,RC,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
    CALL REVADD (.5,W1,IV2,IV2,2, 18,18,24,24, KM1,KZ)

DC 114 I=1,3
    CW(I,1) = CJ(I,1)
    EW(I,1) = EJ(I,1)
    CW(I,2) = CJ(I,2)
    EW(I,2) = EJ(I,2)
    CW(I,3) = CJ(I,3)
114 EW(I,3) = EJ(I,3)
    CALL MAS2 (CW,EW,TMAS,RC,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
    CALL REVADD (.5,W1,IV3,IV3,2, 18,18,24,24, KM1,KZ)

DC 115 I=1,3
    CW(I,1) = CJ(I,2)
    EW(I,1) = EJ(I,2)
    CW(I,2) = CJ(I,3)
    EW(I,2) = EJ(I,2)
    CW(I,3) = CJ(I,4)
115 EW(I,3) = EJ(I,4)
    CALL MAS2 (CW,EW,TMAS,RC,NAMEM,W1,W2,W3,3,3,KW1,KW2,10)
    CALL REVADD (.5,W1,IV4,IV4,2, 18,18,24,24, KM1,KZ)

RETURN

C

999 CALL ZZ6COMB (SHMAS3,NEKFOR)
END
SUBROUTINE MAS3A (CJ,EJ,TMAS,RO,NAMEM,Z,W1,W2,KCJ,KEJ,KZ,KW1,KW2)
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1), W1(KW1,1), W2(KW2,1)

SUBROUTINE TO CALCULATE FINITE ELEMENT...

FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.

MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.

GLOBAL COORDINATE ORDER IS

(U,V,W) JOINT 1, THEN JOINT 2, 3, 4.

WHERE U,V,W ARE TRANSLATIONS.

EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.

CALLS FORMA SUBROUTINES M3C1,Z3CME.

DEVELOPED BY RL WOHLH. APRIL 1974.

LAST REVISION BY RL WOHLH. MAY 1976.

SUBROUTINE ARGUMENTS

CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.

ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.

CCLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).

EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.

ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.

CCLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).

TMAS = INPUT EFFECTIVE MASS THICKNESS.

RO = INPUT MASS DENSITY.

NAMEM = INPUT TYPE OF MASS MATRIX WANTED.

= M1, LUMPED.

Z = OUTPUT MASS MATRIX. SIZE(12,12).

W1 = INPUT WORK SPACE MATRIX. SIZE(12,12).

W2 = INPUT WORK SPACE MATRIX. SIZE(***,***).

KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.

KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.

KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=3.

KW1 = INPUT ROW DIMENSION OF W1 IN CALLING PROGRAM. MIN=12.

KW2 = INPUT ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN=*

C

ERROR EXPLANATION

I = DIMENSION SIZE EXCEEDED (KZ,KW1,KW2).

2 = NAMEM IMPROPERLY DEFINED.

IF (KZ .LT. 12 .OR. KW1 .LT. 12 .OR. KW2 .LT. 0) GO TO 999

SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2

* + (CJ(3,2)-CJ(3,1))**2)

SL14 = SQRT((CJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2

* + (CJ(3,4)-CJ(3,1))**2)

IF (NAMEM .EQ. 'COLT') GO TO 110

GO TO 999
IZ = 3*(IW-1)
Z(IZ+1,IZ+1) = WI(IW,IW)
Z(IZ+2,IZ+2) = WI(IW,IW)
115 Z(IZ+3,IZ+3) = WI(IW,IW)
RETURN

C
999 CALL ZZBOMB (6HMAS3A,NERROR)
END
SUBROUTINE PRESS (CJ,T,NJN,NCOL,KCJ,KW)
DIMENSION CJ(KCJ,1),T(KW,1)
DIMENSION A(8,8),JNM(3,42),VN(3),C(3,9),IV(3),JV(19)

C
C *** SUBROUTINE TO CALCULATE FLUID ELEMENT PRESSURE TRANSFORMATION
C *** MORE DESCRIPTIVE COMMENT CARDS TO BE ADDED AT A LATER DATE.
C *** DEVELOPED BY CARL BODLEY, OCTOBER 1974.
C LAST REVISION BY C S BODLEY, NOVEMBER 1974.
C
DATA JNM / * 1,2,3, 2,4,3, 3,4,1, 1,4,2, 1,2,3, 6,5,4, *
* 2,6,2, 2,5,6, 4,5,2, 4,2,1, 3,6,4, 3,4,1, *
* 3,5,6, 3,2,5, 4,5,1, 1,5,2, 1,3,6, 1,6,4, *
* 1,5,2, 5,6,2, 5,8,7, 5,7,6, 4,7,8, 4,3,7, *
* 1,2,4, 2,3,5, 1,4,5, 4,8,5, 2,6,7, 2,7,3, *
* 1,5,6, 1,6,2, 5,8,6, 6,8,7, 3,7,8, 3,8,4, *
* 1,2,3, 1,3,4, 1,6,5, 1,4,8, 2,6,7, 6,7,3 /
C
CALL ZERO (T,NJN,NCOL,KW)
LC = 18
NTF = 24
IF (NJN.EQ.8) GO TO 5
LO = 4
NTF = 14
IF (NJN.EQ.6) GO TO 5
LO = 0
NTF = 4
5 CONTINUE
C
DO 20 N=1,NTF
LOC = N + LC
J1 = JNM(1,LOC)
J2 = JNM(2,LOC)
J3 = JNM(3,LOC)
VN(1) = CJ(2,J2) - CJ(2,J1)
* - CJ(3,J2) - CJ(3,J1)
VN(2) = CJ(2,J3) - CJ(2,J1)
* - CJ(3,J3) - CJ(3,J1)
VN(3) = CJ(1,J2) - CJ(1,J1)
* - CJ(2,J2) - CJ(2,J1)
* - CJ(1,J3) - CJ(1,J1)
C = SQRT(VN(1)*VN(1) + VN(2)*VN(2) + VN(3)*VN(3))
DC 25 I = 1,3
25 VN(I) = VN(I)/AC
AC = AC/4.*
IF (LOC.EQ.6) AC = 2.*AC
DO 30 I = 1,2
IV(I) = JNM(1,LOC)
DC 30 J = 1,9
J1 = 3*I - 3 + J
JL = (IV(I) - 1)*3 + J
30 JV(J1) = JL
C
DC 35 L = 1,3
DO 35 I = 1,2
IL = I + 3*(L - 1)
DO 35 J=1,3
   F = 1.
   IF (L .EQ. J) F = 2.
35 C(J,IL) = F*VNI(J)
CALL REVADD (AC,C,IV,IV,T,3,9,NJN,NCOL,3,KW)
20 CONTINUE

C
DO 40 I=1,NJN
DC 40 J=1,NJN
A(I,J) = 0.
DO 40 K=1,NCOL
40 A(I,J) = A(I,J) + T(I,K)*T(J,K)
CALL INVINV (A,A,NJN,8)
CALL MULTE (A,T,NJN,NJN,NCOL,8,KW)
C
RETURN
END
SUBROUTINE TO CALCULATE (IN OPTION) FINITE ELEMENT...

MASS MATRICES AND IVECS (IN NUTMX),

STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
AND IVECS (IN NUTX),
UNIT LOAD EUCLLING MATRICES AND IVECS (ON NUTBX), (NOT YET)
LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT), (NOT YET)
STRESS TRANSFORMATION MATRICES AND IVECS (ON NUST), (NOT YET)
FOR COMBINED MEMBRANE-ENDING QUADRILATERAL PLATE ELEMENTS.
MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
DIRECTIONS.

GLOBAL COORDINATE ORDER IS
(U,V,W,P,G,P) JOINT 1, THEN JOINT 2, 3, 4.
WHERE U,V,W ARE TRANSLATIONS AND P,G,R ARE ROTATIONS.
IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
IVEC(3)=0 OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINTS
ELEMENT DOF 3 TO ZERO MOTION.

GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES IN
GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
DIRECTIONS.

ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
(PU,PV,PW,PX,MP) JOINT 1, THEN JOINT 2, 3, 4.
WHERE P IS FORCE AND M IS MOMENT.
LOCAL LOAD TRANSFORMATION MATRICES RELATES LOAD AT QUAD VERTICES IN
LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
DIRECTIONS.
STRESS TRANSFORMATION MATRICES RELATES STRESS AT QUAD VERTICES IN
LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
DIRECTIONS.

DATA ARRANGEMENT ON NUTMX, NUTX, NUTEX, NUTLT, NUST FOR EACH FINITE
ELEMENT IS (W=M,K,P,LT,ST)
WRITE (NUTMX) NAMEW,NFL,NK,NC,NAMEL,(IBLNK,I=1,5),
((X(I,J),I=1,NI,J=1,NC),(IVEC(I),I=1,NC)
CALLS FORMA SUBROUTINES MASS, PAGEHD, STF3, Z2POPR.

****************************************************************************

INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
READ FROM CAFS:
NAMEE,NAMEK,NAMELT,NAMEST,NAMEF FORMAT (5(46,4X)
PC,E,NL
TMAS,TMEM,TENC FORMAT (5(15X,E10))
20 NEL,J1,J2,J3,J4,TMASV,TMEMV,TECVV FORMAT (5(15X,E10))
IF (J1 .GE. 0) RETURN
GO TO 20
C DEFINITION OF INPUT VARIABLES.
C NAMEM = TYPE OF MASS MATRIX WANTED.
C = M1, DIAGONAL LUMPED, OVERLAP AVERAGE OF FOUR TRIANGLES.
C = M2, CONSISTENT, OVERLAP AVERAGE OF FOUR TRIANGLES.
C = 6H OR 6HCMASS, NO MASS MATRIX CALCULATED.
C NAMEM = TYPE OF STIFFNESS MATRIX WANTED.
C = K1, OVERLAP AVERAGE OF FOUR TRIANGLES.
C = 6H OR 6HNCSTIF, NO STIFFNESS MATRIX CALCULATED.
C NAMEL = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C = 6H OR 6HNCLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C = 6H OR 6HNCSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C NAMEB = TYPE OF BUCKLING MATRIX WANTED.
C = 6H OR 6HNCBUCK, NO BUCKLING MATRIX CALCULATED.
C RC = MASS DENSITY.
C E = YOUNG'S MODULUS OF ELASTICITY.
C ANU = POISSON'S RATIO, (E/2G)-1.
C TMASC = EFFECTIVE MASS THICKNESS, (CONSTANT).
C TMASV = EFFECTIVE MASS THICKNESS, (VARIABLE).
C IF .LE. 0., TMASC IS USED.
C TMEMC = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).
C TMEMV = EFFECTIVE MEMBRANE THICKNESS, (VARIABLE).
C IF .LE. 0., TMEMC IS USED.
C TNENC = EFFECTIVE ENDING THICKNESS, (CONSTANT).
C TNENV = EFFECTIVE ENDING THICKNESS, (VARIABLE).
C IF .LE. 0., TNENC IS USED.
C NEL = FINITE ELEMENT NUMBER, FOR REFERENCE ONLY, NOT USED IN
C CALCULATIONS. WRITTEN ON NUTMX, ETC.
C J1 = JOINT NUMBER AT QUADRILATERAL VERTEX 1.
C J2 = JOINT NUMBER AT QUADRILATERAL VERTEX 2.
C J3 = JOINT NUMBER AT QUADRILATERAL VERTEX 3.
C J4 = JOINT NUMBER AT QUADRILATERAL VERTEX 4.
C EXPLANATION OF INPUT --- MATS. NUMBER INDICATES CARD COLUMNS USED.
C I = INTEGER DATA, RIGHT ADJUSTED.
C E = DECIMAL POINT DATA, ANYWHERE IN FIELD, EXPONENT RIGHT ADJUSTED.
C X = CARD COLUMNS SKIPPED.
C ********************************************
C SUBROUTINE ARGUMENTS (ALL INPUT)
C XYZ = MATRIX OF GLOBAL X, Y, Z LOCATIONS. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C JDOP = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C ROTATION DOFS. SIZE(NJ,6).
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C COUNTERCLOCKWISE PERMUTATION. SIZE(NJ,3).
C NUTEI = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C THIS SUBROUTINE. IF NUTEI = 5, DATA IS READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOP), (EUL).
C NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C MASS MATRICES AND IVFCS ARE OUTPUT.
C NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C MATRICES) AND IVECS ARE OUTPUT.
C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTRX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C BUCKLING MATRICES AND IVECS ARE OUTPUT.
C NUTRX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NULTL = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NULTL MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C W = MATRIX WORK SPACE. MIN SIZE(24,24).
C T = MATRIX WORK SPACE. MIN SIZE(24,24).
C S = MATRIX WORK SPACE. MIN SIZE(24,24).
C KK = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C KJ = ROW DIMENSION OF JOINTS IN CALLING PROGRAM.
C KE = ROW DIMENSION OF IVECS IN CALLING PROGRAM.
C
C NEQCR EXPLANATION
C 1 = JOINT NUMBER GREATER THAN NUMBER OF JINTS.
C 2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C 3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C 4 = LT MATRIX FORMED, NULTL .LE. ZERO.
C 5 = ST MATRIX FORMED, NUTST .LE. ZERO.
C
C 1001 FORMAT (5(46,4X))
C 1002 FORMAT (5(46,10.0))
C 1003 FORMAT (5(31,3E16.6))
C 2001 FORMAT (/25X 40+INPUT DATA FOR COMBINED MEMBRANE-BENDING
C * 29H QUADRILATERAL PLATE ELEMENTS)
C 2002 FORMAT (/25X 40+INPUT DATA FOR COMBINED MEMBRANE-BENDING
C * 41H QUADRILATERAL PLATE ELEMENTS (CONTINUED))
C 2003 FORMAT (/ 13X7*MASS = 4.6, 13X7*STIF = A6, 6X13*LOAD TRANS = A6,
C * 3X15*STRESS TRANS = A6, 3X11*BUCKLING = A6,
C * / 15X4*EC = E10.3, 13X3*EH = E10.3,
C * / 16X4*M(TMASS) = E10.3, 12X4*NU = E10.3,
C * / 12X13*M(MEMBRANE) = E10.3,
C * / 3X12*T(BENDING) = E10.3,
C * / 12X 7*ELEMENT 5X 7*JOINT 1 5X 7*JOINT 2 5X 7*JOINT 3
C * 5X 7*JOINT 4 5X 7*M(MASS) 6X 11*T(MEMBRANE)
C * 5X 10*T(BENDING)
C * / 12X 6*NUMFAC = 4.5X 2(5X 10*VARIAFLE))
C 2004 FORMAT (12X 5(15,7X),6((110.,15X)))
C 2005 FORMAT (12X (1F7.1))
C
C READ AND WRITE FINITE ELEMENT DATA.
NLINL = 0
CALL PAGEH0
WRITE (NOT,2001)
READ (NUTFL,1001) NAMEK,NAMEL,NAMET,NAMEB
READ (NUTFL,1002) R,*,E,ANU
READ (NUTFL,1002) TMASC, TMEMC, TREN C
WRITE (NOT,2003) NAMEK,NAMEL,NAMET,NAMEB,
* R,E,TMASC, ANU, TMEMC, TREN C
20 READ (NUTFL,1003) NEL, J1, J2, J3, J4, TMA S V, TM EM V, TBENV
NC THIK = 1
IF (TMASV.LE.0. AND. TM EM V.LE.0. AND. TBENV.LE.0.) NO THIK=0
IF (J1 .LE. 0) RETURN
NLINL = NLINL + 1
IF (NLINL .LE. 42) GO TO 30
CALL PAGEH0
WRITE (NOT,2002)
WRITE (NOT,2003) NAMEK, NAMEL, NAMET, NAMEB,
* R,E,TMASC,ANU, TMEMC, TREN C
NLINL = 0
30 IF (NC THIK.EQ.1) 
"WRITE (NOT,2004) NEL, J1, J2, J3, J4, TMA S V, TM EM V, TREN C
IF (NC THIK.EQ.0) WRITE (NOT,2005) NEL, J1, J2, J3, J4
ERROR=1
IF (J1.GT.NIJ OR J2.GT.NIJ OR J3.GT.NIJ OR J4.GT.NIJ) GO TO 999
C
C SET THICKNESS:
TMAS = TMASC
TMEM = TMEMC
TREN = TREN C
IF (TMASV.GT.0.) TMAS=TMASV
IF (TMEMV.GT.0.) TMEM=TMEMV
IF (TRENV.GT.0.) TREN=TREN C
C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD VEL.
DO 42 I=1,3
CJ(J,I) = YYJ(J,I)
CJ(J,2) = YYJ(J,2)
CJ(J,3) = YYJ(J,3)
CJ(J,4) = YYJ(J,4)
EJ(J,1) = EUL(J,1)
EJ(J,2) = EUL(J,2)
EJ(J,3) = EUL(J,3)
42 EJ(J,4) = EUL(J,4)
DO 44 I=1,6
IVI(I) = JDCF(J1,I)
IVI(I+1) = JDCF(J2,I)
IVI(I+2) = JDCF(J3,I)
IVI(I+3) = JDCF(J4,I)
44 IVI(I+4) = JDCF(J5,I)
C
C FORM MASS MATRIX (W).
IF (AMS .LT. 60) UNITS (NAMEM, CO. 6NHCMASS) GO TO 110
CALL MAT2 (CJ,EJ,TMAS,PL,NAMEM,W, ..., KCJ, KCJ, KW, KW, KW)
ERROR=2
IF (NMIX .LE. 0) GO TO 999
WRITE (NUTMX) NAMEM, NEL, NPW, NFX, NAMEL, (IFLNK,I=1,2),
C FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
C STRESS TRANSFORMATION MATRIX (S).
110 IF (NAMEK .EQ. 6H .OR. NAMEK .EQ. 6HNOSTIF) GO TO 20
   CALL STF3 (CIJ,EJ,TEEN,E,ANU,NAMEK,NAMESW,T,S,NRS1, *
               KLJ,KCJ,KW,KW,KW)
          NERROR=3
   IF (NUTKX .LE. 0) GO TO 999
   WRITE (NUTKX) NAMEK,NEL,NRW,NRW,NAMEL,(IELNK,I=1,5), *
               ((W(I,J),I=1,NRW),J=1,NRW),(IVI(I),I=1,NRW)
   IF (NAMELT .EQ. 6H .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
          NERRCH=4
   IF (NUTLT .LE. 0) GO TO 999
   WRITE (NUTLT) NAMELT,NEL,NL,SRW,NRW,NAMEL,(IELNK,I=1,5), *
                ((T(I,:),I=1,NL),J=1,NRW),(IVI(I),I=1,NRW)
   IF (NAMEST .EQ. 6H .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
          NERRST=5
115 IF (NAMEST .EQ. 6H .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
       NERRST=5
   IF (NUTST .LE. 0) GO TO 999
   WRITE (NUTST) NAMEST,NEL,SRW,SRW,NAMEL,(IBLNK,I=1,5), *
                ((S(I,J),I=1,SRST),J=1,SRW),(IVI(I),I=1,SRW)
       GO TO 20

C 999 CALL ZZPOMP (SHCUAD ,NERROR)
   END
SUBROUTINE RECTSP (XYZ, JDOF, EUL, NUTFL, NJ,
                        NUTMX, NUTKX, NULT, NUST,
                        Wt, Ts, Sk, Kj, KE, KW)

DIMENSION XYZ(KX,1), JDOF(Kj,1), EUL(KE,1), Wt(KW,1), T(KW,1), S(KW,1)
DIMENSION CJ(3,4), EJ(3,4), J(3,4), IV(12)
DATA NAMEL/"MIDECTSP/", NPW,NELT/12,8/, IBLNK/6H 
, KCJ/3/
DATA NIT, NCT/5,6/
C                     M A S S  M A T R I C E S  A N D  I V E C S  ( O N  N U T M X ) ,
C                     S T R E S S  T R A N S F O R M A T I O N  M A T R I C E S  A N D  I V E C S  ( O N  N U T L T ) ,
C                     L O C A L  L O A D  T R A N S F O R M A T I O N  M A T R I C E S  A N D  I V E C S  ( O N  N U T K X ) ,
C                     D I R E C T I O N S .
C                     (PU,PV,PW) J O I N T  1 , T H E N  J O I N T  2 , 3 , 4 .
C                     W H E R E  P  I S  F O R C E .
C                     D I R E C T I O N S .
C                     D I R E C T I O N S .
C                     E L E M E N T  I S  (M,K,L,T,S)
C                     W R I T E (NUTMX) NAMEM,NEL,MR,NC,NAMEL,(JBLNK, I=1,5),
C                     ((W(1,J),J=1,NP),(J=1,NC),(IVEC(1),I=1,NC)
C
C ******************************************************************************
C  R E A D  F R O M  C A D K O .
C  P C , G  F O R M A T ( 2 ( I 5 X , E 1 0 ) )
C  T M A S , I S T F  F O R M A T ( 2 ( I 5 X , E 1 0 ) )
C  2 0  N E L , J 1 , J 2 , J 3 , J 4  F O R M A T ( 5 I 3 )
C  I F  ( J 1 , F C , 0 )  R E T U R N
C  G O  T O  2  C
C
C = NAMEK = TYPE OF STIFFNESS MATRIX WANTED.
C = M1, DIAGONAL LUMPED.
C = M2, CONSISTENT.
C = 6H OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C NAMEK = TYPE OF STIFFNESS MATRIX WANTED.
C = M1, DIAGONAL LUMPED.
C = M2, CONSISTENT.
C = 6H OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C NAMEK = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C = 6H OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C NAMEK = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C = 6H OR 6HNOSTPS, NO STRESS TRANSFORMATIONS CALCULATED.
C = RD = MASS DENSITY.
C = G = S страх MODULUS OF ELASTICITY.
C = TMAS = EFFECTIVE MASS THICKNESS.
C = TSTF = EFFECTIVE STIFFNESS THICKNESS.
C = NEL = FINITE ELEMENT NUMBER, FOR REFERENCE ONLY, NOT USED IN
C = calculations, written on NUTMX, etc.
C = J1 = JOINT NUMBER AT PANEL VERTEX 1.
C = J2 = JOINT NUMBER AT PANEL VERTEX 2.
C = J3 = JOINT NUMBER AT PANEL VERTEX 3.
C = J4 = JOINT NUMBER AT PANEL VERTEX 4.
C = EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C = I = INTEGER DATA, RIGHT ADJUSTED.
C = E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C = X = CARD COLUMNS SKIPPED.
C *****************************************************
C SUBROUTINE ARGUMENTS (ALL INPUT)
C = XYZ = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C = TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C = X,Y,Z LOCATIONS RESPECTIVELY, SIZE(NJ,3).
C = JDOF = MATRIX OF JOINT GLOBAL DEGREE OF FREEDOM. ROWS CORRESPOND
C = TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C = TRANSLATION DOFs AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C = ROTATION DOFs, SIZE(NJ,6).
C = EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C = TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C = GLOBAL X,Y,Z PERMUTATION, SIZE(NJ,3).
C = NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C = THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C = NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C = NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C = MASS MATRICES AND IVECS ARE OUTPUT.
C = NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C = USES FORTRAN READ, WRITE.
C = NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C = STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C = MATRICES) AND IVECS ARE OUTPUT.
C = NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C = USES FORTRAN READ, WRITE.
C = NUTLT = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C = LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C = NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C = USES FORTRAN READ, WRITE.
C = NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C USES FCPTRAN READ, WRITE.
C W = MATIX WORK SPACE. MIN SIZE(12,12).
C T = MATIX WORK SPACE. MIN SIZE(12,12).
C S = MATIX WORK SPACE. MIN SIZE(12,12).
C KX = ROW DIMENSION OF XZ2 IN CALLING PROGRAM.
C KJ = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
C KE = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C KW = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=12.
C
C NERCR EXPLANATION
C 1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
C 2 = NUTMX NON POSITIVE.
C 3 = NUT1X NON POSITIVE.
C 4 = NUTLT NON POSITIVE.
C 5 = NUTST NON POSITIVE.
C
C 1001 FORMAT (4(A6,4X))
C 1002 FORMAT (2(5X,E10.0))
C 1003 FORMAT (5I5)
C 2001 FORMAT (//3EX 47HINPUT DATA FCP RECTANGULAR SHEAR PANEL ELEMENTS)
C 2002 FORMAT (//32X 47HINPUT DATA FOR RECTANGULAR SHEAR PANEL ELEMENTS
C * 12H (CONTINUED))
C 2003 FORMAT (/ 14X7HMASS = A6, 14X7HSTIF = A6, 11X13HLOAD TRANS = A6,
C * 8X15HSTRESS TRANS = A6,
C * / 16X4HRD = E10.3, 14X3H8G = E10.3,
C * / 11X9TS(MASS) = E10.3, 8X9HT(STIF) = E10.3,
C * / 18X7H-ELEMENT 15X7HJOINT 1 13X7HJOINT 2 13X7HJOINT 3
C * / 13X7HJOINT 4 / 18X6HNUMBER)
C 2004 FORMAT (1FX,5(15,15X))
C
C READ AND WRITE FINITE ELEMENT DATA.
C NLINE = 0
C CALL PAGEFD
C WRITE (NCT,2041)
C READ (NUTFL,1001) NAMEM,NAMEK,NAMELT,NAMEST
C READ (NUTFL,1002) RO,G
C READ (NUTFL,1002) TMAS,STSF
C WRITE (NCT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,G,TMAS,STSF
C 20 READ (NUTFL,1003) NEL,J1,J2,J3,J4
C IF (J1 +LE. G) RETURN
C NLINE = NLINE + 1
C IF (NLINE +LE. 42) GO TO 30
C CALL PAGEFD
C WRITE (NCT,2002)
C WRITE (NCT,2003) NAMEM,NAMEK,NAMELT,NAMEST,RO,G,TMAS,STSF
C NLINE = 0
C 30 WRITE (NCT,2004) NEL,J1,J2,J3,J4
C NERROR=1
C IF (J1.GT.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVAADD IVEC.
C DO 42 1=1,3
C CJ(I,1) = YZ2(J1,1)
C
C FORM MASS MATRIX (M).
 IF (NAMFM .EQ. 6)  
    CALL MAS3A (CJ,EJ,tmass,PR,NAMEFM,W,T,S,KCJ,KCJ,KW,KW)
    NERROR=2
  GOTO 999

WRITE (NUTMX) NAMEFM,NFL, NRW,  
 *                   (IBLNK,I=1,5),  
 *           ((W(I,J),I=1,NRW),J=1,MRK),((IVI(I),I=1,MRK)

C
C FORM STIFFNESS MATRIX (K), LOCAL LOAD TRANSFORMATION MATRIX (T),  
C STRESS TRANSFORMATION MATRIX (S).

110 IF (NAMFK .EQ. 6)  
    CALL STF3A (CJ,EJ,TSTF,G,NAMEFK,NAMEST,W,T,S,NRST,
 *         KCJ,KCJ,KW,KW)
    NERROR=3

WRITE (NUTKX) NAMEFK, NEL, NRW,  
 *                  (IBLNK,I=1,5),  
 *          ((W(I,J),I=1,NRW),J=1,MRK),((IVI(I),I=1,MRK)

IF (NAMELT .EQ. 6)  
    CALL HNOLOAD (NAMELT, .EQ. 6)  
    NERROR=4

IF (NUST .EQ. 6)  
    CALL HNOSTR (NAMEST, .EQ. 6)  
    NERROR=5

GO TO 20

999 CALL ZEROM (6,HRECTSP,NERROR)
END
SUBROUTINE STFA (CJ,EJ,A1,A2,E,NAM,E,NAMEST,S,TL,TS,NRST,  
      *  
      DIMENSION CJ(KCJ,1), EJKEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)  
C  
C  SUBROUTINE TO CALCULATE FINITE ELEMENT...  
C  STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),  
C  LOCAL LOAD TRANSFORMATION MATRIX,  
C  STRESS TRANSFORMATION MATRIX,  
C  FOR AN AXIAL ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.  
C  ROD MAY BE LINEARLY TAPERED OR UNIFORM.  
C  STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.  
C  GLOBAL COORDINATE ORDER IS  
C  (U,V,W) JOINT 1, THEN JOINT 2.  
C  WHERE U,V,W ARE TRANSLATIONS.  
C  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL  
C  COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE  
C  DIRECTIONS.  
C  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS  
C  (PV,PW,PR) JOINT 1, THEN JOINT 2.  
C  WHERE P IS FORCE.  
C  LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT POD ENDS IN LOCAL  
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.  
C  ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS  
C  PX1,PX2  
C  WHERE PX IS AXIAL FORCE.  
C  PX1(-), PX2(+) IS TENSION. PX1(+), PX2(-) IS COMPRESSION.  
C  STRESS TRANSFORMATION MATRIX RELATES STRESS AT POD ENDS IN LOCAL  
C  COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.  
C  ROW ORDER IN STRESS TRANSFORMATION MATRIX IS  
C  SIGMA-X1, SIGMA-X2  
C  WHERE SIGMA IS NORMAL STRESS.  
C  SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.  
C  EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.  
C  CALLS FORMA SUBROUTINES ATXB1, DGOSIA, K1A1, MULTA, ZZ60MB.  
C DEVELOPED BY FL WOHLEN. SEPTEMBER 1972.  
C LAST REVISION BY WA BENFIELD. MARCH 1976.  
C  
C SUBROUTINE ARGUMENTS  
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.  
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.  
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).  
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT POD JOINTS.  
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.  
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).  
C A1 = INPUT CROSS-SECTION AREA AT POD END 1.  
C A2 = INPUT CROSS-SECTION AREA AT POD END 2.  
C E = INPUT YOUNG'S MODULUS OF ELASTICITY.  
C NAM = INPUT TYPE OF STIFF MATRIX WANTED.  
C = K1, CONSTANT AXIAL FORCE ASSUMED.  
C NAMEST = INPUT OPTION FOR STRESS TRANSFORMATION.  
C = 6H OR 6HMONST, NO STRESS TRANS CALCULATED.  
C S = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION  
C MATRIX). SIZE(6,6).  
C TL = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(2,6).  
C TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,6).
C NRST  = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C Kcj  = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C KEj  = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C KS  = INPUT ROW DIMENSION OF S IN CALLING PROGRAM. MIN=6.
C KTL  = INPUT ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=2.
C KTS  = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C C NERROR EXPLANATION
C 1 = SIZE LIMITATION EXCEEDED.
C 2 = NAMEK IMPROPERLY DEFINED.
C
    NRST = 2
          NERROR=1

    IF (KS .LT. 6 .OR. KTL .LT. 2 .OR. KTS .LT. NRST) GO TO 999
    PL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
          + (CJ(3,2)-CJ(3,1))**2)
    IF (NAMEK .EQ. 6HK1 ) GO TO 110
          NERROR=2

  110 CALL KIA1 (A1,A2,PL,E,TL,TS,KTL,KTS)      TL=K
C
    CALL DCG1A (CJ,EJ,S,KCJ,KEJ,KS)                  S=DC
    CALL MLA (TL,S,2,2,6,KTL,KS)
    IF (NAMEST .EQ. 6F  .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
    CALL MLA (TS,S,NRST,2,6,KTS,KS)
  210 CALL ATXBA1 (S,TL,2,6,KS,KTL)   RETURN
C
  999 CALL ZZPMRK (6HSTF1A ,NERROR)      END
SUBROUTINE STF18 (CJ,LI,KCODEA1,A2,TJ1,TJ2,R121,R122,R11Y1,R11Y2, 
*   K1,K2,CY1,CY2,CZ1,CZ2,SF,E,NAMEK,NAMES1, 
*   S,T,S,T,KCJ,KEJ,KS,KTL,KTS) 
-DIMENSION CJ(KCJ,1),EJ(KEJ,1),KCODE(1),S(KS,1),T(KTL,1),TS(KTS,1)

C SUBROUTINE TO CALCULATE FINITE ELEMENT... 
C STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX), 
C LOCAL LOAD TRANSFORMATION MATRIX, 
C STRESS TRANSFORMATION MATRIX, 
C FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED 
C BOUNDARIES, 
C BAR MAY BE LINEARLY TAPERED OR UNIFORM. 
C STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS. 
C GLOBAL COORDINATE ORDER IS 
C (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2 
C WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS. 
C GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL 
C COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE 
C DIRECTIONS. 
C ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS 
C WHERE P IS FORCE AND M IS MOMENT. 
C LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN LOCAL 
C COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS. 
C ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS 
C PX1,PX2,MX1,MX2,MY1,MY2,MZ1,MZ2,M21,M22,M23,M24,M25,M26 
C WHERE P IS FORCE AND M IS MOMENT. 
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS IN LOCAL 
C COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS. 
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS 
C PX1/A1,PX2/A2, MX1/A1/TJ1,MX2/A2/TJ2, 
C PY1/A1,PY2/A2,M21*A1/CY1/M22*A2/CY2/B12, 
C M21*A1/CY1/M22*A2/CY2/B12, 
C WHERE P IS FORCE AND M IS MOMENT. 
C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION. 
C CALLS FORMA SUBROUTINES ATXPA1,DCOSIB,KIAI,KIB1,KIC1,MULTA,ZZBOMA. 
C DEVELOPED BY RL WOHLLEN. FEBRUARY 1973. 
C LAST REVISION BY RL WOHLLEN. APRIL 1976. 
C
C SUBROUTINE ARGUMENTS 
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS. 
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES. 
C COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS 
C TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3). 
C EF = INPUT MATRX OF EULER ANGLES (DEGREES) AT BAR JOINTS. 
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION. 
C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,3). 
C KCODE = INPUT OPTION CODE FOR AXIAL, TORSION, BENDING Z, BENDING Y 
C LOCAL STIFFNESS. IF BLANK, ALL FOUR ARE CALCULATED. 
C SIZE(4). 
C KCODE(1)=A , LOCAL STIFFNESS MATRIX IS CALCULATED 
C FOR AXIAL (ALONG LOCAL X-AXIS). 
C KCODE(2)=T , LOCAL STIFFNESS MATRIX IS CALCULATED 
C FOR TORSION (ABOUT LOCAL X-AXIS). 
C KCODE(3)=BZ , LOCAL STIFFNESS MATRIX IS CALCULATED
STF1B -- 2/3

FOR BENDING (ABOUT LOCAL Z-AXIS).

KODE(4)=6Y, LOCAL STIFFNESS MATRIX IS CALCULATED
FOR BENDING (ABOUT LOCAL Y-AXIS).

A1 = INPUT CROSS-SECTION AREA AT BAR END 1.

A2 = INPUT SAME AS A1 AT BAR END 2.

TJ1 = INPUT CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN
JG AT BAR END 1.

TJ2 = INPUT SAME AS TJ1 AT BAR END 2.

B1Z1 = INPUT CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
Z-AXIS (FOR BENDING) AT BAR END 1.

B1Z2 = INPUT SAME AS B1Z1 AT BAR END 2.

B1Y1 = INPUT CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
Y-AXIS (FOR BENDING) AT BAR END 1.

B1Y2 = INPUT SAME AS B1Y1 AT BAR END 2.

K1 = INPUT DISTANCE FROM LOCAL X-AXIS TO OUTER FIBER FOR
TORSION STRESS CALCULATION AT BAR END 1.

R2 = INPUT SAME AS R1 AT BAR END 2.

CY1 = INPUT DISTANCE FROM Z2 PLANE TO OUTER FIBER FOR BENDING
STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.

CY2 = INPUT SAME AS CY1 AT BAR END 2.

CZ1 = INPUT DISTANCE FROM XY PLANE TO OUTER FIBER FOR BENDING
STRESS CALCULATION AT BAR END 1. LOCAL Z DIRECTION.

CZ2 = INPUT SAME AS CZ1 AT BAR END 2.

SF = INPUT SHAPE FACTOR (K) FOR SHEAR IN KAG.

.use SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.

SF=1.0 FOR A SOLID CIRCULAR CYLINDER.

SF=1.5 FOR A THIN WALLED CIRCULAR CYLINDER.

F = INPUT YOUNG'S MODULUS OF ELASTICITY.

G = INPUT SHEAR MODULUS OF ELASTICITY.

NAMEK = INPUT TYPE OF STIF MATPIXX WANTED.

= K1, USES K11 FOR AXIAL, K11 FOR TORSION,
K111 FOR BENDING.

NAMEST = INPUT OPTION FOR STRESS TRANSFORMATION.

= 6H OR 6HNCSTRS, NO STRESS TRANS CALCULATED.

S = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
MATRIX). SIZE(12,12).

TL = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(12,12).

TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NPST,12).

NRST = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.

KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.

KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.

KS = INPUT ROW DIMENSION OF S IN CALLING PROGRAM. MIN=12.

KTL = INPUT ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=12.

KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.

ERROR = ERROR EXPLANATION

1 = SIZE LIMITATION EXCEEDED.

2 = NAMEK IM PROPERLY DEFINED.

NRST = 12

IF (KS .LT. 12 .OR. KTL .LT. 12 .OR. KTS .LT. NRST) GO TO 999

DC = 1,12

DC 5 1=1,12

TL(I,J) = 0.0
5  
TS(I,J) = 0.0

RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
* + (CJ(3,2)-CJ(3,1))**2)

KODEA = 1
KODET = 1
KODEBZ = 1
KODEBY = 1

IF (KODE(1) .EQ. 1H) AND. KODE(2) .EQ. 1H AND.
* KODE(3) .EQ. 2H AND. KODE(4) .EQ. 2H ) GO TO 10

IF (KODE(1) .NE. 1HA ) KODEA = 0
IF (KODE(2) .NE. 1HT ) KODET = 0

C LAST HALF OF NEXT TWO CARDS ALLOW FOR OLD DATA INSERTED APRIL 1976.

IF (KODE(3) .NE. 2HBZ AND. KODE(3) .NE. 2HBY) KODEBZ = 0
IF (KODE(4) .NE. 2HBY AND. KODE(4) .NE. 2HBZ) KODEBY = 0

10 IF (NAMEK .EQ. 6HK1 ) GO TO 110  NERROR=2

GO TO 999

C AXIAL = K1A1 (CONSTANT FORCE), TORSION = K1C1 (CONSTANT TORQUE),
C BENDING = K1B1 (CONSTANT SHEAR, LINEAR BENDING MOMENT).

110 IF (KODEA .EQ. 1) CALL K1A1 (A1,A2,RL,F,TL,T5,KTL,KTS)
IF (KODET .EQ. 1) CALL K1C1 (TJ1,TJ2,R1,R2,RL,G,TL(3,3),TS(3,3),
* KTL,KTS)
IF (KODEBZ .EQ. 1) CALL K1B1 (B1Z1,B1Z2,CY1,CY2,A1,A2,SR,RL,E,G,
* TL(5,5),TS(5,5),KTL,KTS)

DC 115 J=7,8
DD 115 I=5,6
TL(I,J) =-TL(I,J)
TS(I,J) =-TS(I,J)
TL(J,I) =-TL(J,I)
TS(J,I) =-TS(J,I)

115 IF (KODEBY .EQ. 1) CALL K1B1 (PIY1,PIY2,CZ1,CZ2,A1,A2,SR,RL,E,G,
* TL(9,9),TS(9,9),KTL,KTS)

CALL DCOS1E (CJ,FJ,SJ,KJ,KEJ,KS)
CALL MULTA (TL,S,12,12,12,KTL,KTS)
IF (NAMEST .EQ. 6HNOCTRS) GO TO 210
CALL MULTA (TS,S,9R5T,12,12,KTS,KS)

210 CALL ATXEA1 (TL,T1,12,12,KT,KTL)
RETURN

C 999 CALL ZZECME (6HSTF1B ,NERROR)
END
SUBROUTINE STF2 (CJ,EJ,THEM,T,ENN,E,ANU,NAMK,NAMST,S,TL,TS,NRST,  
*  KC,J,EJ,KS,KTL,KTS)  
DIMENTION CJ(KC,1), EJ KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)  
  
SUBROUTINE TO CALCULATE FINITE ELEMENT...  
STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),  
LOCAL LOAD TRANSFORMATION MATRIX,  
STRESS TRANSFORMATION MATRIX,  
FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH  
UNRESTRAINED BOUNDARIES.  
STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.  
GLOBAL COORDINATE ORDER IS  
(U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.  
WHERE U,V,W APE TRANSLATIONS AND P,Q,R ARE ROTATIONS.  
GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN  
GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE  
DIRECTIONS.  
ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS  
WHERE P IS FORCE AND M IS MOMENT.  
LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN  
LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE  
DIRECTIONS.  
ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS  
(PX,PY,PZ) JOINT 1 THEN 2,3, NEXT  
(PZ,XY,XY) JOINT 1 THEN 2,3.  
WHERE P IS FORCE AND M IS MOMENT.  
STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL  
COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.  
ROW ORDER IN STRESS TRANSFORMATION MATRIX IS  
(SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=TNEN/2) AT JOINT 1,  
THEN JOINT 2,3.  
(SIGMA-X,SIGMA-Y,TAU-XY) FOR (Z=-TNEN/2) AT JOINT 1,  
THEN JOINT 2,3.  
WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.  
EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.  
CALLS FORMA SUBROUTINES ATXBAI,DCOS2,KZAI,KZBI,MULTA,ZZBOMB.  
LAST REVISION BY WA BENFIELD. MARCH 1976.  
  
SUBROUTINE ARGUMENTS  
CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.  
ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.  
COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).  
EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.  
ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.  
COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).  
THEM = INPUT EFFECTIVE MEMBRANE THICKNESS.  
TNEN = INPUT EFFECTIVE BENDING THICKNESS.  
E = INPUT YOUNGS MODULUS OF ELASTICITY.  
ANU = INPUT POISSONS RATIO. (E/2G)-1.  
NAMK = INPUT TYPE OF STIF MATRIX WANTED.  
= K1, USFS KZAI FOR MEMBRANE, KZBI FOR BENDING.  
NAMST = INPUT OPTION FOR STRESS TRANSFORMATION.  
= 6H OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
STF2 -- 2/2

C S = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C MATRIX), SIZE(18,18).
C TL = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX, SIZE(18,18).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX, SIZE(NRST,18).
C NRST = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
C KS = INPUT ROW DIMENSION OF S IN CALLING PROGRAM. MIN=18.
C KTL = INPUT ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=18.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.

C NERR = ERROR EXPLANATION
C 1 = SIZE LIMITATION EXCEEDED,
C 2 = NAMEK IMPROPERLY DEFINED.

C

NRST = 18

IF (KS .LT. 18 .OR. KTL .LT. 18 .OR. KTS .LT. NRST) GO TO 999
DO 5 J=1,18
DO 5 I=1,18
TL(I,J) = 0.0
5 TS(I,J) = 0.0
SL12 = SQRT((CJ(1,2)-CJ(1,1))*2 + (CJ(2,2)-CJ(2,1))*2)
* + (CJ(3,2)-CJ(3,1))*2)
SL23 = SQRT((CJ(1,2)-CJ(1,2))*2 + (CJ(2,3)-CJ(2,2))*2)
* + (CJ(3,3)-CJ(3,2))*2)
SL13 = SQRT((CJ(1,3)-CJ(1,1))*2 + (CJ(2,3)-CJ(2,1))*2)
* + (CJ(3,3)-CJ(3,1))*2)
X3 = (SL13**2+SL12**2-SL23**2)/(2.0*SL12)
Y3 = SQRT(SL13**2-X3**2)
IF (NAMEK .EQ. '6HK1') GO TO 110

GO TO 999

C
C 110 CALL K2A1 (SL12, X3, Y3, TME, F, ANU, TL, TS, S, KTL, KTS, KS)
C CALL K2B1 (SL12, X3, TBN, E, ANU, TL(10,10), TS(1,10), S,
C * KTL, KTS, KS)
DO 111 I=1,9
II = I+9
DC 111 J=1,9
111 TS(I1, J) = TS(I, J)

C
C CALL DCOS2 (CJ, EJ, S, KCJ, KEJ, KS)
C CALL MULTA (TL, S, 18, 18, 18, KTL, KTS)
C IF (NAMEST .EQ. '6H .OR. NAMEST .EQ. '6HNOSTRS) GO TO 210
C CALL MULTA (TS, S, NRST, 18, 18, KTS, KS)
210 CALL ATXPA1 (S, TL, 18, 18, KS, KTL)
RETURN

C 999 CALL ZZBOMB (SHSTF2, NERR)
END
SUBROUTINE STF3 (CJ, EJ, TEMB, E, ANU, NAMEK, NAMEST, S, TL, TS, MRST, * KCI, KFJ, KS, KTL, KTS)
DIMENSION CJ(KCI), EJ(KEJ), S(KS), TL(KTL), TS(KTS)
DIMENSION CW(3,3), EW(3,3), WI(16,18), * IVI(18), IV2(18), IV3(18), IV4(18)

DATA KCW, KWI / 3, 18 /
DATA IVI/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18/
 DATA IV2/ 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24/
 DATA IV3/ 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 19, 20, 21, 22, 23, 24/
 DATA IV4/ 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24/

SUBROUTINE TO CALCULATE FINITE ELEMENT...
STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
LOCAL LOAD TRANSFORMATION MATRIX (NOT YET),
STRESS TRANSFORMATION MATRICES (NOT YET),
FOR A COMINFIN MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENT WITH
UNRESTRAINED BOUNDARIES.
STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
GLOBAL COORDINATE ORDER IS
(U, V, W, P, Q, R) JOINT 1, THEN JOINT 2, 3, 4.
WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE ROTATIONS.
GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES TO
GLOBAL COORDINATE DIRECTIONS TO DEFORMATIONS IN THE GLOBAL COORDINATE
DIRECTIONS.
ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
(PU, PV, PW, MP, MQ, MR) JOINT 1, THEN JOINT 2, 3, 4.
WHERE P IS FORCE AND M IS MOMENT.
LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES TO
IN LOCAL COORDINATE SYSTEM TO DEFORMATIONS IN THE GLOBAL COORDINATE
DIRECTION.
STRESS TRANSFORMATION MATRIX RELATES STRESS AT QUAD VERTICES IN LOCAL
COORDINATE SYSTEM TO DEFORMATIONS IN THE GLOBAL COORDINATE DIRECTION.
EULER ANGLE CONVENTION IS GLOBAL X, Y, Z PERMUTATION.
CALLS FORMA SUBROUTINES STF2, PEV040, ZZBMR.
LAST REVISION BY WA BENFIELD. MARCH 1976.

SUBROUTINE ARGUMENTS
CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT QUAD JOINTS.
ROWS 1, 2, 3 CORRESPOND TO X,Y,Z COORDINATES.
COLUMNS 1, 2, 3, 4 CORRESPOND TO JOINTS 1, 2, 3, 4. SIZE(3,4).

EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT QUAD JOINTS.
ROWS 1, 2, 3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
COLUMNS 1, 2, 3, 4 CORRESPOND TO JOINTS 1, 2, 3, 4. SIZE(3,4).

TEM = INPUT EFFECTIVE MEMBRANE THICKNESS.

TBN = INPUT EFFECTIVE THICKNESS.

E = INPUT YOUNG'S MODULUS OF ELASTICITY.

ANU = INPUT POISSON'S RATIO, F/2G-1.

NAMEK = INPUT TYPE OF STIF MATRIX WANTED.

NAMEST = INPUT OPTION FOR STIFFNESS TRANSFORMATION.

S = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
MATRIX). SIZE(24, 24).

TL = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(24, 24).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,24).
C NRST = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C KS = INPUT ROW DIMENSION OF S IN CALLING PROGRAM. MIN=24.
C KTL = INPUT ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=24.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
C NERROR EXPLANATION
C 1 = SIZE LIMITATION EXCEEDED.
C 2 = NAMEK IMPROPERLY DEFINED.
C
NRST = 24
C
IF (KS .LT. 24 OR KTL .LT. 24 OR KS .LT. NRST) GO TO 999
DO 5 J=1,24
DO 5 I=1,24
5 S(I,J) = 0.0
IF (NAMEK .NE. 6H11) GO TO 110
GO TO 999
C
110 DO 200 I=1,3
CWI(I,1) = CJ(I,1)
EWI(I,1) = FJ(I,1)
CWI(I,2) = CJ(I,2)
EWI(I,2) = FJ(I,2)
CWI(I,3) = CJ(I,3)
EWI(I,3) = FJ(I,3)
200 EWI(I,3) = FJ(I,3)
CALL STF2 (CW,EW,TMEF,TEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
*  KCW,KCW,KW1,KTL,KTS)
CALL REVAMD (*.*,W1,IV1,IV1,S,18,18,24,24,18,KS)
DO 201 I=1,3
CWI(I,1) = CJ(I,1)
EWI(I,1) = FJ(I,1)
CWI(I,2) = CJ(I,2)
EWI(I,2) = FJ(I,2)
CWI(I,3) = CJ(I,3)
C
201 EWI(I,2) = FJ(I,2)
CALL STF2 (CW,EW,TMEF,TEN,F,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
*  KCW,KCW,KW1,KTL,KTS)
CALL REVAMD (*.*,W1,IV2,IV2,S,18,18,24,24,18,KS)
DO 203 I=1,3
CWI(I,1) = CJ(I,1)
EWI(I,1) = FJ(I,1)
CWI(I,2) = CJ(I,2)
EWI(I,2) = FJ(I,2)
CWI(I,3) = CJ(I,3)
203 EWI(I,3) = FJ(I,3)
CALL STF2 (CW,EW,TMEF,TEN,F,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
*  KCW,KCW,KW1,KTL,KTS)
CALL REVAMD (*.*,W1,IV3,IV3,S,16,18,24,24,18,KS)
DO 205 I=1,3
CWI(I,1) = CJ(I,2)
EWI(I,1) = FJ(I,2)
CW(I,2) = CJ(I,3)
EW(I,2) = EJ(I,3)
CW(I,3) = CJ(I,4)
EW(I,3) = EJ(I,4)
205 CALL STF2 (CW,EW,TMEM,TBEN,E,ANU,NAMEK,NAMES,TW1,TL,TS,NRSTX,
    *     KCW,KCW,KW1,KTL,KTS)
    CALL REVADD (.5,W1,IV4,IV4,S,18,18,24,24,18,KS)

C  
  DC 300 J=1,24
  DO 300 I=1,24
  TL(I,J) = 0.0
300 TS(I,J) = 0.0
  RETURN

C  
999 CALL ZZROMB (4HSTF3 ,NERROR)
END
SUBROUTINE STF3A (CJ,EJ,TH,G,NAMEK,NAMEST,S,TL,TS,NRST, 
  * 
  KCJ,KEJ,KS,KTL,KTS) 
  DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1) 
C
C SUBROUTINE TO CALCULATE FINITE ELEMENT...
C STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C LOCAL LOAD TRANSFORMATION MATRIX,
C STRESS TRANSFORMATION MATRIX,
C FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C GLOBAL COORDINATE ORDER IS
C (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C WHERE U,V,W ARE TRANSLATIONS.
C GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORD
C DIRECTIONS.
C ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C (PU,PV,PW) JOINT 1, THEN JOINT 2, 3, 4.
C WHERE P IS FORCE.
C LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORD
C DIRECTIONS.
C ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C PX1,PX2,PX3,PX4, PY1, PY2, PY3, PY4, PZ1, PZ2
C WHERE P IS FORCE. X GOES FROM 1 TO 2, Y GOES FROM 1 TO 4.
C STRESS TRANSFORMATION MATRIX RELATES PANEL SHEAR STRESS (CONSTANT) IN
C LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORD
C DIRECTIONS.
C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C CALLS FORMA SUBROUTINES ATXBA1,DCOS3G,K3C1,MULTA,ZZBOMB.
C DEVELOPED BY RL WHELEN. APRIL 1974.
C LAST REVISION BY WA BENFIELD. MARCH 1976.
C
SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT PANEL JOINTS.
C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C EJ = INPUT MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C TH = INPUT PANEL THICKNESS.
C G = INPUT SHEAR MODULUS OF ELASTICITY.
C NAMEK = INPUT TYPE OF STIF MATRIX WANTED.
C = .1, USE K3C1.
C NAMEST = INPUT OPTION FOR STRESS TRANSFORMATION.
C = 6H IF 6MNDSTRS *NO STRESS TRANS CALCULATED.
C S = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C MATRIX). SIZE(12,12).
C TL = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(6,12).
C TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,12).
C NPSST = OUTPUT NUMBER OF ROWS (1) IN STRESS TRANSFORMATION MATRIX.
C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM.
C KEJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM.
C KS = INPUT ROW DIMENSION OF S IN CALLING PROGRAM. MIN=12.
C KTL = INPUT ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=6.
C KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=1.
C
C NERROR EXPLANATION
C 1 = SIZE LIMITATION EXCEEDED
C 2 = NAMEK IMPROPERLY DEFINED
C
C NRST = 1
C
IF (KS .LT. 12 .OR. KTL .LT. & .OR. KTS .LT. NRST) GO TO 999
SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
* + (CJ(3,2)-CJ(3,1))**2)
SL14 = SQRT((CJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2
* + (CJ(3,4)-CJ(3,1))**2)
IF (NAMEK .EQ. 6HK1) GO TO 110
NERROR=2
GO TO 999
C
110 CALL K3C1 (SL12,SL14,TH,G,TL,TS,KTL,KTS) TL=K
C
CALL DOC53C (CJ,EJ,S,KCJ,KEJ,KS) S=DC
CALL MULTA (TL,S,E,12,KTL,KS)
IF (NAMEST .EQ. 6H .OR. NAMEST .EQ. 6HNCSTRS) GO TO 210
CALL MULTA (TS,S,NRST,R,12,KTS,KS)
210 CALL ATXEA1 (S,TL,E,12,KS,KTL)
RETURN
C
999 CALL Z7PCMF (6HSTF3A ,NERROR)
END
SUBROUTINE TEGOM (CJ,JM, VL,DV, KCJ, IFBAD)
DIMENSION CJ(KCJ,1), JM(1), DV(1)
DIMENSION R12(3),R13(3),R14(3)
DATA EPS / 1.E-5 /
C
C SUBROUTINE TO DETERMINE THE VOLUME AND VOLUME CHANGE COEFFICIENTS OF
C A TETRAHEDRON.
C CALLS FORMA SUBROUTINES VCROSS,VDOT.
C DEVELOPED BY C S EDDLEY, FEBRUARY 1974.
C LAST REVISION BY R A PHILIPPUS, AUGUST 1974.
C
C SUBROUTINE ARGUMENTS
C CJ = INPUT MATRIX OF JOINT COORDINATES. SIZE(3,8).
C JM = INPUT VECTOR OF JOINTS DEFINING A TETRAHEDRON. SIZE (4).
C VL = OUTPUT VOLUME OF TETRAHEDRON DEFINED BY JM.
C DV = OUTPUT VECTOR OF VOLUME CHANGE COEFFICIENTS.
C KCJ = INPUT ROW DIMENSION SIZE OF CJ IN CALLING PROGRAM. MIN = 3.
C IFBAD = OUTPUT
C = 0, THE TETRAHEDRON VERTICES ARE NOT NUMBERED ACCORDING
C TO THE ESTABLISHED CONVENTION, OR LIE IN A PLANE.
C
J1 = JM(1)
J2 = JM(2)
J3 = JM(3)
J4 = JM(4)
DC 5 I=1,2
R12(I) = CJ(I,J2) - CJ(I,J1)
R13(I) = CJ(I,J3) - CJ(I,J1)
R14(I) = CJ(I,J4) - CJ(I,J1)
C
CALL VCROSS (R12,P13,DV(10),VAMAG,VPMAG,VZMAG,SINAB)
CALL VDOT (DV(10),R14,VCL,VAMAG,VPMAG,TCOSAB)
IF (VOL.E.EPS) IFBAD=0
VL = VOL/6.
C
CALL VCROSS (P13,P14,DV(4),VAMAG,VPMAG,VZMAG,SINAB)
CALL VCROSS (R14,R12,DV(7),VAMAG,VPMAG,VZMAG,SINAB)
DC 10 I=1,3
10 DV(I) = -DV(I+3) - DV(I+6) - DV(I+9)
DC 15 I=1,12
15 DV(I) = DV(1)/6.
C
RETURN
END
SUBROUTINE TRNGL (XYZ, JDOF, EUL, NUTEL, NJ,
   *                  NUTMX, NUTXX, NUTBX, NULTL, NUSTT,
   *                  W, T, S, KX, KJ, KE, KW)
DIMENSION XYZ(KX,1), JDOF(KJ,1), EUL(KE,1), W(KW,1), T(KW,1), S(KW,1)
DIMENSION CJ(3,3), EJ(3,3), IVI(18)
DATA NAME1 /6HTRNGL /, NRW,NRLT/18,18/, IBLNK/6H /*, KCJ/3/
DATA NIT, NC3T/5, 6/

C SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C MASS Matrices and IVECs (ON NUTMX),
C STIFFNESS Matrices (SAME AS GLOBAL LOAD TRANSFORMATION Matrices)
C AND IVECS (ON NUTRX),
C UNIT LOAD BUCKLING Matrices and IVECS (ON NUTRX), (NOT YET)
C LOCAL LOAD TRANSFORMATION Matrices and IVECS (ON NULTL),
C STRESS TRANSFORMATION Matrices and IVECS (ON NUSTT),
C FOR COMBINED MEMBRANE-PENDING TRIANGLE PLATE ELEMENTS.
C MASS, STIFFNESS, BUCKLING Matrices ARE IN GLOBAL COORDINATE
C DIRECTIONS.
C GLOBAL COORDINATE ORDER IS
C (U, V, H, P, M, R) JOINT 1, THEN JOINT 2, 3.
C WHERE U, V, H ARE TRANSLATIONS AND P, M, R ARE ROTATIONS.
C IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES ...
C IVEC(6)=234 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 234.
C IVEC(3)=0 OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINTS
C ELEMENT DOF 3 TO ZERO MOTION.
C GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C DIRECTIONS.
C ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C (PU, PV, PW, NM, NC, KM) JOINT 1, THEN JOINT 2, 3.
C WHERE P IS FORCE AND M IS MOMENT.
C LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C DIRECTIONS.
C ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C (PX, PY, PM) JOINT 1 THEN 2, 3, NEXT
C (PZ, MX, MY) JOINT 1 THEN 2, 3.
C WHERE P IS FORCE AND M IS MOMENT.
C STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL
C COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C (SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=TBEN/2) AT JOINT 1,
C THEN JOINT 2, 3.
C (SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=-TBEN/2) AT JOINT 1,
C THEN JOINT 2, 3.
C WHERE SIG - IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C DATA ARRANGEMENT ON NUTMX, NUTXX, NUTBX, NULTL, NUST FOR EACH
C FINITE ELEMENT IS (W, M, KX, E, LT, ST)
C WRITE (NUTX) N, M, W, NFW, NP, NC, NAMFL, (IBLNK, I=1, 5),
C ((W(1, J), I=1, N), J=1, NC), (IVEC(I), I=1, NC)
C CALLS FORMA SUBROUTINES M32, PAGEHD, STF2, ZBOME.
C LAST REVISION BY RL WOHLEN. MAY 1976.

***********************************************************************
INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
READ FROM CARDS.

NAMEF, NAMEK, NAMELT, NAMEST, NAMEB

READ E, ANU

TMASC, TMEMC, TBENC

20 NEL, J1, J2, J3, TMASC, TMEMC, TBENC

IF (J1 .EQ. 0) RETURN

GO TO 20

DEFINITION OF INPUT VARIABLES.

NAMEF = TYPE OF MASS MATRIX WANTED.
   = M1, DIAGONAL LUMPED.
   = M2, CONSISTENT.
   = 6H, OR 6HNO MASS, NO MASS MATRIX CALCULATED.

NAMEK = TYPE OF STIFFNESS MATRIX WANTED.
   = K1, QUADRATIC DISPLACEMENT FOR MEMBRANE, CUBIC
   DISPLACEMENT FOR BENDING.
   = 6H, OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.

NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
   = 6H, OR 6HNOLOAD, NC LOAD TRANSFORMATIONS CALCULATED.

NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
   = 6H, OR 6HNOSTPS, NC STRESS TRANSFORMATIONS CALCULATED.

NAMEB = TYPE OF BUCKLING MATRIX WANTED.
   = 6H OR 6HNOBUCK, NO BUCKLING MATRIX CALCULATED.

RO = MASS DENSITY.

E = YOUNG'S MODULUS OF ELASTICITY.

ANU = POISSONS RATIO. (E/2G)-1.

TMASC = EFFECTIVE MASS THICKNESS, (CONSTANT).

TMASC = EFFECTIVE MASS THICKNESS, (VARIABLE).

IF .LT. 0., TMASC IS USED.

TMEMC = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).

TMEMC = EFFECTIVE MEMBRANE THICKNESS, (VARIABLE).

IF .LT. 0., TMEMC IS USED.

TBENC = EFFECTIVE BENDING THICKNESS, (CONSTANT).

TBENC = EFFECTIVE BENDING THICKNESS, (VARIABLE).

IF .LT. 0., TBENC IS USED.

NEL = FINITE ELEMENT NUMBER, FOR REFERENCE ONLY, NOT USED IN

CALCULATIONS. WRITTEN ON NUTMX, ETC.

J1 = JOINT NUMBER AT TRIANGLE VERTEX 1.

J2 = JOINT NUMBER AT TRIANGLE VERTEX 2.

J3 = JOINT NUMBER AT TRIANGLE VERTEX 3.

EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.

I = INTEGER DATA, RIGHT ADJUSTED.

F = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.

X = CARD COLUMNS SKIPPED.

**************************************************************************

SUBROUTINE ARGUMENTS (ALL INPUT)

XYZ = MATRIX OF JOINT GLOBAL X, Y, Z LOCATIONS. ROWS CORRESPOND

TO JOINT NUMBERS. COLUMNS 1, 2, 3 CORRESPOND TO THE JOINT

X, Y, Z LOCATIONS RESPECTIVELY. SIZE(NJ, 3).

JDDF = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND

TO JOINT NUMBERS. COLUMNS 1, 2, 3 CORRESPOND TO THE JOINT

TRANSLATION DOFS AND COLUMNS 4, 5, 6 CORRESPOND TO THE JOINT
C ROTATION DOFS. SIZE(NJ, 6).
C EUL = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C TO JOINT NUMBERS. COLUMNS 1, 2, 3 CORRESPOND TO THE
C GLOBAL X, Y, Z PERMUTATION. SIZE(NJ, 3).
C NUTEL = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C NJ = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JOOF), (EUL).
C NUTMX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C MASS MATRICES AND IVECS ARE OUTPUT.
C NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTKX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C MATRICES) AND IVECS ARE OUTPUT.
C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTEX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C PUCKLING MATRICES AND IVECS ARE OUTPUT.
C NUTEX MAY BE ZERO IF PUCKLING MATRIX IS NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTLT = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C USES FORTRAN READ, WRITE.
C W = MATRIX WOPK SPACE. MIN SIZE(18,18).
C T = MATRIX WORK SPACE. MIN SIZE(18,18).
C S = MATRIX WOPK SPACE. MIN SIZE(18,18).
C KX = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C KJ = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
C KE = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C KW = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=18.
C
C NERC3R EXPLANATION
C 1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C 2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
C 3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C 4 = UT MATRX FORMED, NUTLT .LE. ZERO.
C 5 = ST MATRX FORMED, NUTST .LE. ZERO.
C
1001 FORMAT (5(F6.4))
1002 FORMAT (3(F5.1,E10.0))
1003 FORMAT (4(I5,E10.0))
2001 FORMAT (/32X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
* 15TH PLATE ELEMENTS)
2002 FORMAT (/32X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
* 27TH PLATE ELEMENTS (CONTINUED))
2003 FORMAT (/ 13X7HMST = A6, 13X7HTIF = A6, 6X13MLOAD TRANS = A6,
* 3X15STRESS TRANS = A6, 3X15HPUCKLING = A6,
* / 15X6HPO = E10.3, 13X3HE = E10.3,
* / 10X5HT(MASS) = E10.3, 12X4NU = E10.3,
* / 52X15HT(MEMBRANE) = E10.3,
TRNGL -- 4/5

* / 33X/12 HT(BENDING) = 110.3,
* / 18X T HELEMENT 5X T HJOINT 1 5X T HJOINT 2 5X T HJOINT 3
* 5X T HT(MASS) 6X T 11 HT(MEMBRANE) 5X T 10 HT(BENDING)
* / 18X 6 H NUMBER 36X 3(5X 10 H(VARIABLE) )

2004 FORMAT (T F X 4(15,7X),3(110,3,5X))
2005 FORMAT (T F X 4(15,7X))

C
C READ AND WRITE FINITE ELEMENT DATA.
NL I N E = 0;
CALL PAGEID;
WRITE (NO1,?001)
READ (NU T E L,1001) NAMEM,NAMENK,NAMELT,NAMES T,NAMENB
READ (M UTEL,1002) RO,E,ANU
READ (NU T E L,1002) TMASC,TMEMC,TRENC
WRITE (NO T,2003) NAMEM,NAMENK,NAMELT,NAMES T,NAMENB,
  RC,E,TMASC,ANU,TMEMC,TR ENC

20 READ (NU T E L,1003) NEL,J1,J2,J3,TMASC,TMEMV,TRENV
NO THIK = I
IF (TMASV,LE.0.) AND. T M E MV,LE.0. AND. TBENV,LE.0.) NO THIK=0
IF (J1,LE. 0.) RETURN
NL I N E = NL I N E + 1
IF (NL I N E,LE. 42) GO TO 30
CALL PAGEFD;
WRITE (NO T,2002)
WRITE (NO T,2003) NAMEM,NAMENK,NAMELT,NAMES T,NAMENB,
  RC,E,TMASC,ANU,TMEMC,TR ENC
NL I N E = 0
30 IF (NO THIK,EQ.1)
  *WRITE (NO T,2004) NEL,J1,J2,J3,TMASV,TMEMV,TR ENV
IF (NO THIK,EQ.0) WRITE (NO T,2005) NEL,J1,J2,J3
  NERRDR=1
IF (J1,GT. NJ OR. J2,GT. NJ OR. J3,GT. NJ) GO TO 999

C
C SET THICKNESS.
TM AS = TM ASV
TM EM = TM EM V
TBEN = TR ENC
IF (TMASV,GT.0.) TMAS=TMASV
IF (TMEMV,GT.0.) TMEM=TMEM V
IF (TBENV,GT.0.) TBEN=TR ENC

C
C FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
DO 42 I=1,3
  CJ(I,1) = YYZ(J1,I)
  CJ(I,2) = YYZ(J2,I)
  CJ(I,3) = YYZ(J3,I)
  EJ(I,1) = FUL(J1,I)
  EJ(I,2) = FUL(J2,I)
  EJ(I,3) = FUL(J3,I)
42 DO 44 I=1,3
  IV1(I) = JD0F(J1,I)
  IV1(I+6) = JD0F(J2,I)
  IV1(I+12) = JD0F(J3,I)

C
C FORM MASS MATRIX (W).

IF (NAMEM .EQ. 6H) STOP
C

CALL MAS2 (CJ,EJ,TMAS,PO,NAMEM,W,T,S,KCJ,KKJ,KWW,KW)

IF (NUMX .LE. 0) GO TO 999
WRITE (NUMX) NAMEM,NEL,NRW,NRW,NAML,(I壹LK,I=1,5),
* ((W(I,J),I=1,NRW),J=1,NPW),(IV(I),I=1,NRW)

C

FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
STRESS TRANSFORMATION MATRIX (S).

110 IF (NAMEK .EQ. 6H) STOP
C

CALL STF2 (CJ,EJ,STF,EBF,E,ANU,NAMEK,NAMEST,W,T,S,NRST,
* KCJ,KKJ,KWW,KW)

IF (NUMX .LE. 0) GO TO 999
WRITE (NUMX) NAMEK,NEL,NPW,NRW,NAML,(I壹LK,I=1,5),
* ((W(I,J),I=1,NPW),J=1,NRW),(IV(I),I=1,NRW)

115 IF (NAMELT .EQ. 6H) STOP
C

IF (NUMX .LE. 0) GO TO 999
WRITE (NUMX) NAMELT,NEL,NPLT,NRW,NAML,(I壹LK,I=1,5),
* ((T(I,J),I=1,NPLT),J=1,NPW),(IV(I),I=1,NPW)

115 IF (NAMEST .EQ. 6H) STOP
C

IF (NUMX .LE. 0) GO TO 999
WRITE (NUMX) NAMEST,NEL,NSRST,NRW,NAML,(I壹LK,I=1,5),
* ((S(I,J),I=1,NSRST),J=1,NRW),(IV(I),I=1,NRW)

GO TO 20

C

999 CALL ZZBOME (6HTRGGL,NERR0)
END