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A user-defined subroutine has been developed to implement special 2-D and 3-D layered continuum elements in the commercial finite element program ABAQUS. These elements are specially configured to accurately predict interface stresses in adhesively bonded joints and are formulated using the hybrid stress technique to explicitly enforce stress equilibrium throughout the element domain and stress continuity conditions at layer interfaces. This report details the use of developed special 'adhesive elements' in ABAQUS for elastostatic analysis together with several numerical examples which demonstrate an improved accuracy and convergence behavior over conventional displacement-based elements. Sample input and output datasets and the complete FORTRAN subroutine which performs all element computations are presented in separate appendices.

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1 Introduction

The widespread application of adhesively bonded joints has necessitated the development of methodology to predict ultimate static joint strength and service life under cyclic loading. Due to the complexity of mathematically modelling adhesive joint response, analytical treatments are limited to highly idealized joint configurations and simplified assumed stress states, applied loading and material behavior. To overcome these limitations, a specialized finite element-based numerical approach is advocated to provide a versatile approach to analyze actual bonded joint concepts with complex geometries, load paths and support conditions. To enhance a finite-element based methodology, special 2-D and 3-D layered elements have been developed in Reference [1] to improve the computational efficiency and accuracy of determining stresses in adhesive joints. The special 2-D and 3-D layered continuum elements are formulated using the hybrid stress technique to explicitly enforce stress equilibrium throughout the element domain and stress continuity conditions at layer interfaces. In an extensive investigation presented in Reference [1], optimum element configurations have been determined and demonstrate improved performance compared to standard displacement-based finite elements in predicting joint stresses.

This report details the use of several special 2-D and 3-D continuum elements in the commercial finite element code ABAQUS through a developed user-defined subroutine. The elements are specialized for the analysis of adhesive joints by incorporating a layered hybrid formulation to accurately model the adhesive/adherend interface and are, thus, referred to as 'adhesive elements'. The adhesive elements are currently restricted to linear elastic behavior and a geometric constraint is imposed which requires that all element layers are rectangular. To permit the representation of composite laminate adherends and property variation through the adhesive layer, material properties are input as orthotropic laminae within each element layer. In addition, 2-D adhesive elements are supported for arbitrary orientation in the global X-Y plane and 3-D elements may be arbitrarily oriented in space. Element stress and strain output may be selected in either global or local coordinate systems.

A brief description of the support of user-defined elements in *ABAQUS* is presented in the next section followed by a description of the input format established for the adhesive elements. The basic element library is discussed in subsequent sections detailing element configuration, coordinate system convention and comments on their use. Two illustrative numerical examples are presented demonstrating the use of selected 2-D and 3-D adhesive elements. Sample input and output datasets together with the complete FORTRAN source code performing all element computations are presented in separate appendices.

2 User-Defined Elements in ABAQUS

New finite elements may be used with ABAQUS via a subroutine denoted *UEL* (for *<u>U</u>ser<u>EL</u>ement*) which performs the necessary element computations and interfaces with the main ABAQUS program through a strandardized parameter list in the subroutine call statement.
The **USER SUBROUTINE* statement in the input deck alerts ABAQUS to the presence of user-defined subroutines which either immediatelly follow this data entry or are contained in a separate file. These subroutines are then compiled and linked to the main ABAQUS executable prior to job execution. A complete description of this and other user-defined capabilities in ABAQUS may be found in [2]. Shown in Figure 1 is the basic format of the *UEL* subroutine with the argument list used by ABAQUS to pass into the user-defined subroutine all necessary information needed to compute element siffness matrices. Once computed, these matrices are then passed back to ABAQUS for global assembly and problem solution. In static analysis, data recovery is performed during a second pass through the user-defined subroutine after the solution for global displacements has been obtained. During this phase, ABAQUS passes in the nodal displacements for the current element from which all element stresses and strains can be computed. In addition to linear static analysis, the information passed into the *UEL* subroutine is sufficient to support material and geometric nonlinear analysis.

The complete source code supporting linear static analysis for the special adhesive elements in ABAQUS is listed in Appendix A.

```
      SUBROUTINE UEL(RHS,AMATRX,SVARS,ENERGY,NDOFEL,NRHS,NSVARS,
     1                   PROPS,NPROPS,COORDS,MCRD,NNODE,U,DU,V,A,
     2                   JTYPE,TIME,DTIME,KSTEP,KINC,JELEM,PARAMS,
     3                   NDLOAD,JDLTYP,ADLMAG,PREDEF,NPREDF,LFLAGS,
     4                   MLVARX,DDLMAG,MDLOAD,PNEWDT )
C
       IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C      VARIABLE AND ARRAY DECLARATIONS FOR UEL/ABAQUS INTERFACE
C
       DIMENSION RHS(MLVARX,*),AMATRX(NDOFEL,NDOFEL),PROPS(*),
     1              SVARS(1),ENERGY(8),COORDS(MCRD,NNODE),U(NDOFEL),
     2              DU(MLVARX),V(NDOFEL),A(NDOFEL),TIME(2),
     3              PARAMS(*),JDLTYP(MDLOAD,*),ADLMAG(MDLOAD,*),
     4              DDLMAG(MDLOAD,*),PREDEF(2,NPREDF,NNODE),LFLAGS(5)

                 ******************************************
                 ***  Source code for user-defined elements  ***
                 ******************************************


       RETURN
       END
```

Figure 1. Format of the user-defined subroutine *UEL* supporting the special adhesive elements in ABAQUS.

3 Use of Special Adhesive Elements in ABAQUS

Three sets of statments are used to describe the adhesive elements in the ABAQUS input deck. Each of these statements may be identified in the sample input files presented in Appendices B and C. The first set, **USER ELEMENT*, defines the basic parameters of the user elements. All parameters are mandatory and the user must set the N, n and M values as described below.

<u>Statement set I:</u>

(*i*) $*USER\ ELEMENT,\ NODES = N,\ TYPE = Un,\ PROPERTIES = M$

(*ii*) $n_1, n_2, \ldots$

where the various input parameters are:

Card (i): $NODES = N$ specifies the total number of nodes present in the adhesive element selected.
$TYPE = Un$ specifies the internal designation of the element through setting the value of n. The element type designation, n, will be given in the discussions of the various elements in following sections.
$PROPERTIES = M$ specifies that a user-defined property list of length M is to established for each element as explained below.

Card(ii): This entry indicates the active degrees of freedom at each node in the element.
For 2-D elements, this list is: 1,2; for 3-D elements, this list is: 1,2,3.

The second entry, $*UEL\ PROPERTY$, is the primary list of input data used to compute element quantities for each adhesive element. The material input has been made general to allow the input of composite laminate material for the adherends, or to specify property variations in the adhesive layer. The size of this list is determined by the user as function of the total number of plies in each of the element layers. Only a single ply would be specified for a homogeneous material whereas any number may be specified to define laminate properties. ABAQUS requires for each line in the property list that all quantities be expressed as real numbers in free format with up to eight entries per line - missing entries are simply treated as zeros. In the basic format of the property list shown below, the total length of the property list is calculated as

$$M = 8(1 + \sum_{i}^{k}[2NLAY_i + 1])$$

where k is equal to the number of layers in the element and $NLAY_i$ is the number of plies used within the i^{th} layer. This length is then entered as a parameter on the $*USER\ ELEMENT$ entry.

Statement set II

(i) $*UEL\ PROPERTY,\ ELSET = NM$
(ii) $NVER,\ IPLANE,\ OUTPUT,\ NSIDE$
(iii) $NPLY_1,\ WDTH_1$
(iv) $PTHK_1,\ \Theta_1,\ E_1,\ E_2,\ E_3,\ \mu_{12},\ \mu_{23},\ \mu_{13}$
(v) $G_{12},\ G_{23},\ G_{31}$
(vi) $NPLY_2,\ WDTH_2$
(vii) $PTHK_2,\ \Theta_2,\ E_1,\ E_2,\ E_3,\ \mu_{12},\ \mu_{23},\ \mu_{13}$
(viii) $G_{12},\ G_{23},\ G_{31}$
(ix) $NPLY_3,\ WDTH_3$
(x) $PTHK_3,\ \Theta_3,\ E_1,\ E_2,\ E_3,\ \mu_{12},\ \mu_{23},\ \mu_{13}$
(xi) $G_{12},\ G_{23},\ G_{31}$

where the input parameters are defined by:

Card(i): NM is the set Id of the adhesive element for which the following properties are to be used.
Card(ii): $NVER$ designates a particular version of an element type.
$IPLANE$ is used to select plane stress/plane strain assumptions in the use of 2-D elements. For 3-D elements, this field is ignored.
$IPLANE = 1$ for plane stress.
$IPLANE = 2$ for plane strain.
$OUTPUT$ is the element output control flag.
$OUTPUT = 0$ for surpression of element data output.
$OUTPUT = 1$ for output of stresses and strains in local element coordinates.
$OUTPUT = 2$ for output of stresses and strains in global coordinates.
$NSIDE$ indicates the face on which zero tractions are explicitly enforced. This property is only recognized by the element types which support this option.
Card(iii): $NPLY_1$ is the number of plies in layer 1.
$WDTH_1$ is the width of layer number 1 in 2-D elements. The width dimension is defined as normal to the element plane. This entry is left blank in 3-D elements.
Card(iv): $PTHK_1$ is the ply thickness for the first ply in layer 1.
Θ_1 is the orientation of the first ply in layer 1.
$E_1 - \mu_{13}$ are layer Youngs moduli and Poisson ratios.
Card(v): $G_{12} - G_{31}$ are layer shear moduli.

Cards (iv) and (v) are repeated for each ply specified. The data block represented by cards (vi) through (viii) follow the same format. The data block represented by cards (ix) through (xi) are used only if a third element layer is present in the element.

The last entry is the **USER SUBROUTINE* statement. As stated above, this alerts ABAQUS to the presence of souce code which is to be included together with the main execuable code prior to running the requested job. This data statement is given by

<u>Statement set III:</u>

$$(i) * USER\ SUBROUTINE,\ INPUT = uel\_hybrid.f$$

where the optional parameter, *INPUT*, specifies the name of an external file containing the source code for the user-defined adhesive elements. If this parameter is omitted, ABAQUS assumes that the source code immediately follows this statement.

The library of adhesive elements is discussed below.

4 Special Adhesive Elements

The element library presented herein contains several 2-D and 3-D special adhesive elements for general use in the analysis of bonded joint stresses. These elements are assumed to be used specifically for the numerical representation of the local region encompassing the adhesive bond with standard elements representing all other regions of the joint adherends. The use of 2-layer and 3-layer elements in modelling the bond layer is depicted in figures 2 and 3. Specific details of the specialized adhesive elements are described below.

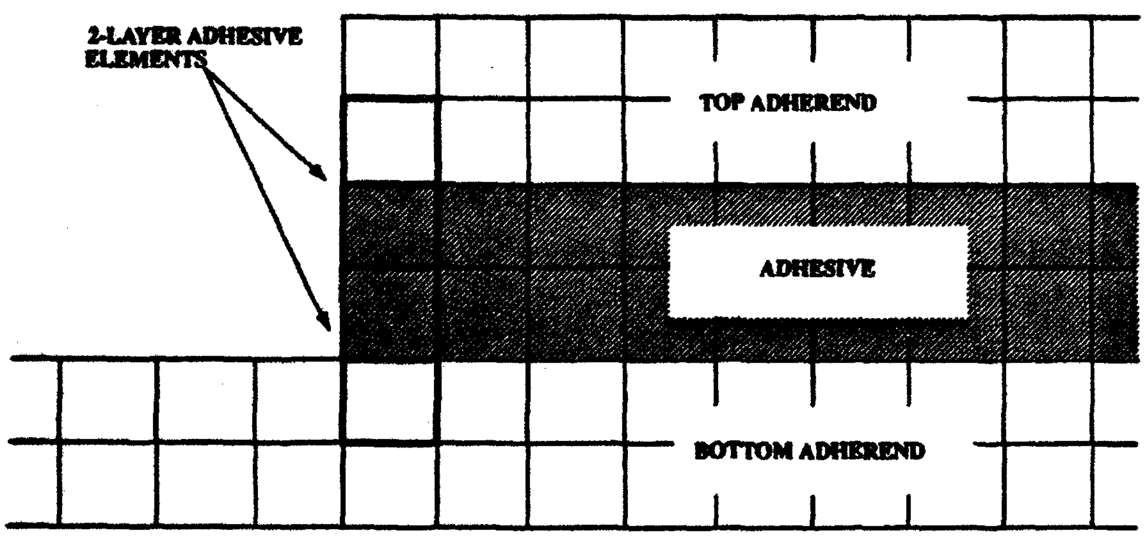

Figure 2. Use of the 2-layered elements in modelling an adhesive layer.

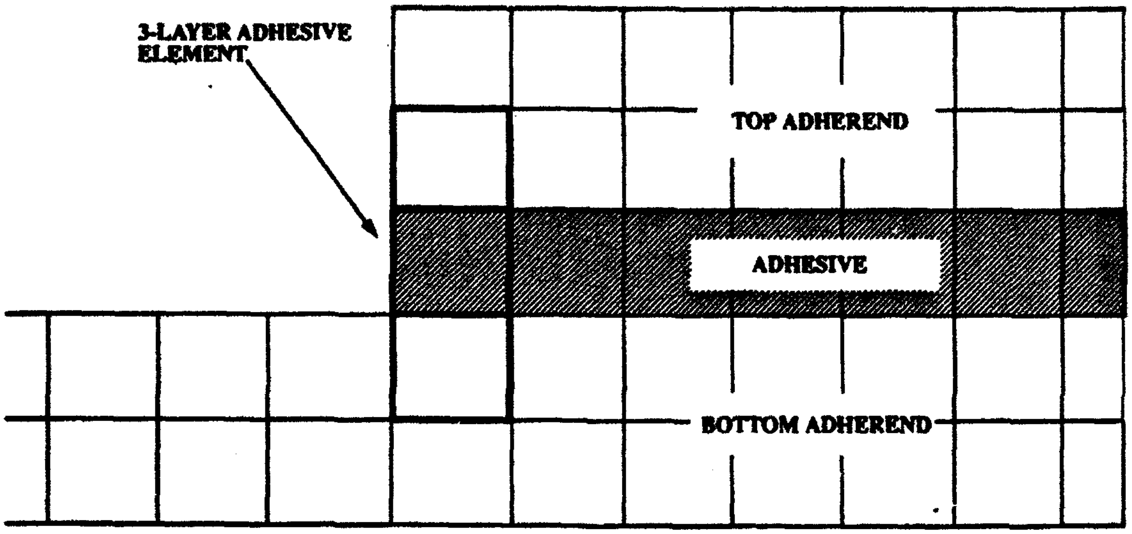

Figure 3. Use of the 3-layered elements in modelling an adhesive layer.

4.1 2-D Adhesive Elements

Several 2-D special adhesive elements have been incorporated in the user-defined subroutine. The elements differ in number of layers, element order, assumed order of stress expansions and applied stress field constraints. An account of their performance in predicting bondline stresses is extensively examined in Reference [1]. Details of the 2-D elements, designated *H2L6N*, *H2L10N*, *H3L8N* and *H2L13N*, are discussed in the following subsections.

4.1.1 The H2L6N Element

The configuration of the H2L6N element is depicted in Figure 4. As shown, a local element coordinate system is defined at each layer centroid with the local ξ and η axes parallel to adjacent sides of the layer.

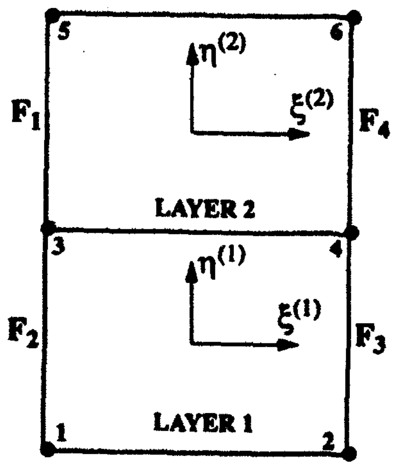

Figure 4. H2L6N element configuration and local layer coordinate system.

The H2L6N element is designated as $TYPE = U1$ and two versions are available incorporating complete linear and quadratic stress expansions. These versions are selected by setting the element version parameter as $NVER = 11$ and $NVER = 12$, respectively. The H2L6N element is also supported for use as an *end-element* in which zero traction conditions are enforced in the τ_{xy} stress component. This version is selected as $NVER = 13$ and the input parameter $NSIDE$ is used to select the traction-free element side by setting the property parameter $NSIDE = i$ where i is indicated by the Fi designation in the above figure.

This element has demonstrated excellent convergence properties in a study of bondline stress prediction in single-lap joints. The linear field used in version 11 yields good convergence behavior but the quadratic field used in version 12 should be selected if a coarse mesh is used along the bond axis. The increase in computational cost is minimal.

4.1.2 The H2L10N Element

The configuration of the H2L10N element is depicted in Figure 5. As shown, a local element coordinate system is defined at each layer centroid with the local ξ and η axes parallel to adjacent sides of the layer.

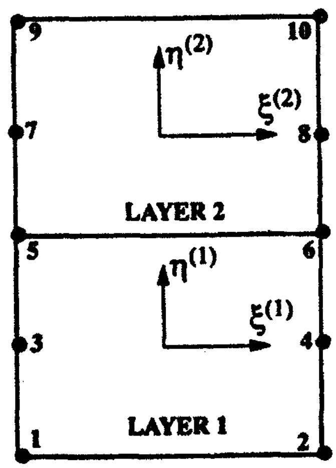

Figure 5. H2L10N element node configuration and local layer coordinate system.

The H2L10N element is designated as $TYPE = U2$ and two versions are available incorporating complete quadratic and cubic stress expansions. These versions are selected by setting the parameter $NVER = 11$ and $NVER = 12$, respectively.

The H2L10N element formulation has a higher-order strain field representation in the normal bondline direction. However, this selective increase in the degree of freedom representation in the bond thickness direction has not demonstrated an overall improvement in bond stress prediction in the single-lap joint case over the H2L6N element. It is maintained in the element library for a further assessment in analyzing other joint configurations.

4.1.3 The H2L13N Element

The configuration of the H2L13N element together with local layer coordinate system convention is depicted in Figure 6.

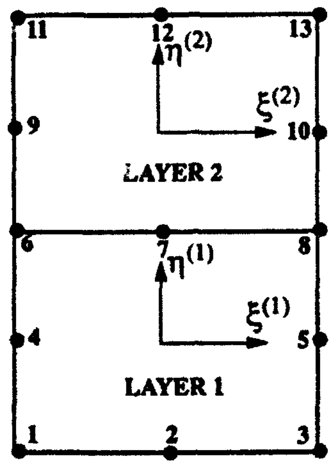

Figure 6. H2L13N element node configuration and local layer coordinate system.

The H2L13N element is designated as $TYPE = U3$ and two versions are contained in the element library. A difficulty was encountered in Reference [1] in the formulation of this element. It was found that adopting a higher-order displacement field and strictly enforcing all stress field constraints inevitably leads to spurious kinematic deformation modes in the resulting element stiffness matrix. Therefore, selective relaxation of some constraints were made in the two versions of this element. One version, selected using $NVER = 11$, incorporates a complete cubic stress field with the addition of two quartic terms in the shear stress expansion which are not constrained to enforce continuity at the element layer interface. These two terms are added to surpress zero energy modes which result from using complete expansions satisfying all equilibrium and continuity constraints. A second version, designated $NVER = 12$, is formulated using a complete quadratic field with only stress continuity conditions applied at the layer interface.

The performance of these versions in the analysis of a single-lap joint configuration has shown that both demonstrate accurate stress predictions with element version 12 showing a faster rate of convergence and a highly accurate recovery of bondline stresses. The violation of strict continuity enforcement in element version 11 has been shown to be of minimal consequence due to the high-order of the unconstrained stress expansion terms.

4.1.4 The H3L8N Element

The configuration of the H2L8N element and local coordinate system is depicted in Figure 7.

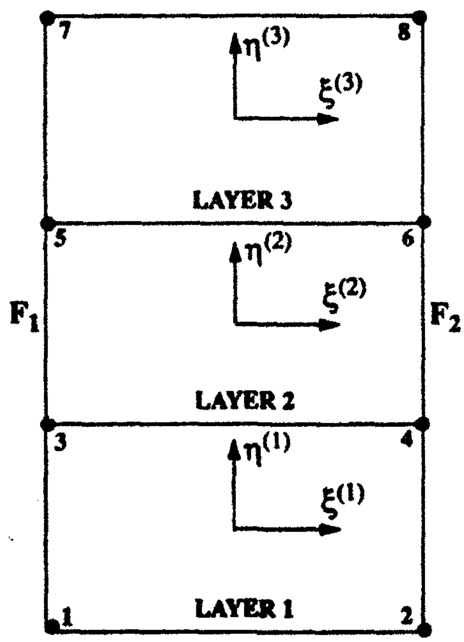

Figure 7. H3L8N element node configuration and local layer coordinate system.

The H3L8N element is designated as $TYPE = U4$ and two versions are available incorporating complete quadratic and cubic stress expansions. These versions are denoted as $NVER = 11$ and $NVER = 12$, respectively. The H3L8N element is aιso supported for use as an *end*-element in which zero traction conditions are enforced in the τ_{xy} stress component. This version is selected by setting $NVER = 13$ and the $NSIDE$ input parameter is set to i from the Fi designations shown above to select the traction-free element face.

The performance of H3L8N has been shown to be accurate in the prediction of joint stresses in single-lap configurations with faster convergence rates obtained by using the higher-order cubic stress field in coarse mesh models.

4.2 3-D Adhesive Elements

All 2-D elements developed have a theoretical counterpart in a 3-D formulation, however, from the study of 2-D element behavior, a single 3-D solid element has been developed and incorporated into the user-element library.

4.3 The H2L12N Element

The H2L12N element configuration and local coordinate system are depicted in Figure 8.

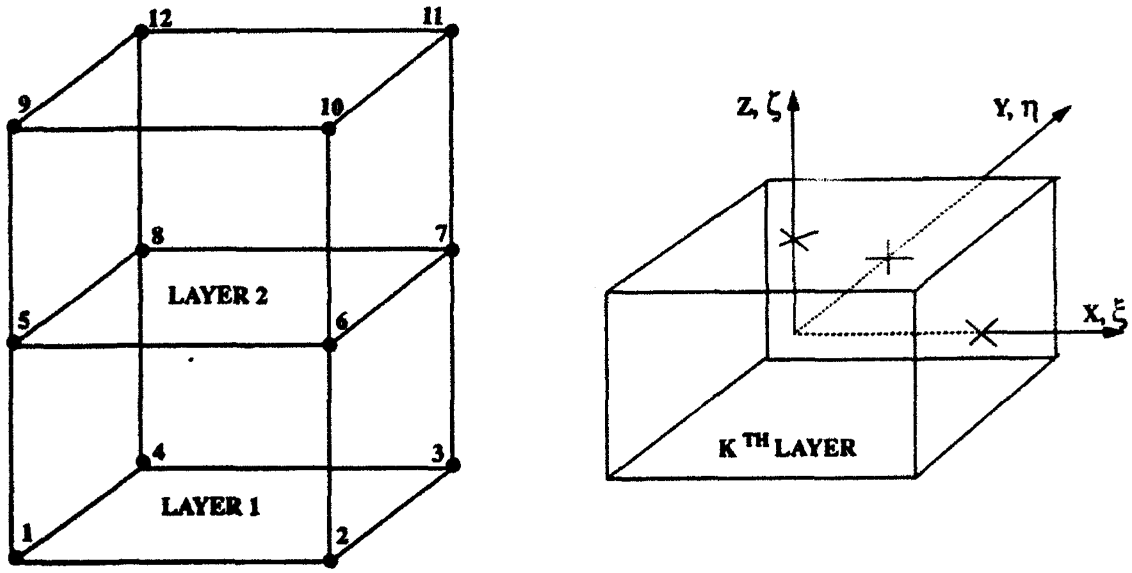

Figure 8. H2L12N element and local layer coordinate system.

The H2L12N element, designated as $TYPE = U5$, permits a general adhesive joint planform to be modelled and is available in two versions incorporating complete linear and quadratic stress fields. These versions are designated as $NVER = 11$ and $NVER = 12$, respectively.

Studies have shown that, as in the case of the 2-D H2L6N element, the higher-order quadratic expansion yields improved coarse mesh performance - for finer levels of discretization along the bondline the distinction between the performance of the two versions vanish.

5 Demonstration Problems

The analysis of two single-lap joints are presented in this section. Results are taken from Reference [1] and used to demonstrate the use of two representative adhesive elements, namely, the 2-D H2L6N and 3-D H2L12N elements. The material properties selected are given by:

$$Adherend: \quad E = 69000.0 \quad \mu = 0.32$$

$$Adhesive: \quad E = 3000.0 \quad \mu = 0.36$$

All stresses are normalized as $\sigma^*_{ij} = \sigma_{ij}/\sigma_{ref}$ where $\sigma_{ref} = P/A$ in which P is an uniformly applied tensile load and A is the cross-sectional area of the adherend end.

5.1 Problem I: 2-D Single-Lap Joint

Figures 9 and 10 show the geometry and boundary conditions, respectively, of a 2-D single-lap joint. A state of plane strain is assumed to exist in the joint and H2L6N elements are used to model the adhesive and locally adjacent regions of the adhesive.

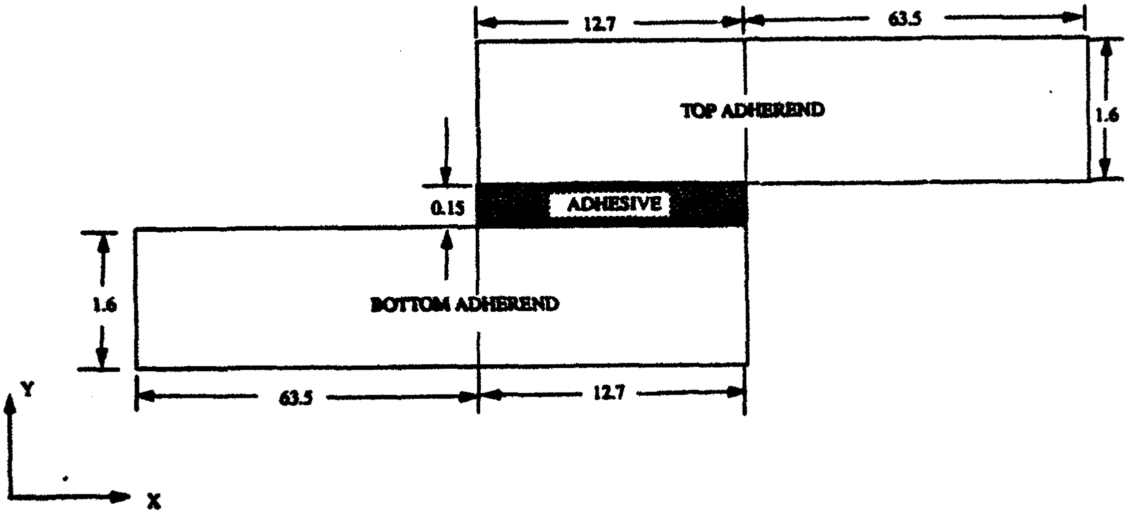

Figure 9. 2-D Single-lap joint geometry.

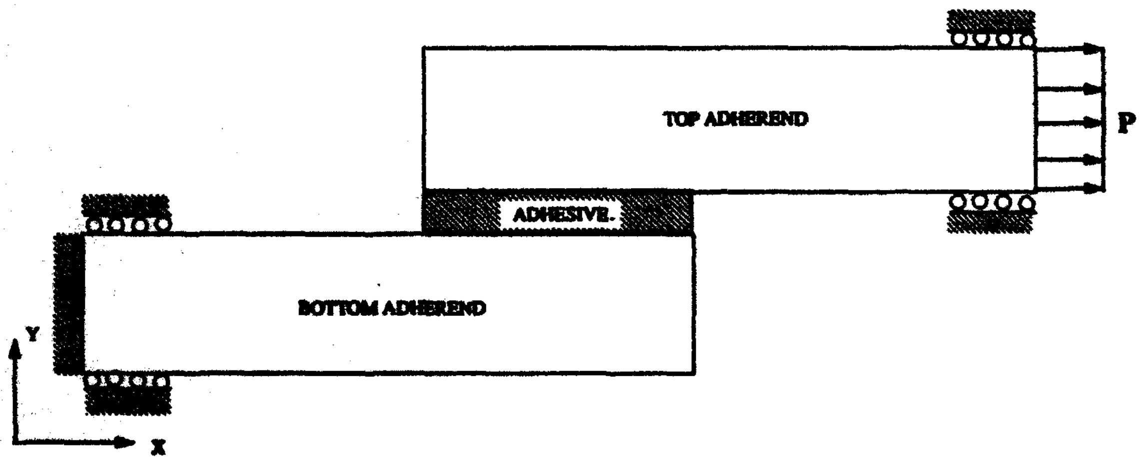

Figure 10. Applied boundary conditions.

Figures 11 and 12 show the convergence of models incorporating 10, 25, 50 and 100 H2L6N elements along the bondline in comparison to a reference solution. Details of the model descretization is presented in Reference [1]. Stress predictions were made for the σ_{yy} and τ_{xy} stress components along the adhesive/adherend interface. Element version 12, incorporating complete quadratic stress fields, was selected in generating these results. To show the improvement in element performance over standard displacement-based elements, the same models were used in which the layered adhesive elements were each replaced by two 4-node plane-strain elements (CPE4) from the ABAQUS library. As can be seen in Figures 13 and 14, the purely displacement-based solutions actually converge away from the reference solution which validates the improvement in element efficiency afforded by the layered hybrid formulation. The ABAQUS input deck and selected output associated with the refined model using the H2L6N element is presented in Appendix B.

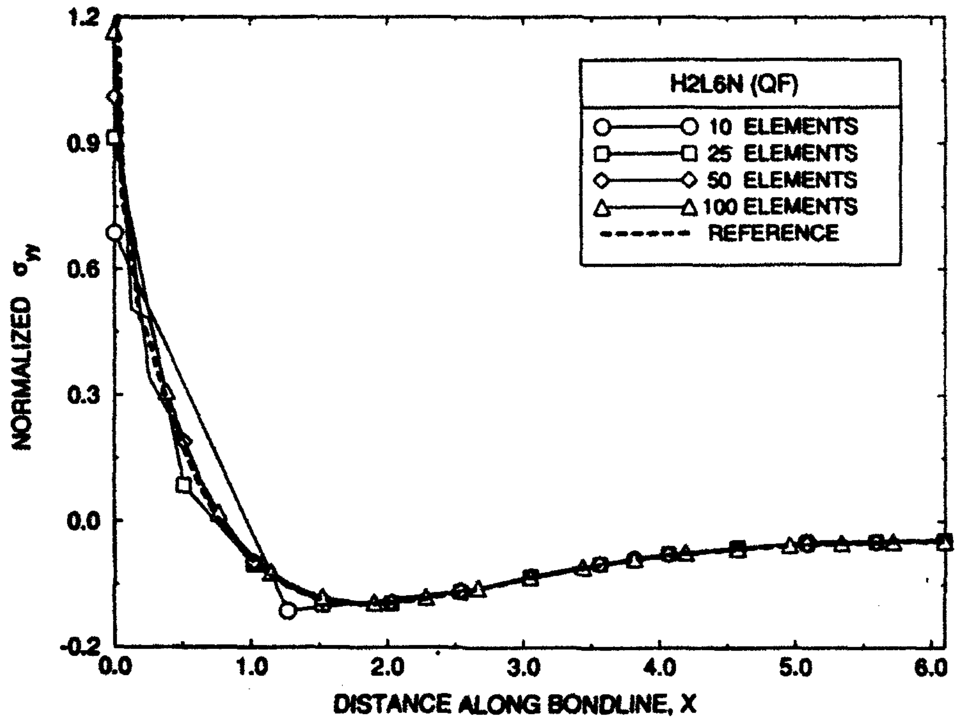

Figure 11. H2L6N prediction of σ_{yy} distribution along the bondline.

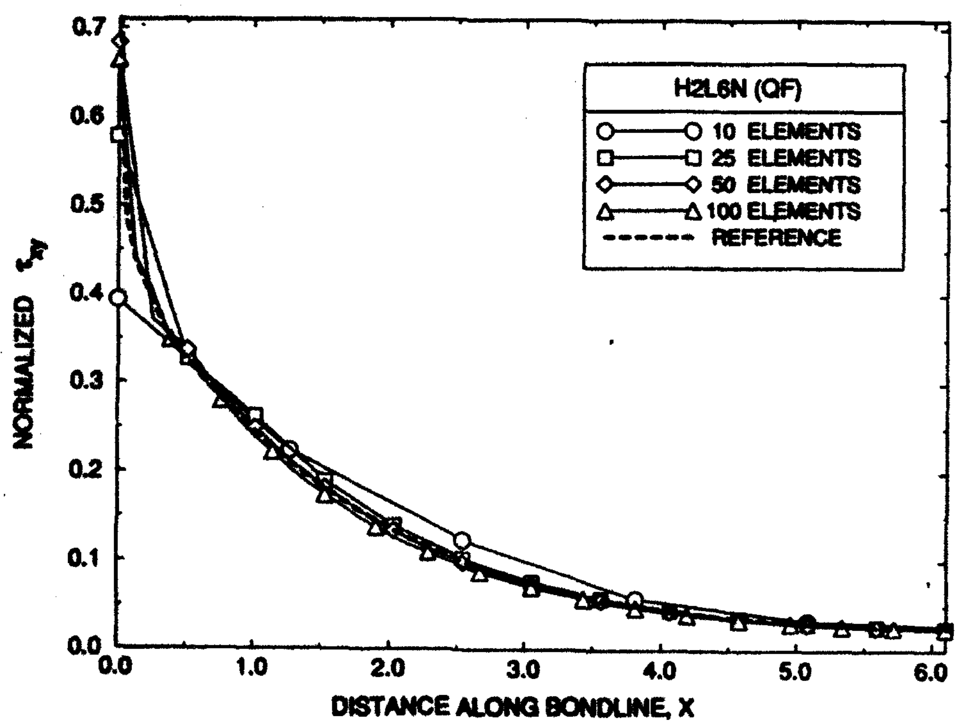

Figure 12. H2L6N prediction of τ_{xy} distribution along the bondline.

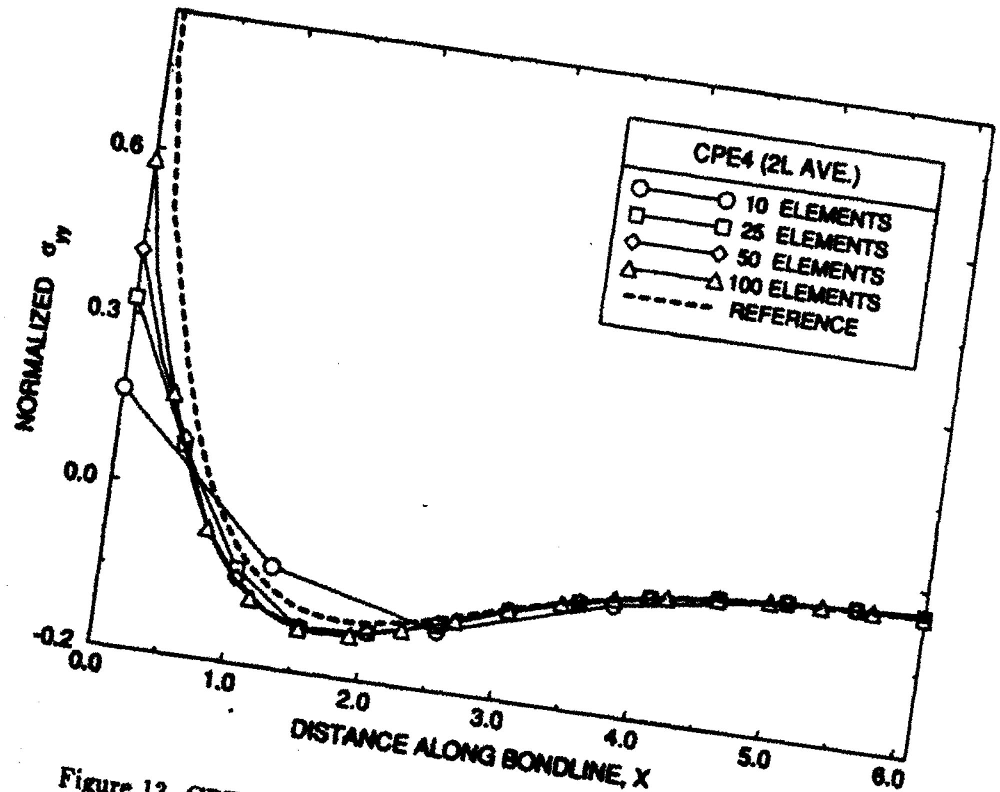

Figure 13. CPE4 Prediction of σ_{yy} distribution along the bondline.

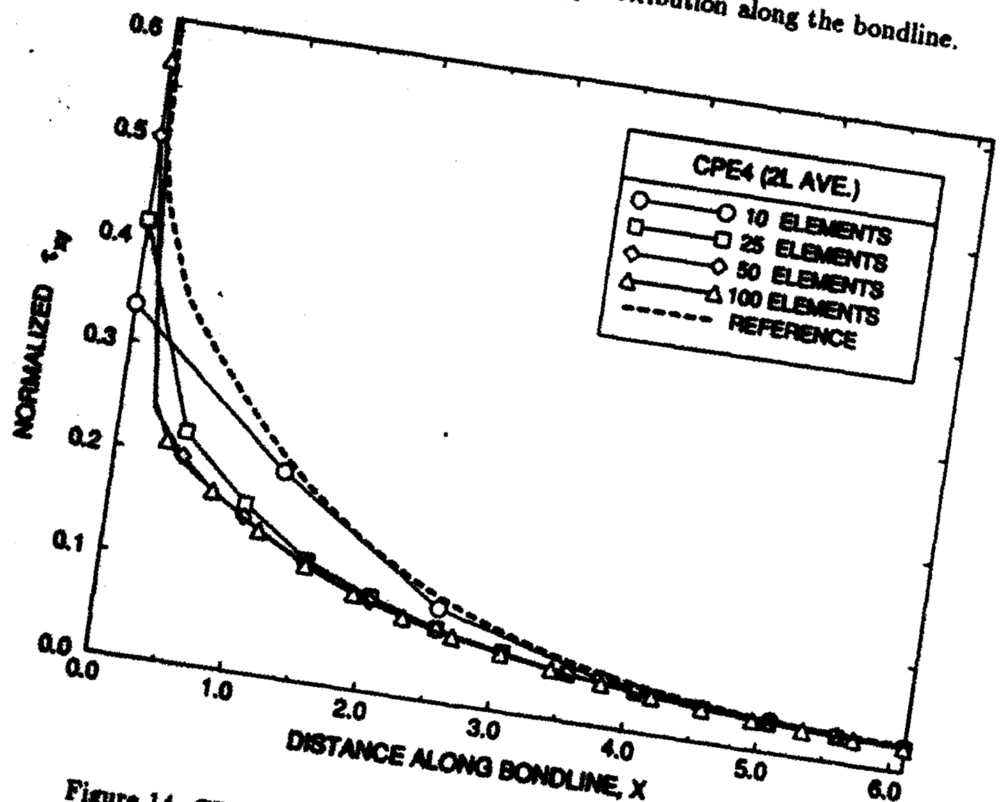

Figure 14. CPE4 prediction of τ_{xy} distribution along the bondline.

5.2 Problem II: 3-D Single-Lap Joint

A rectangular 3-D single lap joint is analyzed using H2L12N elements to model the bond region along the adhesive/adherend interface. The geometry is depicted in Figure 15 and the applied boundary conditions are identical to those presented above in figure 10.

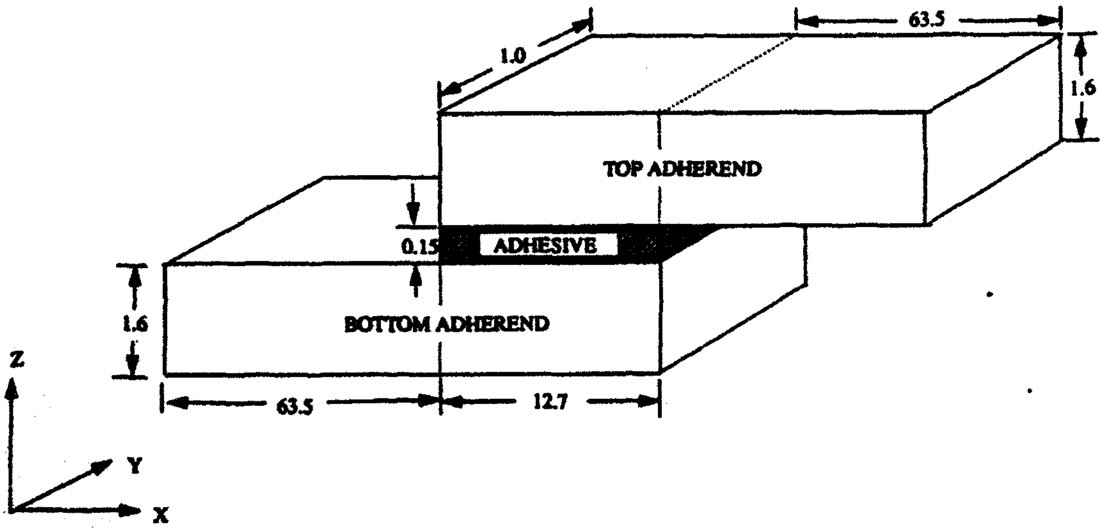

Figure 15. 3-D Single-lap joint geometry.

The convergence behavior is identical to that shown in the 2-D lap joint example presented above. For clarity, 3-D solutions are depicted for a model incorporating 100 elements along the bondline showing comparisons between the special layered hybrid adhesive element and standard displacement-based elements with a reference solution. In generating the displacement-based solution, the same model was used in which the layered H2L12N elements were each replaced by two 8-node brick elements (C3D8) from the ABAQUS library. Figures 16 and 17 show predictions for σ_{zz} and τ_{xz} over the bond interface using the H2L12N element. The τ_{yz} shear stress component is essentially zero for this particular joint problem and is, therefore, not shown. The purely displacement-based element solution is shown in figures 18 and 19 and demonstrates a convergence away from the reference solution. The ABAQUS input deck and selected output is presented in Appendix C.

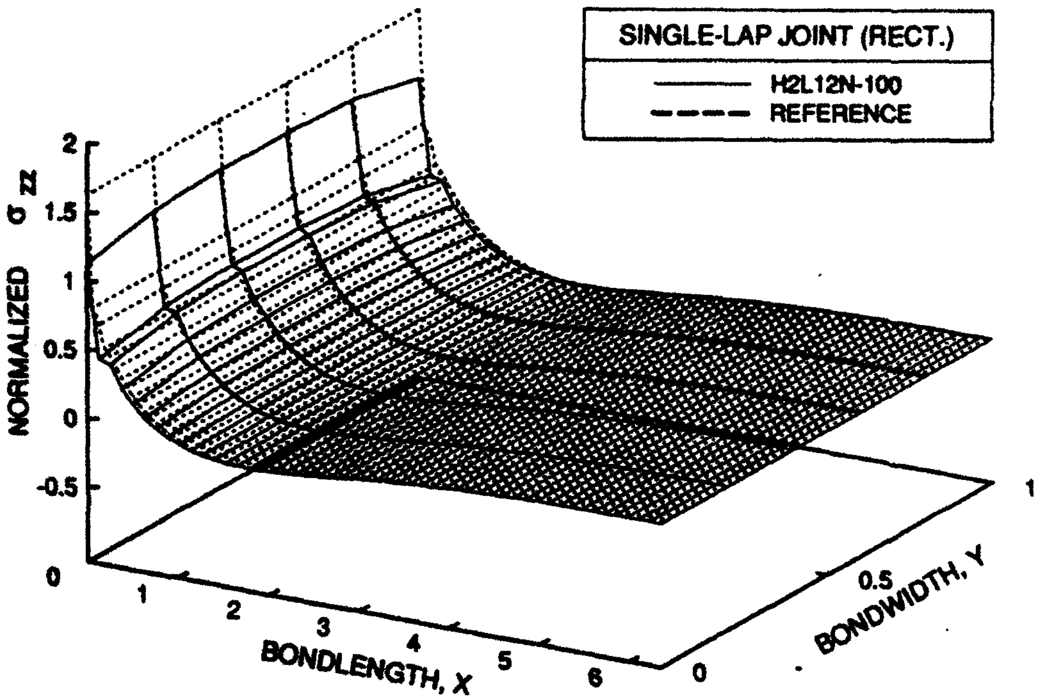

Figure 16. H2L12N prediction of σ_{zz} distribution along the bondline.

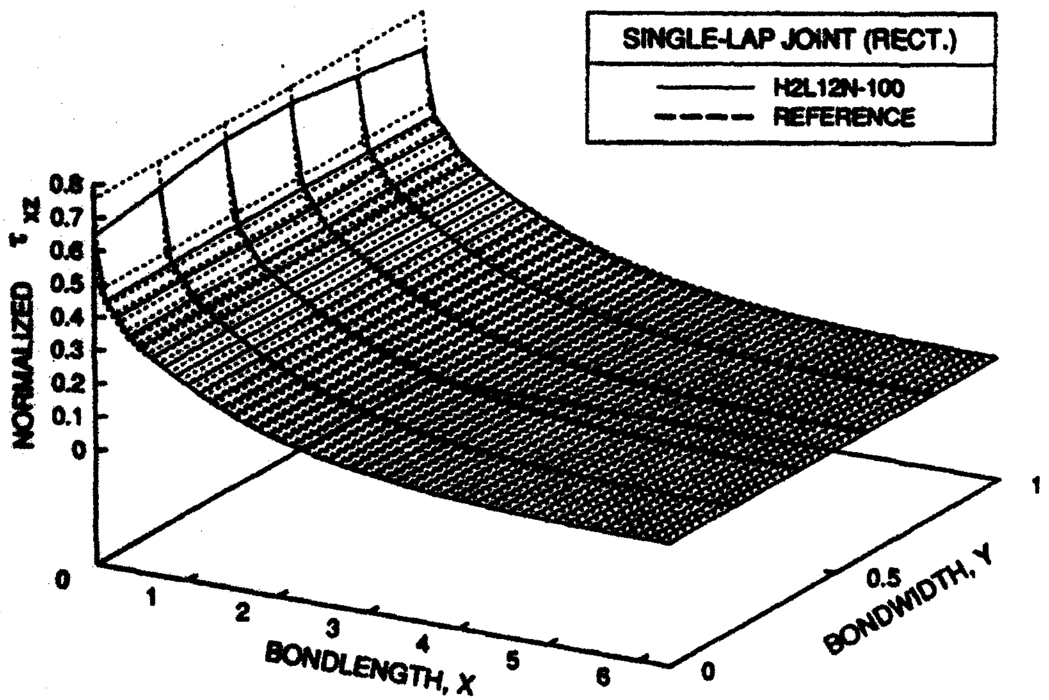

Figure 17. H2L12N prediction of τ_{xz} distribution along the bondline.

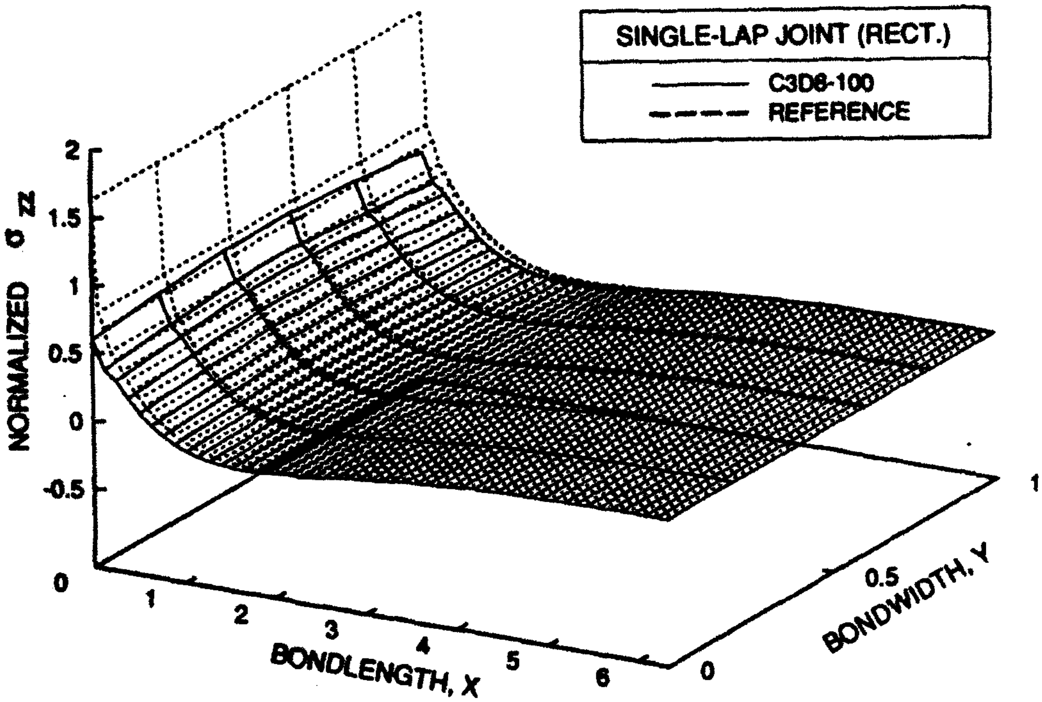

Figure 18. C3D8 prediction of σ_{zz} distribution along the bondline.

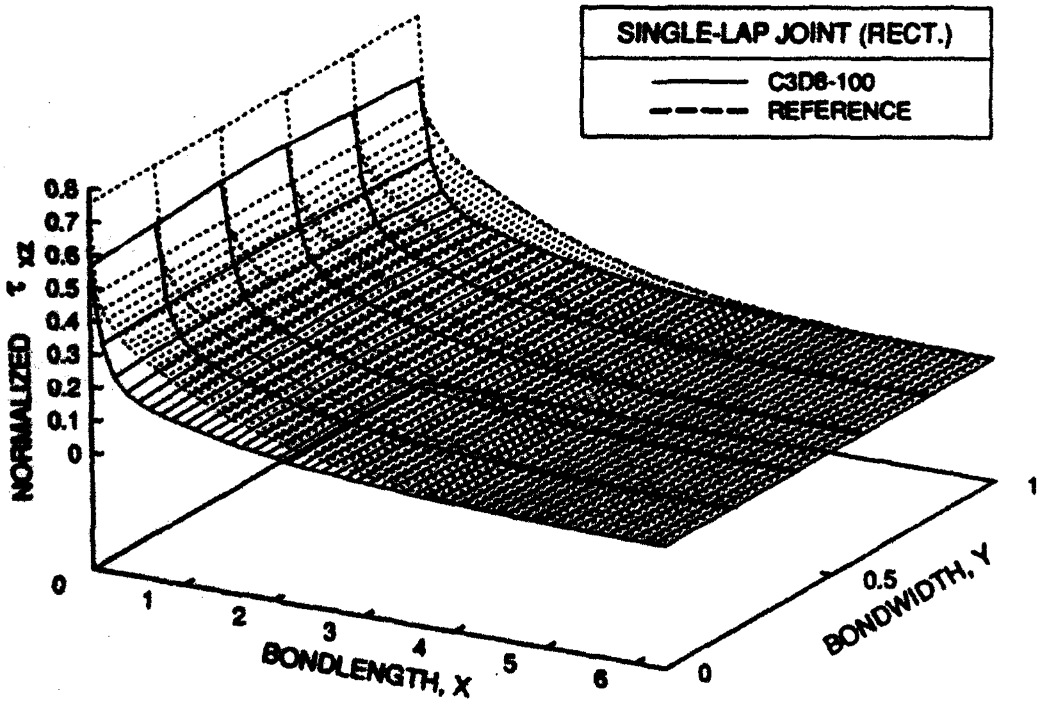

Figure 19. C3D8 prediction of τ_{xz} distribution along the bondline.

6 Conclusion

A variety of 2-D and 3-D special layered hybrid element formulations have been developed for the analysis of bondline stresses in adhesive joints. The hybrid stress method was selected to allow the explicit enforcement of layer domain equilibrium and interface continuity constraints. In addition, for the H2L6N and H3L8N elements, stress fields have been derived to enforce zero traction conditions along element sides. The elements demonstrate improved efficiency over similar displacement-based elements and are fully supported for use in the commercial finite element code ABAQUS through the development of a user-defined subroutine. The required input format has been detailed and element performance demonstrated in two example problems. Sample input and output datasets together with the complete source code performing all element computations have been included in separate appendices. The developed special adhesive elements provide an ideal basis for further enhancements such as the incorporation of nonlinear material and geometric capabilities to accurately model bondline stresses in complex adhesive joint designs.

References

[1] E. Saether and K. Weight, 'Special hybrid stress finite elements for the analysis of interface stress distribution in adhesive joints,' ARL-TR-449, U.S. Army Research Laboratory, June, (1994).

[2] Hibbit, Karlsson and Sorensen, Inc., ABAQUS USER'S MANUAL, Version 5.3, 1994.

APPENDIX A

Soure code listing of subroutine UEL supporting special adhesive elements in ABAQUS.

```
C
C   **************************************************************
C   **   USER DEFINED ELEMENT SUBROUTINE UEL FOR THE ABAQUS CODE  **
C   **   INCORPORATING SPECIAL LAYERED ELEMENT FORMULATIONS FOR   **
C   **   THE ANALYSIS OF ADHESIVE JOINTS.                         **
C   **************************************************************
C
      SUBROUTINE UEL(RHS,AMATRX,SVARS,ENERGY,NDOFEL,NRHS,NSVARS,
     1               PROPS,NPROPS,COORDS,MCRD,NNODE,U,DU,V,A,
     2               JTYPE,TIME,DTIME,KSTEP,KINC,JELEM,PARAMS,
     3               NDLOAD,JDLTYP,ADLMAG,PREDEF,NPREDF,LFLAGS,
     4               MLVARX,DDLMAG,MDLOAD,PNEWDT                     )
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C     VARIABLE AND ARRAY DECLARATIONS FOR UEL/ABAQUS INTERFACE
C
      DIMENSION RHS(MLVARX,*),AMATRX(NDOFEL,NDOFEL),PROPS(*),
     1          SVARS(1),ENERGY(8),COORDS(MCRD,NNODE),U(NDOFEL),
     2          DU(MLVARX),V(NDOFEL),A(NDOFEL),TIME(2),
     3          PARAMS(*),JDLTYP(MDLOAD,*),ADLMAG(MDLOAD,*),
     4          DDLMAG(MDLOAD,*),PREDEF(2,NPREDF,NNODE),LFLAGS(5)
      DIMENSION HINV(100,100),GMAT(100,36)
C
      DATA  EPS / 1.0D-8 /
C
C     TEST IF ABAQUS IS IN THE ELEMENT DATA RECOVERY
C     PHASE BY CHECKING DISPLACEMENTS
C
      TEST = 0.0
      DO I = 1, NDOFEL
         TEST = TEST + ABS(DU(I))
      END DO
C
      IF ( TEST .LT. EPS ) THEN
C
C        COMPUTE ELEMENT STIFFNESS MATRIX
C
         CALL HSTIFF( AMATRX,PROPS,COORDS,HINV,GMAT,TEST,NPROPS,
     1                NDOFEL,MCRD,NNODE,JTYPE,JELEM,NBVAL )
C
C        SET RHS VECTOR TO ZERO
C
         CALL MXINT ( RHS(1,1), NDOFEL, 1, 0.0D0)
C
      ELSE IF ( TEST .GT. EPS) THEN
C
C        PERFORM REQUESTED ELEMENT DATA RECOVERY
C
C        COMPUTE ELEMENT G AND H MATRIX
C
         CALL HSTIFF( AMATRX,PROPS,COORDS,HINV,GMAT,TEST,NPROPS,
     1                NDOFEL,MCRD,NNODE,JTYPE,JELEM,NBVAL )
C
         CALL RECOV( COORDS,PROPS,DU,HINV,GMAT,MLVARX,NDOFEL,
     1               NPROPS,MCRD,NNODE,JTYPE,JELEM,NBVAL )
C
      END IF
C
      RETURN
      END
C
C
C
      SUBROUTINE HSTIFF( AMATRX,PROPS,COORDS,HINV,GSMBL,TEST,NPROPS,
     1                   NDOFEL,MCRD,NNODE,JTYPE,JELEM,NBVAL )
C
C     *********************************************
```

```
C     **                                            **
C     **  ADHESIVE ELEMENT STIFFNESS GENERATION     **
C     **                                            **
C     ************************************************
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION AMATRX(NDOFEL,NDOFEL),PROPS(*),COORDS(MCRD,NNODE)
C
      DIMENSION HMAT(100,100),HINV(100,100),AJINV(3,3),
     1          XH(20),YH(20),ZH(20),TMP1(100,100),TMP2(100,100),
     2          DXSI(20),DETA(20),DCEE(20),BMATS(6,60)
      DIMENSION SMAT(6,6),PMAT(6,100),THETA(100),
     1          GMAT(100,36),INDX1(36),GSMBL(100,36),HSMBL(100,100),
     2          PTHK(100),E1(100),E2(100),E3(100),V12(100),
     3          V23(100),V13(100),G12(100),G23(100),G31(100)
      DIMENSION WDT(3),NLAY(3),THK(3),ETRN(6,6),STRN(6,6),TRI(3,3),
     1          CTRN(36,36)
C
      DATA  EPS / 1.0D-8 /
C
C     READ IN ELEMENT DATA FROM PROPS ARRAY AND
C     SET ELEMENT PARAMETERS
C
      CALL ELDATA( PROPS,PTHK,THETA,E1,E2,E3,V12,V23,V13,G12,G23,G31,
     1             WDT,THK,NORD,IPLANE,IOTYPE,NLAYR,NELDIM,NDOFN,INTNOD,
     2             NODNUM,JTYPE,NSIDE,NDV,INTDOF,NDOFT,NDOFL,MORD,NLAY,
     3             NVER )
C
      CALL MXINT( GSMBL,100, 36,0.0D0 )
      CALL MXINT( HSMBL,100,100,0.0D0 )
C
C     CHECK GEOMETRY OF ELEMENTS ON INITIAL PAST
C
      IF ( TEST .LT. EPS ) CALL VCHECK ( COORDS,MCRD,NNODE,JTYPE,JELEM )
C
C     OBTAIN TRANSFORMATION MATRIX BETWEEN GLOBAL AND
C     LOCAL ELEMENT COORDINATES
C
      CALL TRANS( COORDS,CTRN,STRN,ETRN,TRI,JTYPE,MCRD,NNODE )
C
C     LOOP OVER AND ASSEMBLE ALL ELEMENT LAYERS
C
      DO K = 1, NLAYR
C
         LAYER = K
         TFAC  = 1.0
         IF ( NELDIM .EQ. 2 ) TFAC = WDT(K)
C
         N = (NODNUM-INTNOD)*(K-1)
         DO I = 1, NODNUM
            N = (NODNUM-INTNOD)*(K-1)
            AX = COORDS(1,I+N)
            BY = COORDS(2,I+N)
            CZ = COORDS(3,I+N)
C
C           TRANSFORM TO LOCAL COORDINATES
C
            XH(I) = TRI(1,1)*AX+TRI(1,2)*BY+TRI(1,3)*CZ
            YH(I) = TRI(2,1)*AX+TRI(2,2)*BY+TRI(2,3)*CZ
            ZH(I) = TRI(3,1)*AX+TRI(3,2)*BY+TRI(3,3)*CZ
         END DO
C
C        COMPUTE ELEMENT MATERIAL PROPERTY MATRICES
C
         CALL MATPROP(PTHK,THETA,E1,E2,E3,G12,G23,G31,V12,V23,V13,
     1                SMAT,NELDIM,IPLANE,MORD,LAYER,NLAY)
C
```

```
      CALL MXINT( HMAT, 100,  100,  0.0D0 )
      CALL MXINT( GMAT, 100,   36,  0.0D0 )
C
C     STRAIN VECTOR CONVENTION: {EX,EY,EZ,TYZ,TXZ,TXY}
C
      NRDZ = NORD
      IF ( NELDIM .EQ. 2 ) NRDZ = 1
C
      DO  IXSI = 1, NORD
        DO  JETA = 1, NORD
          DO  KCEE = 1, NRDZ
C
C             OBTAIN GAUSS POINTS AND WEIGHTS
C
              CALL GAUSS(NORD,NELDIM,IXSI,JETA,KCEE,XSI,ETA,CEE,WEIGHT)
C
C             COMPUTE SHAPE FUNCTIONS AND THEIR DERIVATIVES AT
C             THE CURRENT GAUSS POINT
C
              CALL SHAPE(NODNUM,NELDIM,XSI,ETA,CEE,DXSI,DETA,DCEE)
C
C             COMPUTE JACOBIAN MATRIX, ITS DETERMINANT AND
C             INVERSE
C
              CALL JACOB(NODNUM,NELDIM,XH,YH,ZH,DXSI,DETA,DCEE,
     1                   AJINV,DETJ )
C
C             COMPUTE MATRIX OF ASSUMED STRESS FUNCTIONS AT
C             CURRENT GAUSS POINT
C
              CALL ASTRSS(XSI,ETA,CEE,JTYPE,LAYER,NELDIM,NODNUM,
     1                    PMAT,THK,NBVAL,XH,YH,ZH,NSIDE,NVER)
C
C             COMPUTE THE STRAIN-DISPACEMENT MATRIX BMATS
C
              CALL BMAT(NELDIM,MORD,NODNUM,NDOFL,AJINV,DXSI,DETA,
     1                  DCEE,BMATS)
C
C             FORM G AND H MATRICES
C
              CALL MXATB(PMAT,BMATS,TMP2,6,6,100,NBVAL,MORD,NDOFL)
C
C             INTEGRATE GMAT COEFFICIENTS
C
              DO II = 1, NBVAL
              DO JJ = 1, NDOFL
                GMAT(II,JJ) = GMAT(II,JJ)+DETJ*WEIGHT*TFAC*TMP2(II,JJ)
              END DO
              END DO
C
              CALL MXMUL(SMAT,PMAT,TMP1,6,6,100,MORD,MORD,NBVAL)
              CALL MXATB(PMAT,TMP1,TMP2,6,100,100,NBVAL,MORD,NBVAL)
C
C             INTEGRATE HMAT COEFFICIENTS
C
              DO II = 1, NBVAL
              DO JJ = 1, NBVAL
                HMAT(II,JJ) = HMAT(II,JJ)+DETJ*WEIGHT*TFAC*TMP2(II,JJ)
              END DO
              END DO
C
          END DO
        END DO
      END DO
C
C     ASSEMBLE GMAT AND HMAT
C
      N = (NODNUM-INTNOD)*(K-1)*NDOFN
```

```
      DO I = 1, NBVAL
         DO J = 1, NDOFL
            GSMBL(I,J+N) = GSMBL(I,J+N) + GMAT(I,J)
         END DO
         DO J = 1, NBVAL
            HSMBL(I,J) = HSMBL(I,J) + HMAT(I,J)
         END DO
      END DO
C
      END DO
C
C     COMPUTE THE INVERSE OF HSMBL
C
      NDIM = 100
      CALL INVERS(HSMBL,HINV,INDX1,NDIM,NBVAL)
C
      IF ( TEST .GT. EPS ) RETURN
C
C     COMPUTE STIFFNESS COEFFICIENTS
C
      CALL MXMUL(HINV,GSMBL,TMP1,100,100,100,NBVAL,NBVAL,NDOFT)
      CALL MXATB(GSMBL,TMP1,AMATRX,100,100,NDOFT,NDOFT,NBVAL,NDOFT)
C
C     TRANSFORM ELEMENT STIFFNESSES TO GLOBAL COORDINATES
C
      CALL MXMUL(AMATRX,CTRN,TMP1,NDOFEL,36,100,NDOFEL,NDOFEL,NDOFEL)
      CALL MXATB(CTRN,TMP1,AMATRX,36,100,NDOFEL,NDOFEL,NDOFEL,NDOFEL)
C
      RETURN
      END
C
C
C
      SUBROUTINE RECOV( COORDS,PROPS,DU,HINV,GMAT,MLVARX,NDOFEL,
     1                  NPROPS,MCRD,NNODE,JTYPE,JELEM,NBVAL )
C
C     *************************************************
C     **                                             **
C     **    PERFORM REQUESTED ELEMENT DATA RECOVERY  **
C     **                                             **
C     *************************************************
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION PROPS(*),COORDS(MCRD,NNODE),DU(MLVARX)
C
      DIMENSION HINV(100,100),TMP2(100,100),TMP1(100,100),AJINV(3,3),
     1          STRN(6,6),ETRN(6,6),XH(20),YH(20),ZH(20),
     2          ULI(36),UL(36),DXSI(20),DETA(20),DCEE(20)
      DIMENSION PMAT(6,100),BMATS(6,60),GMAT(100,36),BETA(100),
     1          THETA(100),WDT(3),THK(3),PTHK(100),E1(100),
     2          E2(100),E3(100),V12(100),V23(100),V13(100),
     3          G12(100),G23(100),G31(100),TRI(3,3)
      DIMENSION CTRN(36,36),SCOMP(27,6),ECOMP(27,6),NLAY(3)
C
      CALL ELDATA( PROPS,PTHK,THETA,E1,E2,E3,V12,V23,V13,G12,G23,G31,
     1             WDT,THK,NORD,IPLANE,IOTYPE,NLAYR,NELDIM,NDOFN,INTNOD,
     2             NODNUM,JTYPE,NSIDE,NDV,INTDOF,NDOFT,NDOFL,MORD,NLAY,
     3             NVER )
C
      IF ( IOTYPE .EQ. 0 ) RETURN
C
      WRITE(6,6794) JELEM
C
C     OBTAIN ORTHOGONAL AND TENSORIAL TRANSFORMATION MATRICES FOR
C     DISPLACEMENTS, STRESSES AND STRAINS
C
      CALL TRANS( COORDS,CTRN,STRN,ETRN,TRI,JTYPE,MCRD,NNODE )
```

```
C
C     TRANSFORM GLOBAL DISPLACEMENTS INTO LOCAL SYSTEM
C
      CALL MXMUL(CTRN,DU,ULI,36,MLVARX,36,NDOFEL,NDOFEL,1)
C
C     COMPUTE BETA VALUES FOR STRESS RECOVERY
C
      CALL MXMUL(GMAT,ULI,TMP1,100,36,100,NBVAL,NDOFEL,1)
      CALL MXMUL(HINV,TMP1,BETA,100,100,100,NBVAL,NBVAL,1)
C
C     LOOP OVER ALL ELEMENT LAYERS
C
      DO K = 1, NLAYR
C
         CALL MXINT( SCOMP, 27,  6, 0.0D0 )
         CALL MXINT( ECOMP, 27,  6, 0.0D0 )
C
         LAYER = K
C
C        COMPUTE THE ELEMENT STRESS RECOVERY MATRICES
C
         N = (NODNUM-INTNOD)*(K-1)
         DO I = 1, NODNUM
            AX = COORDS(1,I+N)
            BY = COORDS(2,I+N)
            CZ = COORDS(3,I+N)
C
C           TRANSFORM TO LOCAL COORDINATES
C
            XH(I)  = TRI(1,1)*AX+TRI(1,2)*BY+TRI(1,3)*CZ
            YH(I)  = TRI(2,1)*AX+TRI(2,2)*BY+TRI(2,3)*CZ
            ZH(I)  = TRI(3,1)*AX+TRI(3,2)*BY+TRI(3,3)*CZ
         END DO
C
C        EXTRACT DISPLACEMENT SET FOR THE CURRENT LAYER
C
         N = (NODNUM-INTNOD)*(K-1)*NDOFN
         DO I = 1, NDOFL
            UL(I)  = ULI(I+N)
         END DO
C
C        COMPUTE STRESSES AND STRAINS AT SELECTED
C        ELEMENT COORDINATES
C
         IET = 0
         CALL IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1               XSI,ETA,CEE)
C
         DO IET = 1, NTPS
C
            CALL IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1                  XSI,ETA,CEE)
C
C           COMPUTE SHAPE FUNCTIONS AND THEIR DERIVATIVES AT
C           THE CURRENT RECOVERY POINT
C
            CALL SHAPE(NODNUM,NELDIM,XSI,ETA,CEE,DXSI,DETA,DCEE)
C
C           COMPUTE JACOBIAN MATRIX, ITS DETERMINANT AND INVERSE
C
            CALL JACOB(NODNUM,NELDIM,XH,YH,ZH,DXSI,DETA,DCEE,
     1                 AJINV,DETJ                          )
C
C           COMPUTE MATRIX OF ASSUMED STRESS FUNCTIONS AT
C           CURRENT GAUSS POINT
C
            CALL ASTRSS(XSI,ETA,CEE,JTYPE,LAYER,NELDIM,NODNUM,
     1                  PMAT,THK,NBVAL,XH,YH,ZH,NSIDE,NVER )
```

```
C
C         COMPUTE THE STRAIN-DISPACEMENT MATRIX BMATS
C
          CALL BMAT(NELDIM,MORD,NODNUM,NDOFL,AJINV,DXSI,DETA,
     1              DCEE,BMATS)
C
C         COMPUTE ELEMENT STRAINS AT OUTPUT POINT
C
          CALL MXMUL(BMATS,UL,TMP1,6,36,100,MORD,NDOFL,1)
C
          DO IS = 1, MORD
             IF ( IOTYPE .EQ. 2) THEN
C
C               TRANSFORM STRAINS IN LOCAL ELEMENT COORDINATES TO
C               GLOBAL SYSTEM
C
                DO IT = 1, MORD
                  ECOMP(IET,IS) = ECOMP(IET,IS)+STRN(IT,IS)*TMP1(IT,1)
                END DO
             ELSE
                ECOMP(IET,IS) = TMP1(IS,1)
             END IF
          END DO
C
          CALL MXMUL(PMAT,BETA,TMP2,6,100,100,MORD,NBVAL,1)
C
          DO IS = 1, MORD
             IF ( IOTYPE .EQ. 2) THEN
C
C               TRANSFORM STRESSES IN LOCAL ELEMENT COORDINATES TO
C               GLOBAL SYSTEM
C
                DO IT = 1, MORD
                  SCOMP(IET,IS) = SCOMP(IET,IS)+ETRN(IT,IS)*TMP2(IT,1)
                END DO
             ELSE
                SCOMP(IET,IS) = TMP2(IS,1)
             END IF
          END DO
C
       END DO
C
C      OUTPUT ELEMENT STRESSES AND STRAINS AT SELECTED POINTS
C
       IF ( NELDIM .EQ. 2 ) THEN
C
          IF ( IOTYPE .EQ. 1 ) WRITE(6,892) LAYER
          IF ( IOTYPE .EQ. 2 ) WRITE(6,893) LAYER
C
C         OUTPUT LAYER STRESSES
C
          DO IET = 1, NTPS
C
            CALL IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1                  XSI,ETA,CEE)
C
            WRITE(6,994) XSI,ETA,(SCOMP(IET,I),ECOMP(IET,I),I=1,3)
C
          END DO
C
       ELSE IF ( NELDIM .EQ. 3 ) THEN
C
C         OUTPUT ELEMENT STRESSES AND STRAINS AT SELECTED POINTS
C
          IF ( IOTYPE .EQ. 1 ) WRITE(6,894) LAYER
          IF ( IOTYPE .EQ. 2 ) WRITE(6,895) LAYER
C
C         OUTPUT LAYER STRESSES
```

```
C
            DO IET = 1, NTPS
C
              CALL IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1                    XSI,ETA,CEE)
C
              WRITE(6,995) XSI,ETA,CEE,(SCOMP(IET,I),I=1,6)
C
            END DO
C
            IF ( IOTYPE .EQ. 1 ) WRITE(6,896) LAYER
            IF ( IOTYPE .EQ. 2 ) WRITE(6,897) LAYER
C
C           OUTPUT LAYER STRAINS
C
            DO IET = 1, NTPS
C
              CALL IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1                    XSI,ETA,CEE)
C
              WRITE(6,995) XSI,ETA,CEE,(ECOMP(IET,I),I=1,6)
C
            END DO
C
         END IF
C
      END DO
C
C     FORMAT STATEMENTS FOR HYBRID ELEMENT OUTPUT
C
855   FORMAT(///,45X,'H Y B R I D   E L E M E N T   D A T A  ',//)
848   FORMAT(//,' ELEMENT ID: ',I5,//)
800   FORMAT(/,20X,'HYBRID STIFFNESS MATRIX:',/)
801   FORMAT(/,10I11)
815   FORMAT(1X,I3,2X,10(E9.3,2X))
892   FORMAT(20X,/,'STRESS/STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER'
     1,I5,//,2X,'RECOVERY POINTS',24X,'STRESS/STRAIN
     2COMPONENTS',/,3X,' CI        CJ',9X,'SXX',8X,'EXX',8X,'SYY',8X,
     3'EYY',8X,'SXY',8X,'EXY')
893   FORMAT(20X,/,'STRESS/STRAIN OUTPUT IN GLOBAL COORDINATES FOR LAYER
     1',I5,//,2X,'RECOVERY POINTS',24X,'STRESS/STRAIN
     2COMPONENTS',/,3X,' CI        CJ',9X,'SXX',8X,'EXX',8X,'SYY',8X,
     3'EYY',8X,'SXY',8X,'EXY')
894   FORMAT(20X,/,'STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER',I5,//,
     19X,'RECOVERY POINTS',29X,'STRESS COMPONENTS',/,
     23X,' CI        CJ        CK',9X,'SXX',8X,'SYY',8X,'SZZ',8X,
     3'SYZ',8X,'SZX',8X,'SXY')
895   FORMAT(20X,/,'STRESS OUTPUT IN GLOBAL COORDINATES FOR LAYER',I5,//
     1,9X,'RECOVERY POINTS',29X,'STRESS COMPONENTS',/,
     23X,' CI        CJ        CK',9X,'SXX',8X,'SYY',8X,'SZZ',8X,
     3'SYZ',8X,'SZX',8X,'SXY')
896   FORMAT(20X,/,'STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER',I5,//,
     19X,'RECOVERY POINTS',29X,'STRAIN COMPONENTS',/,
     23X,' CI        CJ        CK',9X,'EXX',8X,'EYY',8X,
     3'EZZ',8X,'EYZ',8X,'EZX',8X,'EXY')
897   FORMAT(20X,/,'STRAIN OUTPUT IN GLOBAL COORDINATES FOR LAYER',I5,//
     1,9X,'RECOVERY POINTS',29X,'STRAIN COMPONENTS',/,
     23X,' CI        CJ        CK',9X,'EXX',8X,'EYY',8X,
     3'EZZ',8X,'EYZ',8X,'EZX',8X,'EXY')
994   FORMAT(2(F7.4,2X),2X,6(E9.3,2X))
995   FORMAT(3(F7.4,2X),2X,12(E9.3,2X))
6794  FORMAT(/,' ELEMENT ID ',I5,/)
C
      RETURN
      END
C
C
C
```

```
      SUBROUTINE VCHECK( COORDS,MCRD,NNODE,JTYPE,JELEM )
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION COORDS(MCRD,NNODE),X(20),Y(20),Z(20)
C
      DATA  NONE / 0 /
C
C     TEST FOR IRREGULAR ELEMENT GEOMETRY BY CHECKING
C     INTERNAL ANGLES IN ELEMENT LAYERS
C
      DO I = 1, NNODE
         X(I) = COORDS(1,I)
         Y(I) = COORDS(2,I)
         Z(I) = COORDS(3,I)
      END DO
C
C     INITIALIZE LAYER ERROR FLAGS
C
      NERRL1 = 0
      NERRL2 = 0
      NERRL3 = 0
C
      IF ( JTYPE .EQ. 1 ) THEN
C
         CALL ANGLE ( X,Y,Z,1,2,3,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,4,3,2,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,3,4,5,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,6,5,4,JELEM,NERRL1 )
C
      ELSE IF ( JTYPE .EQ. 2 ) THEN
C
         CALL ANGLE ( X,Y,Z,1, 2,5,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,6, 5,2,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,5, 6,9,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,10,9,6,JELEM,NERRL2 )
C
      ELSE IF ( JTYPE .EQ. 3 ) THEN
C
         CALL ANGLE ( X,Y,Z,1,  3,  6,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,8,  6,  3,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,6,  8,11,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,13,11,8,JELEM,NERRL2 )
C
      ELSE IF ( JTYPE .EQ. 4 ) THEN
C
         CALL ANGLE ( X,Y,Z,1,2,3,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,3,4,5,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,4,3,2,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,6,5,4,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,5,6,7,JELEM,NERRL3 )
         CALL ANGLE ( X,Y,Z,8,7,6,JELEM,NERRL3 )
C
      ELSE IF ( JTYPE .EQ. 5 ) THEN
C
         CALL ANGLE ( X,Y,Z,1,  2,  5,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,6,  5,  2,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,2,  3,  6,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,7,  6,  3,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,3,  4,  7,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,8,  7,  4,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,4,  1,  8,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,5,  8,  1,JELEM,NERRL1 )
         CALL ANGLE ( X,Y,Z,5,  6,  9,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,10,9,  6,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,6,  7,10,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,11,10,7,JELEM,NERRL2 )
         CALL ANGLE ( X,Y,Z,7,  8,11,JELEM,NERRL2 )
```

```
          CALL ANGLE ( X,Y,Z,12,11,8,JELEM,NERRL2 )
          CALL ANGLE ( X,Y,Z,8, 5,12,JELEM,NERRL2 )
          CALL ANGLE ( X,Y,Z,9,12, 5,JELEM,NERRL2 )
C
      END IF
C
      IF ( NERRL1 .EQ. 1 .OR. NERRL2 .EQ. 1 .OR. NERRL3 .EQ. 1) THEN
         IF ( NONE .EQ. 0 ) THEN
            WRITE(6,100)
            NONE = 1
         END IF
      END IF
C
      IF ( NERRL1 .NE. 0 ) WRITE(6,10) JELEM
      IF ( NERRL2 .NE. 0 ) WRITE(6,20) JELEM
      IF ( NERRL3 .NE. 0 ) WRITE(6,30) JELEM
C
10    FORMAT(' ERROR - ELEMENT #',I10,' IS DEFORMED IN LAYER 1')
20    FORMAT(' ERROR - ELEMENT #',I10,' IS DEFORMED IN LAYER 2')
30    FORMAT(' ERROR - ELEMENT #',I10,' IS DEFORMED IN LAYER 3')
100   FORMAT(//,' ELEMENT LAYERS MUST BE OF RECTANGULAR GEOMETRY',//)
C
      RETURN
      END
C
C
C
      SUBROUTINE ANGLE ( X,Y,Z,N1,N2,N3,JELEM,NERR )
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION X(20),Y(20),Z(20)
C
      PI = ACOS(-1.0D0)
C
      V1  = X(N2) - X(N1)
      V2  = Y(N2) - Y(N1)
      V3  = Z(N2) - Z(N1)
      V4  = X(N3) - X(N1)
      V5  = Y(N3) - Y(N1)
      V6  = Z(N3) - Z(N1)
C
      DOT   =  V1*V4 + V2*V5 + V3*V6
      ADA   = (V1*V1 + V2*V2 + V3*V3)**0.5
      BDB   = (V4*V4 + V5*V5 + V6*V6)**0.5
      THETA = ABS(180*ACOS(DOT/(ADA*BDB))/PI)
C
      IF ( THETA .GE. 95.0 .OR. THETA .LE. 85.0 ) NERR = 1
C
      RETURN
      END
C
C
C
      SUBROUTINE ELDATA( PROPS,PTHK,THETA,E1,E2,E3,V12,V23,V13,G12,
     1                   G23,G31,WDT,THK,NORD,IPLANE,IOTYPE,NLAYR,
     2                   NELDIM,NDOFN,INTNOD,NODNUM,JTYPE,NSIDE,NDV,
     3                   INTDOF,NDOFT,NDOFL,MORD,NLAY,NVER          )
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION E1(100),E2(100),E3(100),G12(100),G23(100),G31(100),
     1          V12(100),V23(100),V13(100),PTHK(100),THETA(100),
     2          PROPS(1),WDT(3),NLAY(3),THK(3)
C
C     NOTE: ALL PROPERTY VALUES MUST BE INPUTTED AS REAL
C           NUMBERS ON THE UEL PROPERTY INPUT BLOCK
C
```

```
C     ELEMENT PARAMETERS:
C
C     NLAYR    = N : NUMBER OF LAYERS IN ELEMENT
C     NELDIM   = N : ELEMENT DIMENSION
C     NDOFN    = N : NUMBER OF DEGREES OF FREEDOM PER NODE
C     INTNOD   = N : NUMBER OF NODES ALONG LAYER INTERFACE
C     NODNUM   = N : NUMBER OF NODES PER LAYER
C     INTDOF   = N : NUMBER OF DOF ALONG INTERFACE (=INTNOD*NDOFN)
C     NDOFT    = N : TOTAL NUMBER OF DOF PER ELEMENT (=NDOFEL)
C     NDOFL    = N : TOTAL NUMBER OF DOF PER LAYER (=NODNUM*NDOFN)
C     NDV      = N : DIMENSION OF ISOPARAMETRIC TRANSFORMATION
C                    MATRIX (=NDOFN*NELDIM)
C     NSIDE    = N   FOR ZERO TRACTION CONDITION ON PRESCRIBED FACE N
C
      CALL MXINT( THK, 3, 1, 0.0D0 )
C
      IF ( JTYPE .EQ. 1 ) THEN
C
C        *********************
C        *   H2L6N ELEMENT   *
C        *********************
C
C        LOCAL LAYER COORDINATE SYSTEM CONVENTION:
C
C
C         5---------Y--------6
C         |         ^        |
C         |         |        |
C         |         |----> X |
C         |                  |
C         |                  |
C         3---------Y------- 4
C         |         ^        |
C         |         |        |
C         |         |----> X |
C         |                  |
C         |                  |
C         1------------------2
C
C
         NLAYR  = 2
         NELDIM = 2
         NDOFN  = 2
         INTNOD = 2
         NODNUM = 4
         NDV    = NDOFN*NELDIM
         INTDOF = INTNOD*NDOFN
         NDOFT  = 12
         NDOFL  = NODNUM*NDOFN
         MORD   = 3
C
C        ELEMENT INPUT PROPERTIES:
C
C        NVER    - ELEMENT VERSION DESIGNATION
C        IPLANE  - 0 FOR PLANE STRESS
C                  1 FOR PLANE STRAIN
C        IOTYPE  - 0 TO SUPPRESS OUTPUT OF ELEMENT DATA
C                  1 FOR ELEMENT OUTPUT IN LOCAL COORDINATES
C                  2 FOR ELEMENT OUTPUT IN GLOBAL COORDINATES
C        NSIDE   - ELEMENT SIDE DESIGNATION FOR ZERO TRACTIONS
C        NLAY1   - NUMBER OF PLIES IN ELEMENT LAYER 1
C        NLAY2   - NUMBER OF PLIES IN ELEMENT LAYER 2
C        WDT(1)  - DEPTH DIMENSION (WIDTH) OF LAYER 1
C        WDT(2)  - DEPTH DIMENSION (WIDTH) OF LAYER 2
C        THK(1)  - THICKNESS OF LAYER 1 (CALCULATED FROM PLY THICKNESS)
C        THK(2)  - THICKNESS OF LAYER 2 (CALCULATED FROM PLY THICKNESS)
C
C        PTHK        - PLY THICKNESS
```

```
C         THETA          - PLY ORIENTATION
C         E1,E2,E3       - NORMAL MATERIAL MODULII
C         G12,G23,G31 - SHEAR MODULII
C         V12,V23,V13 - POISSON RATIOS
C
C         PROPERTY LIST FORMAT:
C
C         1)   NVER,IPLANE,IOTYPE,NSIDE
C         2)   NLAY1,WDT1,
C         3)   PHTK,THETA,E1,E2,E3,V12,V23,V13
C         4)   G12,G23,G31
C                    .
C                    . REPEAT FOR EACH PLY IN LAYER 1
C                    .
C         I)   NLAY2,WDT2
C         J)   PHTK,THETA,E1,E2,E3,V12,V23,V13
C         K)   G12,G23,G31
C                    .
C                    . REPEAT FOR EACH PLY IN LAYER 2
C                    .
C
C         EXTRACT ELEMENT DATA OFF PROPS ARRAY
C
          NVER     = INT(PROPS(1))
          IPLANE   = INT(PROPS(2))
          IOTYPE   = INT(PROPS(3))
          NSIDE    = INT(PROPS(4))
          NLAY(1)  = INT(PROPS(9))
          WDT(1)   = PROPS(10)
          DO I = 1, NLAY(1)
             N          = I*16
             PTHK(I)    = PROPS(N+1)
             THK(1)     = THK(1) + PTHK(I)
             THETA(I)   = PROPS(N+2)
             E1(I)      = PROPS(N+3)
             E2(I)      = PROPS(N+4)
             E3(I)      = PROPS(N+5)
             V12(I)     = PROPS(N+6)
             V23(I)     = PROPS(N+7)
             V13(I)     = PROPS(N+8)
             G12(I)     = PROPS(N+9)
             G23(I)     = PROPS(N+10)
             G31(I)     = PROPS(N+11)
          END DO
          NLAY(2)  = INT(PROPS(16*NLAY(1)+17))
          WDT(2)   = PROPS(16*NLAY(1)+18)
          M        = NLAY(1)
          DO I = 1, NLAY(2)
             N            = 24+16*(M+I-1)
             PTHK(I+M)    = PROPS(N+1)
             THK(2)       = THK(2) + PTHK(I+M)
             THETA(I+M)   = PROPS(N+2)
             E1(I+M)      = PROPS(N+3)
             E2(I+M)      = PROPS(N+4)
             E3(I+M)      = PROPS(N+5)
             V12(I+M)     = PROPS(N+6)
             V23(I+M)     = PROPS(N+7)
             V13(I+M)     = PROPS(N+8)
             G12(I+M)     = PROPS(N+9)
             G23(I+M)     = PROPS(N+10)
             G31(I+M)     = PROPS(N+11)
          END DO
C
C         SET GAUSSIAN INTEGRATION ORDER
C
          IF ( NVER .EQ. 11 ) NORD = 2
          IF ( NVER .EQ. 12 ) NORD = 3
          IF ( NVER .EQ. 13 ) NORD = 3
```

```
C
      ELSE IF ( JTYPE .EQ. 2 ) THEN
C
C        ************************
C        *   H2L10N  ELEMENT    *
C        ************************
C
C        LOCAL LAYER COORDINATE SYSTEM CONVENTION:
C
C
C          9--------Y--------10
C          |        ^        |
C          |        |        |
C          7        |---> X  8
C          |                 |
C          |                 |
C          5--------Y------- 6
C          |        ^        |
C          |        |        |
C          3        |---> X  4
C          |                 |
C          |        .        |
C          1-----------------2
C
C
         NLAYR  = 2
         NELDIM = 2
         NDOFN  = 2
         INTNOD = 2
         NODNUM = 6
         NDV    = NDOFN*NELDIM
         INTDOF = INTNOD*NDOFN
         NDOFT  = 20
         NDOFL  = NODNUM*NDOFN
         MORD   = 3
C
C        ELEMENT INPUT PROPERTIES:
C
C        NVER     - ELEMENT VERSION DESIGNATION
C        IPLANE   - 0 FOR PLANE STRESS
C                   1 FOR PLANE STRAIN
C        IOTYPE   - 0 TO SUPPRESS OUTPUT OF ELEMENT DATA
C                   1 FOR ELEMENT OUTPUT IN LOCAL COORDINATES
C                   2 FOR ELEMENT OUTPUT IN GLOBAL COORDINATES
C        NLAY1    - NUMBER OF PLIES IN ELEMENT LAYER 1
C        NLAY2    - NUMBER OF PLIES IN ELEMENT LAYER 2
C        WDT(1)   - DEPTH DIMENSION (WIDTH) OF LAYER 1
C        WDT(2)   - DEPTH DIMENSION (WIDTH) OF LAYER 2
C        THK(1)   - THICKNESS OF LAYER 1 (CALCULATED FROM PLY THICKNESS)
C        THK(2)   - THICKNESS OF LAYER 2 (CALCULATED FROM PLY THICKNESS)
C
C        PTHK         - PLY THICKNESS
C        THETA        - PLY ORIENTATION
C        E1,E2,E3     - NORMAL MATERIAL MODULII
C        G12,G23,G31  - SHEAR MODULII
C        V12,V23,V13  - POISSON RATIOS
C
C        PROPERTY LIST FORMAT:
C
C        1)   NVER,IPLANE,IOTYPE
C        2)   NLAY1,WDT1,
C        3)   PHTK,THETA,E1,E2,E3,V12,V23,V13
C        4)   G12,G23,G31
C                 .
C                 . REPEAT FOR EACH PLY IN LAYER 1
C                 .
C        I)   NLAY2,WDT2
C        J)   PHTK,THETA,E1,E2,E3,V12,V23,V13
```

```
C          K)  G12,G23,G31
C                  .
C                  . REPEAT FOR EACH PLY IN LAYER 2
C                  .
C
C          EXTRACT ELEMENT DATA OFF PROPS ARRAY
C
           NVER     = INT(PROPS(1))
           IPLANE   = INT(PROPS(2))
           IOTYPE   = INT(PROPS(3))
           NLAY(1)  = INT(PROPS(9))
           WDT(1)   = PROPS(10)
           DO I = 1, NLAY(1)
              N          = I*16
              PTHK(I)    = PROPS(N+1)
              THK(1)     = THK(1) + PTHK(I)
              THETA(I)   = PROPS(N+2)
              E1(I)      = PROPS(N+3)
              E2(I)      = PROPS(N+4)
              E3(I)      = PROPS(N+5)
              V12(I)     = PROPS(N+6)
              V23(I)     = PROPS(N+7)
              V13(I)     = PROPS(N+8)
              G12(I)     = PROPS(N+9)
              G23(I)     = PROPS(N+10)
              G31(I)     = PROPS(N+11)
           END DO
           NLAY(2)  = INT(PROPS(16*NLAY(1)+17))
           WDT(2)   = PROPS(16*NLAY(1)+18)
           M        = NLAY(1)
           DO I = 1, NLAY(2)
              N            = 24+16*(M+I-1)
              PTHK(I+M)    = PROPS(N+1)
              THK(2)       = THK(2) + PTHK(I+M)
              THETA(I+M)   = PROPS(N+2)
              E1(I+M)      = PROPS(N+3)
              E2(I+M)      = PROPS(N+4)
              E3(I+M)      = PROPS(N+5)
              V12(I+M)     = PROPS(N+6)
              V23(I+M)     = PROPS(N+7)
              V13(I+M)     = PROPS(N+8)
              G12(I+M)     = PROPS(N+9)
              G23(I+M)     = PROPS(N+10)
              G31(I+M)     = PROPS(N+11)
           END DO
C
C          SET GAUSSIAN INTEGRATION ORDER
C
           IF ( NVER .EQ. 11 ) NORD = 4
           IF ( NVER .EQ. 12 ) NORD = 5
C
        ELSE IF ( JTYPE .EQ. 3 ) THEN
C
C          **********************
C          *   H2L13N ELEMENT   *
C          **********************
C
C          LOCAL LAYER COORDINATE SYSTEM CONVENTION:
C
C
C            11--------12--------13
C            |          Y         |
C            |          ^         |
C            |          |         |
C            9          |---> X   10
C            |                    |
C            |                    |
C            |                    |
```

```
C          6--------7------- 8
C          |        Y        |
C          |        ^        |
C          |        |        |
C          4        |---> X  5
C          |                 |
C          |                 |
C          |                 |
C          1--------2--------3
C
C
           NLAYR  = 2
           NELDIM = 2
           NDOFN  = 2
           INTNOD = 3
           NODNUM = 8
           NDV    = NDOFN*NELDIM
           INTDOF = INTNOD*NDOFN
           NDOFT  = 26
           NDOFL  = NODNUM*NDOFN
           MORD   = 3
C
C          ELEMENT INPUT PROPERTIES:
C
C          NVER    - ELEMENT VERSION DESIGNATION
C          IPLANE  - 0 FOR PLANE STRESS
C                    1 FOR PLANE STRAIN
C          IOTYPE  - 0 TO SUPPRESS OUTPUT OF ELEMENT DATA
C                    1 FOR ELEMENT OUTPUT IN LOCAL COORDINATES
C                    2 FOR ELEMENT OUTPUT IN GLOBAL COORDINATES
C          NLAY1   - NUMBER OF PLIES IN ELEMENT LAYER 1
C          NLAY2   - NUMBER OF PLIES IN ELEMENT LAYER 2
C          WDT(1)  - DEPTH DIMENSION (WIDTH) OF LAYER 1
C          WDT(2)  - DEPTH DIMENSION (WIDTH) OF LAYER 2
C          THK(1)  - THICKNESS OF LAYER 1 (CALCULATED FROM PLY THICKNESS)
C          THK(2)  - THICKNESS OF LAYER 2 (CALCULATED FROM PLY THICKNESS)
C
C          PTHK        - PLY THICKNESS
C          THETA       - PLY ORIENTATION
C          E1,E2,E3    - NORMAL MATERIAL MODULII
C          G12,G23,G31 - SHEAR MODULII
C          V12,V23,V13 - POISSON RATIOS
C
C          PROPERTY LIST FORMAT:
C
C          1)   NVER,IPLANE,IOTYPE
C          2)   NLAY1,WDT1,
C          3)   PHTK,THETA,E1,E2,E3,V12,V23,V13
C          4)   G12,G23,G31
C                   .
C                   . REPEAT FOR EACH PLY IN LAYER 1
C                   .
C          I)   NLAY2,WDT2
C          J)   PHTK,THETA,E1,E2,E3,V12,V23,V13
C          K)   G12,G23,G31
C                   .
C                   . REPEAT FOR EACH PLY IN LAYER 2
C                   .
C
C          EXTRACT ELEMENT DATA OFF PROPS ARRAY
C
           NVER   = INT(PROPS(1))
           IPLANE = INT(PROPS(2))
           IOTYPE = INT(PROPS(3))
           NSIDE  = INT(PROPS(4))
           NLAY(1) = INT(PROPS(9))
           WDT(1)  = PROPS(10)
           DO I = 1, NLAY(1)
```

```
            N           = I*16
            PTHK(I)     = PROPS(N+1)
            THK(1)      = THK(1)  + PTHK(I)
            THETA(I)    = PROPS(N+2)
            E1(I)       = PROPS(N+3)
            E2(I)       = PROPS(N+4)
            E3(I)       = PROPS(N+5)
            V12(I)      = PROPS(N+6)
            V23(I)      = PROPS(N+7)
            V13(I)      = PROPS(N+8)
            G12(I)      = PROPS(N+9)
            G23(I)      = PROPS(N+10)
            G31(I)      = PROPS(N+11)
         END DO
         NLAY(2) = INT(PROPS(16*NLAY(1)+17))
         WDT(2)  = PROPS(16*NLAY(1)+18)
         M       = NLAY(1)
         DO I = 1, NLAY(2)
            N           = 24+16*(M+I-1)
            PTHK(I+M)   = PROPS(N+1)
            THK(2)      = THK(2)  + PTHK(I+M)
            THETA(I+M)  = PROPS(N+2)
            E1(I+M)     = PROPS(N+3)
            E2(I+M)     = PROPS(N+4)
            E3(I+M)     = PROPS(N+5)
            V12(I+M)    = PROPS(N+6)
            V23(I+M)    = PROPS(N+7)
            V13(I+M)    = PROPS(N+8)
            G12(I+M)    = PROPS(N+9)
            G23(I+M)    = PROPS(N+10)
            G31(I+M)    = PROPS(N+11)
         END DO
C
C        SET GAUSSIAN INTEGRATION ORDER
C
         IF ( NVER .EQ. 11 ) NORD = 4
         IF ( NVER .EQ. 12 ) NORD = 5
C
      ELSE IF ( JTYPE .EQ. 4 ) THEN
C
C        *********************
C        *   H3L8N ELEMENT   *
C        *********************
C
C        LOCAL LAYER COORDINATE SYSTEM CONVENTION:
C
C
C            7--------Y------- 8
C            |        ^        |
C            |        |        |
C            |        |---> X  |
C            |                 |
C            |                 |
C            5--------Y--------6
C            |        ^        |
C            |        |        |
C         F1 |        |---> X  | F2
C            |                 |
C            |                 |
C            3--------Y------- 4
C            |        ^        |
C            |        |        |
C            |        |---> X  |
C            |                 |
C            |                 |
C            1-----------------2
C
C
```

```
      NLAYR  = 3
      NELDIM = 2
      NDOFN  = 2
      INTNOD = 2
      NODNUM = 4
      NDV    = NDOFN*NELDIM
      INTDOF = INTNOD*NDOFN
      NDOFT  = 16
      NDOFL  = NODNUM*NDOFN
      MORD   = 3
C
C     ELEMENT INPUT PROPERTIES:
C
C     NVER    - ELEMENT VERSION DESIGNATION
C     IPLANE  - 0 FOR PLANE STRESS
C               1 FOR PLANE STRAIN
C     IOTYPE  - 0 TO SUPPRESS OUTPUT OF ELEMENT DATA
C               1 FOR ELEMENT OUTPUT IN LOCAL COORDINATES
C               2 FOR ELEMENT OUTPUT IN GLOBAL COORDINATES
C     NSIDE   - ELEMENT SIDE DESIGNATION FOR ZERO TRACTIONS
C     NLAY1   - NUMBER OF PLIES IN ELEMENT LAYER 1
C     NLAY2   - NUMBER OF PLIES IN ELEMENT LAYER 2
C     NLAY3   - NUMBER OF PLIES IN ELEMENT LAYER 3
C     WDT(1)  - DEPTH DIMENSION (WIDTH) OF LAYER 1
C     WDT(2)  - DEPTH DIMENSION (WIDTH) OF LAYER 2
C     WDT(3)  - DEPTH DIMENSION (WIDTH) OF LAYER 3
C     THK(1)  - THICKNESS OF LAYER 1 (CALCULATED FROM PLY THICKNESS)
C     THK(2)  - THICKNESS OF LAYER 2 (CALCULATED FROM PLY THICKNESS)
C     THK(3)  - THICKNESS OF LAYER 3 (CALCULATED FROM PLY THICKNESS)
C
C     PTHK          - PLY THICKNESS
C     THETA         - PLY ORIENTATION
C     E1,E2,E3      - NORMAL MATERIAL MODULII
C     G12,G23,G31 - SHEAR MODULII
C     V12,V23,V13 - POISSON RATIOS
C
C     PROPERTY LIST FORMAT:
C
C     1)  NTYPE,IPLANE,IOTYPE
C     2)  NLAY1,WDT1,
C     3)  PHTK,THETA,E1,E2,E3,V12,V23,V13
C     4)  G12,G23,G31
C                .
C                . REPEAT FOR EACH PLY IN LAYER 1
C                .
C     I)  NLAY2,WDT2
C     J)  PHTK,THETA,E1,E2,E3,V12,V23,V13
C     K)  G12,G23,G31
C                .
C                . REPEAT FOR EACH PLY IN LAYER 2
C                .
C     L)  NLAY3,WDT3
C     M)  PHTK,THETA,E1,E2,E3,V12,V23,V13
C     N)  G12,G23,G31
C                .
C                . REPEAT FOR EACH PLY IN LAYER 3
C                .
C
C     EXTRACT ELEMENT DATA OFF PROPS ARRAY
C
      NVER    = INT(PROPS(1))
      IPLANE  = INT(PROPS(2))
      IOTYPE  = INT(PROPS(3))
      NSIDE   = INT(PROPS(4))
      NLAY(1) = INT(PROPS(9))
      WDT(1)  = PROPS(10)
      DO I = 1, NLAY(1)
         N = I*16
```

```
            PTHK(I)    = PROPS(N+1)
            THK(1)     = THK(1) + PTHK(I)
            THETA(I)   = PROPS(N+2)
            E1(I)      = PROPS(N+3)
            E2(I)      = PROPS(N+4)
            E3(I)      = PROPS(N+5)
            V12(I)     = PROPS(N+6)
            V23(I)     = PROPS(N+7)
            V13(I)     = PROPS(N+8)
            G12(I)     = PROPS(N+9)
            G23(I)     = PROPS(N+10)
            G31(I)     = PROPS(N+11)
         END DO
         NLAY(2)  = INT(PROPS(16*NLAY(1)+17))
         WDT(2)   = PROPS(16*NLAY(1)+18)
         M        = NLAY(1)
         DO I = 1, NLAY(2)
            N             = 24+16*(M+I-1)
            PTHK(I+M)     = PROPS(N+1)
            THK(2)        = THK(2)  + PTHK(I+M)
            THETA(I+M)    = PROPS(N+2)
            E1(I+M)       = PROPS(N+3)
            E2(I+M)       = PROPS(N+4)
            E3(I+M)       = PROPS(N+5)
            V12(I+M)      = PROPS(N+6)
            V23(I+M)      = PROPS(N+7)
            V13(I+M)      = PROPS(N+8)
            G12(I+M)      = PROPS(N+9)
            G23(I+M)      = PROPS(N+10)
            G31(I+M)      = PROPS(N+11)
         END DO
         NLAY(3)  = INT(PROPS(16*(NLAY(1)+NLAY(2))+25))
         WDT(3)   = PROPS(16*(NLAY(1)+NLAY(2))+26)
         M        = NLAY(1)+NLAY(2)
         DO I = 1, NLAY(3)
            N             = 32+16*(M+I-1)
            PTHK(I+M)     = PROPS(N+1)
            THK(3)        = THK(3)  + PTHK(I+M)
            THETA(I+M)    = PROPS(N+2)
            E1(I+M)       = PROPS(N+3)
            E2(I+M)       = PROPS(N+4)
            E3(I+M)       = PROPS(N+5)
            V12(I+M)      = PROPS(N+6)
            V23(I+M)      = PROPS(N+7)
            V13(I+M)      = PROPS(N+8)
            G12(I+M)      = PROPS(N+9)
            G23(I+M)      = PROPS(N+10)
            G31(I+M)      = PROPS(N+11)
         END DO
C
C        SET GAUSSIAN INTEGRATION ORDER
C
         IF ( NVER .EQ. 11 ) NORD = 3
         IF ( NVER .EQ. 12 ) NORD = 4
C
      ELSE IF ( JTYPE .EQ. 5 ) THEN
C
C        ********************
C        *  H2L12N ELEMENT  *
C        ********************
C
C        NODE NUMBERING CONVENTION:
C
C              12-------11
C             /|       /|
C            / |      / |
C           9--------10 |
C           |  |     |  |
```

```
C           |  8------|--7
C           | /|      | /|
C           |/ |      |/ |
C           5---------6  |
C           |  |      |  |
C           |  4------|--3
C           | /       | /
C           |/        |/
C           1---------2
C
C         LOCAL LAYER COORDINATE SYSTEM CONVENTION:
C
C                 Z,W    Y,V
C                  ^     /
C                  |    /
C                  |   /
C              I+7-|-----I+6
C              /|  |    /|
C             / |      / |
C           I+4-------I+5|
C           |  |      | -------> X,U
C           |  I+3----|--I+2
C           | /       | /
C           |/        |/
C           I---------I+1
C
C
          NLAYR  = 2
          NELDIM = 3
          NDOFN  = 3
          INTNOD = 4
          NODNUM = 8
          NDV    = NDOFN*NELDIM
          INTDOF = INTNOD*NDOFN
          NDOFL  = NODNUM*NDOFN
          NDOFT  = 36
          MORD   = 6
C
C         ELEMENT INPUT PROPERTIES:
C
C         NVER    - ELEMENT VERSION DESIGNATION
C         IOTYPE  - 0 TO SUPPRESS OUTPUT OF ELEMENT DATA
C                   1 FOR ELEMENT OUTPUT IN LOCAL COORDINATES
C                   2 FOR ELEMENT OUTPUT IN GLOBAL COORDINATES
C         NLAY1   - NUMBER OF PLIES IN ELEMENT LAYER 1
C         NLAY2   - NUMBER OF PLIES IN ELEMENT LAYER 2
C         THK(1)  - THICKNESS OF LAYER 1 (CALCULATED FROM PLY THICKNESS)
C         THK(2)  - THICKNESS OF LAYER 2 (CALCULATED FROM PLY THICKNESS)
C
C         PTHK        - PLY THICKNESS
C         THETA       - PLY ORIENTATION
C         E1,E2,E3    - NORMAL MATERIAL MODULII
C         G12,G23,G31 - SHEAR MODULII
C         V12,V23,V13 - POISSON RATIOS
C
C         PROPERTY LIST FORMAT:
C
C         1)  NVER,IOTYPE
C         2)  NLAY1
C         3)  PHTK,THETA,E1,E2,E3,V12,V23,V13
C         4)  G12,G23,G31
C                 .
C                 . REPEAT FOR EACH PLY IN LAYER 1
C                 .
C         I)  NLAY2
C         J)  PHTK,THETA,E1,E2,E3,V12,V23,V13
C         K)  G12,G23,G31
C                 .
```

```
C                 . REPEAT FOR EACH PLY IN LAYER 2
C                 .
C
C       EXTRACT ELEMENT DATA OFF PROPS ARRAY
C
        NVER     = INT(PROPS(1))
        IOTYPE   = INT(PROPS(2))
        NLAY(1)  = INT(PROPS(9))
        DO I = 1, NLAY(1)
           N         = I*16
           PTHK(I)   = PROPS(N+1)
           THK(1)    = THK(1) + PTHK(I)
           THETA(I)  = PROPS(N+2)
           E1(I)     = PROPS(N+3)
           E2(I)     = PROPS(N+4)
           E3(I)     = PROPS(N+5)
           V12(I)    = PROPS(N+6)
           V23(I)    = PROPS(N+7)
           V13(I)    = PROPS(N+8)
           G12(I)    = PROPS(N+9)
           G23(I)    = PROPS(N+10)
           G31(I)    = PROPS(N+11)
        END DO
        NLAY(2) = INT(PROPS(16*NLAY(1)+17))
        M  = NLAY(1)
        DO I = 1, NLAY(2)
           N            = 24+16*(M+I-1)
           PTHK(I+M)    = PROPS(N+1)
           THK(2)       = THK(2) + PTHK(I+M)
           THETA(I+M)   = PROPS(N+2)
           E1(I+M)      = PROPS(N+3)
           E2(I+M)      = PROPS(N+4)
           E3(I+M)      = PROPS(N+5)
           V12(I+M)     = PROPS(N+6)
           V23(I+M)     = PROPS(N+7)
           V13(I+M)     = PROPS(N+8)
           G12(I+M)     = PROPS(N+9)
           G23(I+M)     = PROPS(N+10)
           G31(I+M)     = PROPS(N+11)
        END DO
C
C       SET GAUSSIAN INTEGRATION ORDER
C
        IF ( NVER .EQ. 11 ) NORD = 2
        IF ( NVER .EQ. 12 ) NORD = 3
C
      END IF
C
      RETURN
      END
C
C
C
      SUBROUTINE BMAT(ND,MORD,NODNUM,NDOFL,AJINV,DXSI,DETA,
     1                 DCEE,BMATS)
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION AJINV(3,3),DXSI(20),DETA(20),DCEE(20),BMATS(6,60)
      DIMENSION TMP1(36,36),HMATS(6,9),TMAT(9,9),UMAT(9,60)
C
      CALL MXINT( HMATS, 6,  9, 0.0D0 )
      CALL MXINT( TMAT,  9,  9, 0.0D0 )
      CALL MXINT( UMAT,  6, 60, 0.0D0 )
C
      IF ( ND .EQ. 2 ) THEN
C
         HMATS(1,1) = 1.0
```

```
          HMATS(2,4)  = 1.0
          HMATS(3,2)  = 1.0
          HMATS(3,3)  = 1.0
C
      ELSE IF ( ND .EQ. 3 ) THEN
C
          HMATS(1,1)  = 1.0
          HMATS(2,5)  = 1.0
          HMATS(3,9)  = 1.0
          HMATS(4,6)  = 1.0
          HMATS(4,8)  = 1.0
          HMATS(5,3)  = 1.0
          HMATS(5,7)  = 1.0
          HMATS(6,2)  = 1.0
          HMATS(6,4)  = 1.0
C
      END IF
C
      DO I = 1, ND
         DO J = 1, ND
            IF ( ND .EQ. 2 ) THEN
               TMAT(I,J)                = AJINV(I,J)
               TMAT(I+ND,J+ND)          = AJINV(I,J)
            ELSE IF ( ND .EQ. 3 ) THEN
               TMAT(I,J)                = AJINV(I,J)
               TMAT(I+ND,J+ND)          = AJINV(I,J)
               TMAT(I+2*ND,J+2*ND)      = AJINV(I,J)
            END IF
         END DO
      END DO
C
C     COMPUTE THE TRANSFORMATION MATRIX UMAT
C
      IF ( ND .EQ. 2 ) THEN
         DO J = 1, NODNUM
            UMAT(1,2*(J-1)+1)  = DXSI(J)
            UMAT(2,2*(J-1)+1)  = DETA(J)
            UMAT(3,2*(J-1)+2)  = DXSI(J)
            UMAT(4,2*(J-1)+2)  = DETA(J)
         END DO
      ELSE IF ( ND .EQ. 3 ) THEN
         DO J = 1, NODNUM
            UMAT(1,3*(J-1)+1)  = DXSI(J)
            UMAT(2,3*(J-1)+1)  = DETA(J)
            UMAT(3,3*(J-1)+1)  = DCEE(J)
            UMAT(4,3*(J-1)+2)  = DXSI(J)
            UMAT(5,3*(J-1)+2)  = DETA(J)
            UMAT(6,3*(J-1)+2)  = DCEE(J)
            UMAT(7,3*(J-1)+3)  = DXSI(J)
            UMAT(8,3*(J-1)+3)  = DETA(J)
            UMAT(9,3*(J-1)+3)  = DCEE(J)
         END DO
      END IF
C
      NDV = ND**2
      CALL MXMUL(TMAT,UMAT,TMP1,9,9,36,NDV,NDV,NDOFL)
      CALL MXMUL(HMATS,TMP1,BMATS,6,36,6,MORD,NDV,NDOFL)
C
      RETURN
      END
C
C
C
      SUBROUTINE TRANS( COORDS,CTRN,STRN,ETRN,TRI,JTYPE,MCRD,NNODE )

      IMPLICIT REAL*8 (A-H,O-Z)
C
C     CALCULATE TRANSFORMATION MATRICES FOR CONVERTING QUANTITIES
```

```
C     BETWEEN ELEMENT AND GLOBAL COORDINATE SYSTEMS
C
      DIMENSION X(20),      Y(20),     Z(20),     EO(3,3),
     1          EP(3,3),    TRI(3,3),  STRN(6,6),
     2          ETRN(6,6),  CTRN(36,36), COORDS(MCRD,NNODE)
C
      CALL MXINT ( CTRN, 36, 36, 0.0D0 )
      CALL MXINT ( STRN,  6,  6, 0.0D0 )
      CALL MXINT ( ETRN,  6,  6, 0.0D0 )
C
      DO I = 1, NNODE
         X(I) = COORDS(1,I)
         Y(I) = COORDS(2,I)
         Z(I) = COORDS(3,I)
      END DO
C
C     UNIT VECTORS IN GLOBAL SYSTEM
C
      EO(1,1) = 1.0
      EO(1,2) = 0.0
      EO(1,3) = 0.0
      EO(2,1) = 0.0
      EO(2,2) = 1.0
      EO(2,3) = 0.0
      EO(3,1) = 0.0
      EO(3,2) = 0.0
      EO(3,3) = 1.0
C
C     DETERMINE ELEMENT COORDINATE VECTORS
C
      IF ( JTYPE .EQ. 1 .OR. JTYPE .EQ. 2 .OR.
     1     JTYPE .EQ. 4 ) THEN
C
         AL = SQRT( (X(2)-X(1))**2+(Y(2)-Y(1))**2 )
         EP(1,1) = (X(2)-X(1))/AL
         EP(1,2) = (Y(2)-Y(1))/AL
         AL = SQRT( (X(3)-X(1))**2+(Y(3)-Y(1))**2 )
         EP(2,1) = (X(3)-X(1))/AL
         EP(2,2) = (Y(3)-Y(1))/AL
C
         NDIM   = 2
C
      ELSE IF ( JTYPE .EQ. 3 ) THEN
C
         AL = SQRT( (X(3)-X(1))**2+(Y(3)-Y(1))**2 )
         EP(1,1) = (X(3)-X(1))/AL
         EP(1,2) = (Y(3)-Y(1))/AL
         AL = SQRT( (X(6)-X(1))**2+(Y(6)-Y(1))**2 )
         EP(2,1) = (X(6)-X(1))/AL
         EP(2,2) = (Y(6)-Y(1))/AL
C
         NDIM   = 2
C
      ELSE IF ( JTYPE .EQ. 5 ) THEN
C
         AL = SQRT( (X(2)-X(1))**2+(Y(2)-Y(1))**2+(Z(2)-Z(1))**2 )
         EP(1,1) = (X(2)-X(1))/AL
         EP(1,2) = (Y(2)-Y(1))/AL
         EP(1,3) = (Z(2)-Z(1))/AL
         AL = SQRT( (X(4)-X(1))**2+(Y(4)-Y(1))**2+(Z(4)-Z(1))**2 )
         EP(2,1) = (X(4)-X(1))/AL
         EP(2,2) = (Y(4)-Y(1))/AL
         EP(2,3) = (Z(4)-Z(1))/AL
         AL = SQRT( (X(5)-X(1))**2+(Y(5)-Y(1))**2+(Z(5)-Z(1))**2 )
         EP(3,1) = (X(5)-X(1))/AL
         EP(3,2) = (Y(5)-Y(1))/AL
         EP(3,3) = (Z(5)-Z(1))/AL
C
```

```
            NDIM = 3
C
         END IF
C
C
C        CONSTRUCT COORDINATE TRANSFORMATION MATRIX
C
C                                                   T
C        {X'} = [TRI]{X};     {X} = [TRI] {X'}
C
C
         DO I = 1, NDIM
            DO J = 1, NDIM
               TRI(I,J) = 0.0
               DO K = 1, NDIM
                  TRI(I,J) = TRI(I,J) + EP(I,K)*EO(J,K)
               END DO
            END DO
         END DO
C
         DO I = 1, NNODE
            NF = NDIM*(I-1)
            DO J = 1, NDIM
               DO K = 1, NDIM
                  CTRN(NF+J,NF+K) = TRI(J,K)
               END DO
            END DO
         END DO
C
C        CONSTRUCT STRESS AND STRAIN TRANSFORMATION MATRICES
C        TO CONVERT BETWEEN ELEMENT COORDINATE SYSTEM AND
C        GLOBAL SYSTEM
C
C        [STRN] = STRESS TRANSFORMATION
C        [ETRN] = STRAIN TRANSFORMATION
C
C        {E'} = [ETRN]{E};     {S'} = [STRN]{S}
C
C                        T                    T
C        {E}  = [STRN]{E'};  {S}   = [ETRN]{S'}
C
         IF ( NDIM .EQ. 2 ) THEN
C
C           [SX,SY,TXY]
C
C           STRESS TRANSFORMATION MATRIX, [STRN]:
C
            STRN(1,1) = TRI(1,1)**2
            STRN(1,2) = TRI(2,1)**2
            STRN(1,3) = 2*TRI(1,1)*TRI(2,1)
            STRN(2,1) = TRI(1,2)**2
            STRN(2,2) = TRI(2,2)**2
            STRN(2,3) = 2*TRI(1,2)*TRI(2,2)
            STRN(3,1) = TRI(1,1)*TRI(1,2)
            STRN(3,2) = TRI(2,1)*TRI(2,2)
            STRN(3,3) = TRI(1,1)*TRI(2,2)+TRI(2,1)*TRI(1,2)
C
         ELSE IF ( NDIM .EQ. 3 ) THEN
C
C           [SX,SY,SZ,TYZ,TXZ,TXY]
C
C           STRESS TRANSFORMATION MATRIX, [STRN]:
C
            STRN(1,1) =  TRI(1,1)**2
            STRN(1,2) =  TRI(1,2)**2
            STRN(1,3) =  TRI(1,3)**2
            STRN(1,4) =  2*TRI(1,2)*TRI(1,3)
            STRN(1,5) =  2*TRI(1,3)*TRI(1,1)
```

```
         STRN(1,6) =  2*TRI(1,1)*TRI(1,2)
         STRN(2,1) =  TRI(2,1)**2
         STRN(2,2) =  TRI(2,2)**2
         STRN(2,3) =  TRI(2,3)**2
         STRN(2,4) =  2*TRI(2,2)*TRI(2,3)
         STRN(2,5) =  2*TRI(2,3)*TRI(2,1)
         STRN(2,6) =  2*TRI(2,1)*TRI(2,2)
         STRN(3,1) =  TRI(3,1)**2
         STRN(3,2) =  TRI(3,2)**2
         STRN(3,3) =  TRI(3,3)**2
         STRN(3,4) =  2*TRI(3,2)*TRI(3,3)
         STRN(3,5) =  2*TRI(3,3)*TRI(3,1)
         STRN(3,6) =  2*TRI(3,1)*TRI(3,2)
         STRN(4,1) =  TRI(2,1)*TRI(3,1)
         STRN(4,2) =  TRI(2,2)*TRI(3,2)
         STRN(4,3) =  TRI(2,3)*TRI(3,3)
         STRN(4,4) =  TRI(2,2)*TRI(3,3)  + TRI(3,2)*TRI(2,3)
         STRN(4,5) =  TRI(2,3)*TRI(3,1)  + TRI(3,3)*TRI(2,1)
         STRN(4,6) =  TRI(2,1)*TRI(3,2)  + TRI(3,1)*TRI(2,2)
         STRN(5,1) =  TRI(3,1)*TRI(1,1)
         STRN(5,2) =  TRI(3,2)*TRI(1,2)
         STRN(5,3) =  TRI(3,3)*TRI(1,3)
         STRN(5,4) =  TRI(3,2)*TRI(1,3)  + TRI(1,2)*TRI(3,3)
         STRN(5,5) =  TRI(3,3)*TRI(1,1)  + TRI(1,3)*TRI(3,1)
         STRN(5,6) =  TRI(3,1)*TRI(1,2)  + TRI(1,1)*TRI(3,2)
         STRN(6,1) =  TRI(1,1)*TRI(2,1)
         STRN(6,2) =  TRI(1,2)*TRI(2,2)
         STRN(6,3) =  TRI(1,3)*TRI(2,3)
         STRN(6,4) =  TRI(1,2)*TRI(2,3)  + TRI(2,2)*TRI(1,3)
         STRN(6,5) =  TRI(1,3)*TRI(2,1)  + TRI(2,3)*TRI(1,1)
         STRN(6,6) =  TRI(1,1)*TRI(2,2)  + TRI(2,1)*TRI(1,2)
C
      END IF
C
C     STRAIN TRANSFORMATION MATRIX, [ETRN]:
C
      DO I = 1, NDIM
         DO J = 1, NDIM
            ETRN(I,J)           = STRN(I,J)
            ETRN(I,J+NDIM)      = STRN(I,J+NDIM)/2.0
            ETRN(I+NDIM,J)      = STRN(I+NDIM,J)/0.5
            ETRN(I+NDIM,J+NDIM) = STRN(I+NDIM,J+NDIM)
         END DO
      END DO
C
      RETURN
      END
C
C
C
      SUBROUTINE MATPROP(PTHK,THETA,E1,E2,E3,G12,G23,G31,V12,V23,V13,
     1                   SMAT,NELDIM,IPLANE,MORD,K,NLAY    )
C
C     COMPUTATION OF ELEMENT MATERIAL PROPERTY MATRICES
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION E1(100),E2(100),E3(100),V12(100),V23(100),V13(100),
     1          G12(100),G23(100),G31(100),V21(100),V32(100),V31(100),
     2          THETA(100),PTHK(100),DMAT(6,6),SMAT(6,6),QBAR(6,6),
     3          CL(6,6),INDEX(6),NLAY(3)
C
      PI  = ACOS(-1.0D0)
      TLM = 0.0
      CALL MXINT( DMAT, 6, 6, 0.0D0 )
      CALL MXINT( QBAR, 6, 6, 0.0D0 )
C
      NOFF = 1
```

```
      DO I = 1, K-1
         NOFF = NOFF + NLAY(I)
      END DO
      NL = NLAY(K) + NOFF - 1
C
      IF ( NELDIM .EQ. 2 ) THEN
C
C        [EX,EY,GXY]
C
         IF ( IPLANE .EQ. 0 ) THEN
C
C           PLANE STRESS
C
            DO I = NOFF, NL
C
              PHI = THETA(I) * PI / 180.0
              C   = COS(PHI)
              S   = SIN(PHI)
              C2  = C*C
              S2  = S*S
              C3  = C2*C
              S3  = S2*S
              C4  = C2*C2
              S4  = S2*S2
C
              TLM = TLM + PTHK(I)
              V21(I)  = V12(I)*E2(I)/E1(I)
              Q11 = E1(I)/(1.0-V12(I)*V21(I))
              Q12 = V21(I)*Q11
              Q22 = E2(I)/(1.0-V12(I)*V21(I))
              Q66 = G12(I)
              QBAR(1,1) =  Q11*C4+2.*(Q12+2.*Q66)*C2*S2+Q22*S4
              QBAR(1,2) = (Q11+Q22-4.*Q66)*S2*C2+Q12*(C4+S4)
              QBAR(1,3) = (Q11-Q12-2.*Q66)*S*C3+(Q12-Q22+2.*Q66)*S3*C
              QBAR(2,1) =  QBAR(1,2)
              QBAR(2,2) =  Q11*S4+2.*(Q12+2.*Q66)*S2*C2+Q22*C4
              QBAR(2,3) = (Q11-Q12-2.*Q66)*S3*C+(Q12-Q22+2.*Q66)*S*C3
              QBAR(3,1) =  QBAR(1,3)
              QBAR(3,2) =  QBAR(2,3)
              QBAR(3,3) = (Q11+Q22-2.*Q12-2.*Q66)*S2*C2+Q66*(S4+C4)
C
              DO L = 1, 3
                DO J = 1, 3
                  DMAT(L,J) = DMAT(L,J) + QBAR(L,J) * PTHK(I)
                END DO
              END DO
C
            END DO
C
            DO L = 1, 3
              DO J = 1, 3
                DMAT(L,J) = DMAT(L,J)/TLM
              END DO
            END DO
C
         ELSE
C
C           PLANE STRAIN
C
            DO I = NOFF, NL
C
              PHI = THETA(I) * PI / 180.0
              C   = COS(PHI)
              S   = SIN(PHI)
              C2  = C*C
              S2  = S*S
              C3  = C2*C
              S3  = S2*S
```

```
            C4   = C2*C2
            S4   = S2*S2
C
            TLM = TLM + PTHK(I)
            S11 = 1./E1(I)
            S12 = -V12(I)/E1(I)
            S13 = -V13(I)/E1(I)
            S22 = 1./E2(I)
            S23 = -V23(I)/E2(I)
            S33 = 1./E3(I)
            S66 = 1./G12(I)
            R11 = S11 - S13**2/S33
            R12 = S12 - S13*S23/S33
            R22 = S22 - S23**2/S33
            R33 = S66
            Q11 = R22/(R11*R22-R12**2)
            Q12 = -R12/(R11*R22-R12**2)
            Q22 = R11/(R11*R22-R12**2)
            Q66 = 1./R33
            QBAR(1,1) =  Q11*C4+2.*(Q12+2.*Q66)*C2*S2+Q22*S4
            QBAR(1,2) = (Q11+Q22-4.*Q66)*S2*C2+Q12*(C4+S4)
            QBAR(1,3) = (Q11-Q12-2.*Q66)*S*C3+(Q12-Q22+2.*Q66)*S3*C
            QBAR(2,1) =  QBAR(1,2)
            QBAR(2,2) =  Q11*S4+2.*(Q12+2.*Q66)*S2*C2+Q22*C4
            QBAR(2,3) = (Q11-Q12-2.*Q66)*S3*C+(Q12-Q22+2.*Q66)*S*C3
            QBAR(3,1) =  QBAR(1,3)
            QBAR(3,2) =  QBAR(2,3)
            QBAR(3,3) = (Q11+Q22-2.*Q12-2.*Q66)*S2*C2+Q66*(S4+C4)
C
            DO L = 1, 3
              DO J = 1, 3
                DMAT(L,J) = DMAT(L,J) + QBAR(L,J) * PTHK(I)
              END DO
            END DO
C
          END DO
C
          DO L = 1, 3
            DO J = 1, 3
              DMAT(L,J) = DMAT(L,J)/TLM
            END DO
          END DO
C
        END IF
C
      ELSE IF ( NELDIM .EQ. 3 ) THEN
C
C       [EX,EY,EZ,GYZ,GZX,GXY]
C
        DO I = NOFF, NL

          V21(I) = V12(I) * (E2(I)/E1(I))
          V32(I) = V23(I) * (E3(I)/E2(I))
          V31(I) = V13(I) * (E3(I)/E1(I))
          DEL = (1.0-V12(I)*V21(I)-V23(I)*V32(I)-V13(I)*V31(I)-
     1          2.*V21(I)*V32(I)*V13(I))/(E1(I)*E2(I)*E3(I))
C
          CL(1,1) = ( 1.0000 - V23(I)*V32(I) ) / ( E2(I)*E3(I)*DEL )
          CL(1,2) = ( V12(I) + V32(I)*V13(I) ) / ( E1(I)*E3(I)*DEL )
          CL(1,3) = ( V13(I) + V12(I)*V23(I) ) / ( E1(I)*E2(I)*DEL )
          CL(2,2) = ( 1.0000 - V13(I)*V31(I) ) / ( E1(I)*E3(I)*DEL )
          CL(2,3) = ( V23(I) + V21(I)*V13(I) ) / ( E1(I)*E2(I)*DEL )
          CL(3,3) = ( 1.0000 - V12(I)*V21(I) ) / ( E1(I)*E2(I)*DEL )
          CL(2,1) = CL(1,2)
          CL(3,1) = CL(1,3)
          CL(3,2) = CL(2,3)
          CL(4,4) = G23(I)
          CL(5,5) = G31(I)
```

```
          CL(6,6) = G12(I)
C
C         COMPUTE THE KTH REDUCED C MATRIX (PLATE COORDINATES)
C
          C0 = COS(PHI)
          C2 = C0*C0
          C3 = C0*C0*C0
          C4 = C2*C2
          S0 = SIN(PHI)
          S2 = S0*S0
          S3 = S0*S0*S0
          S4 = S2*S2
          C2T = COS(2.*PHI)
C
          QBAR(1,1) = CL(1,1)*C4 + CL(2,2)*S4 + 2*CL(1,2)*S2*C2 +
     1                4*CL(6,6)*C2*S2
          QBAR(2,2) = CL(1,1)*S4 + CL(2,2)*C4 + 2*(CL(1,2) +
     1                2*CL(6,6))*S2*C2
          QBAR(3,3) = CL(3,3)
          QBAR(4,4) = CL(4,4)*C2 + CL(5,5)*S2
          QBAR(5,5) = CL(5,5)*C2 + CL(4,4)*S2
          QBAR(6,6) = CL(6,6) + (CL(1,1) + CL(2,2) - 2*CL(1,2) -
     1                4*CL(6,6))*S2*C2
          QBAR(1,2) = CL(1,2) + (CL(1,1) + CL(2,2) - 2*CL(1,2) -
     1                4*CL(6,6))*S2*C2
          QBAR(2,1) = QBAR(1,2)
          QBAR(1,3) = CL(1,3)*C2 + CL(2,3)*S2
          QBAR(3,1) = QBAR(1,3)
          QBAR(2,3) = CL(1,3)*S2 + CL(2,3)*C2
          QBAR(3,2) = QBAR(2,3)
          QBAR(1,6) = C0*S0*(CL(1,1)*C2 - CL(2,2)*S2 - C2T*(CL(1,2) +
     1                2*CL(6,6)))
          QBAR(6,1) = QBAR(1,6)
          QBAR(2,6) = S0*C0*(CL(1,1)*S2 - CL(2,2)*C2 + C2T*(CL(1,2) +
     1                2*CL(6,6)))
          QBAR(6,2) = QBAR(2,6)
          QBAR(3,6) = S0*C0*(CL(1,3) - CL(2,3))
          QBAR(6,3) = QBAR(3,6)
          QBAR(4,5) = S0*C0*(CL(5,5) - CL(4,4))
          QBAR(5,4) = QBAR(4,5)
C
          TLM = TLM + PTHK(I)
C
          DO L = 1, 6
            DO J = 1, 6
              DMAT(L,J) = DMAT(L,J) + QBAR(L,J) * PTHK(I)
            END DO
          END DO
C
        END DO
C
        DO L = 1, 6
          DO J = 1, 6
            DMAT(L,J) = DMAT(L,J)/TLM
          END DO
        END DO
C
      END IF
C
C                            -1
C     COMPUTE SMAT = DMAT
C
      NDIM = 6
      CALL INVERS(DMAT,SMAT,INDEX,NDIM,MORD)
C
      RETURN
      END
C
```

```
C
C
      SUBROUTINE SHAPE( NODNUM,NELDIM,XSI,ETA,CEE,DXSI,DETA,DCEE )
C
C     COMPUTATION OF SHAPE FUNCTIONS AND THEIR DERIVATIVES
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION SFUNC(20),DXSI(20),DETA(20),DCEE(20)
C
      IF ( NELDIM .EQ. 2 ) THEN
C
         IF ( NODNUM .EQ. 4 ) THEN
C
            SFUNC(1) = 0.25*(1.-XSI)*(1.-ETA)
            SFUNC(2) = 0.25*(1.+XSI)*(1.-ETA)
            SFUNC(3) = 0.25*(1.-XSI)*(1.+ETA)
            SFUNC(4) = 0.25*(1.+XSI)*(1.+ETA)
C
            DXSI(1) = -0.25*(1.-ETA)
            DXSI(2) =  0.25*(1.-ETA)
            DXSI(3) = -0.25*(1.+ETA)
            DXSI(4) =  0.25*(1.+ETA)
C
            DETA(1) = -0.25*(1.-XSI)
            DETA(2) = -0.25*(1.+XSI)
            DETA(3) =  0.25*(1.-XSI)
            DETA(4) =  0.25*(1.+XSI)
C
         ELSE IF ( NODNUM .EQ. 6 ) THEN
C
            SFUNC(1) = 0.25*(1.-XSI)*(1.-ETA) -
     1                 0.25*(1.-XSI)*(1.-ETA**2)
            SFUNC(2) = 0.25*(1.+XSI)*(1.-ETA) -
     1                 0.25*(1.+XSI)*(1.-ETA**2)
            SFUNC(3) = 0.50*(1.-XSI)*(1.-ETA**2)
            SFUNC(4) = 0.50*(1.+XSI)*(1.-ETA**2)
            SFUNC(5) = 0.25*(1.-XSI)*(1.+ETA) -
     1                 0.25*(1.-XSI)*(1.-ETA**2)
            SFUNC(6) = 0.25*(1.+XSI)*(1.+ETA) -
     1                 0.25*(1.+XSI)*(1.-ETA**2)
C
            DXSI(1) = -0.25*(1.-ETA) + 0.25*(1.-ETA**2)
            DXSI(2) =  0.25*(1.-ETA) - 0.25*(1.-ETA**2)
            DXSI(3) = -0.50*(1.-ETA**2)
            DXSI(4) =  0.50*(1.-ETA**2)
            DXSI(5) = -0.25*(1.+ETA) + 0.25*(1.-ETA**2)
            DXSI(6) =  0.25*(1.+ETA) - 0.25*(1.-ETA**2)
C
            DETA(1) = -0.25*(1.-XSI) + 0.50*ETA*(1.-XSI)
            DETA(2) = -0.25*(1.+XSI) + 0.50*ETA*(1.+XSI)
            DETA(3) = -ETA*(1.-XSI)
            DETA(4) = -ETA*(1.+XSI)
            DETA(5) =  0.25*(1.-XSI) + 0.50*ETA*(1.-XSI)
            DETA(6) =  0.25*(1.+XSI) + 0.50*ETA*(1.+XSI)
C
         ELSE IF ( NODNUM .EQ. 8 ) THEN
C
            SFUNC(1) = 0.25*(1.-XSI)*(1.-ETA) -
     1                 0.25*(1.-XSI**2)*(1.-ETA) -
     2                 0.25*(1.-XSI)*(1.-ETA**2)
            SFUNC(2) = 0.50*(1.-XSI**2)*(1.-ETA)
            SFUNC(3) = 0.25*(1.+XSI)*(1.-ETA) -
     1                 0.25*(1.-XSI**2)*(1.-ETA) -
     2                 0.25*(1.+XSI)*(1.-ETA**2)
            SFUNC(4) = 0.50*(1.-XSI)*(1.-ETA**2)
            SFUNC(5) = 0.50*(1.+XSI)*(1.-ETA**2)
            SFUNC(6) = 0.25*(1.-XSI)*(1.+ETA) -
```

```
     1                0.25*(1.-XSI)*(1.-ETA**2) -
     2                0.25*(1.-XSI**2)*(1.+ETA)
           SFUNC(7) = 0.50*(1.-XSI**2)*(1.+ETA)
           SFUNC(8) = 0.25*(1.+XSI)*(1.+ETA) -
     1                0.25*(1.-XSI**2)*(1.+ETA) -
     2                0.25*(1.+XSI)*(1.-ETA**2)
C
           DXSI(1) = -0.25*(1.-ETA) + 0.5*XSI*(1.-ETA) +
     1                0.25*(1.-ETA**2)
           DXSI(2) = -XSI*(1.-ETA)
           DXSI(3) =  0.25*(1.-ETA) + 0.5*XSI*(1.-ETA) -
     1                0.25*(1.-ETA**2)
           DXSI(4) = -0.50*(1.-ETA**2)
           DXSI(5) =  0.50*(1.-ETA**2)
           DXSI(6) = -0.25*(1.+ETA) + 0.25*(1.-ETA**2) +
     1                0.50*XSI*(1.+ETA)
           DXSI(7) = -XSI*(1.+ETA)
           DXSI(8) =  0.25*(1.+ETA) + 0.5*XSI*(1.+ETA) -
     1                0.25*(1.-ETA**2)
C
           DETA(1) = -0.25*(1.-XSI) + 0.5*ETA*(1.-XSI) +
     1                0.25*(1.-XSI**2)
           DETA(2) = -0.50*(1.-XSI**2)
           DETA(3) = -0.25*(1.+XSI) + 0.5*ETA*(1.+XSI) +
     1                0.25*(1.-XSI**2)
           DETA(4) = -ETA*(1.-XSI)
           DETA(5) = -ETA*(1.+XSI)
           DETA(6) =  0.25*(1.-XSI) - 0.25*(1.-XSI**2) +
     1                0.50*ETA*(1.-XSI)
           DETA(7) =  0.50*(1.-XSI**2)
           DETA(8) =  0.25*(1.+XSI) + 0.5*ETA*(1.+XSI) -
     1                0.25*(1.-XSI**2)
C
        END IF
C
      ELSE IF ( NELDIM .EQ. 3 ) THEN
C
        SFUNC(1) = 0.125*(1.-XSI)*(1.-ETA)*(1.-CEE)
        SFUNC(2) = 0.125*(1.+XSI)*(1.-ETA)*(1.-CEE)
        SFUNC(3) = 0.125*(1.+XSI)*(1.+ETA)*(1.-CEE)
        SFUNC(4) = 0.125*(1.-XSI)*(1.+ETA)*(1.-CEE)
        SFUNC(5) = 0.125*(1.-XSI)*(1.-ETA)*(1.+CEE)
        SFUNC(6) = 0.125*(1.+XSI)*(1.-ETA)*(1.+CEE)
        SFUNC(7) = 0.125*(1.+XSI)*(1.+ETA)*(1.+CEE)
        SFUNC(8) = 0.125*(1.-XSI)*(1.+ETA)*(1.+CEE)
C
        DXSI(1) = -0.125*(1.-ETA)*(1.-CEE)
        DXSI(2) =  0.125*(1.-ETA)*(1.-CEE)
        DXSI(3) =  0.125*(1.+ETA)*(1.-CEE)
        DXSI(4) = -0.125*(1.+ETA)*(1.-CEE)
        DXSI(5) = -0.125*(1.-ETA)*(1.+CEE)
        DXSI(6) =  0.125*(1.-ETA)*(1.+CEE)
        DXSI(7) =  0.125*(1.+ETA)*(1.+CEE)
        DXSI(8) = -0.125*(1.+ETA)*(1.+CEE)
C
        DETA(1) = -0.125*(1.-XSI)*(1.-CEE)
        DETA(2) = -0.125*(1.+XSI)*(1.-CEE)
        DETA(3) =  0.125*(1.+XSI)*(1.-CEE)
        DETA(4) =  0.125*(1.-XSI)*(1.-CEE)
        DETA(5) = -0.125*(1.-XSI)*(1.+CEE)
        DETA(6) = -0.125*(1.+XSI)*(1.+CEE)
        DETA(7) =  0.125*(1.+XSI)*(1.+CEE)
        DETA(8) =  0.125*(1.-XSI)*(1.+CEE)
C
        DCEE(1) = -0.125*(1.-XSI)*(1.-ETA)
        DCEE(2) = -0.125*(1.+XSI)*(1.-ETA)
        DCEE(3) = -0.125*(1.+XSI)*(1.+ETA)
        DCEE(4) = -0.125*(1.-XSI)*(1.+ETA)
```

```
         DCEE(5) =  0.125*(1.-XSI)*(1.-ETA)
         DCEE(6) =  0.125*(1.+XSI)*(1.-ETA)
         DCEE(7) =  0.125*(1.+XSI)*(1.+ETA)
         DCEE(8) =  0.125*(1.-XSI)*(1.+ETA)
C
      END IF
C
      RETURN
      END
C
C
C
      SUBROUTINE JACOB( NODNUM,NELDIM,X,Y,Z,DXSI,DETA,DCEE,
     1                  AJINV,DETJ                              )
C
C     COMPUTE JACOBIAN MATRIX, ITS DETERMINANT AND INVERSE
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION X(20),Y(20),Z(20),DXSI(20),DETA(20),DCEE(20),
     1          AJMT(3,3),AJINV(3,3)
C
      CALL MXINT( AJMT, 3, 3, 0.0D0 )
C
      IF ( NELDIM .EQ. 2 ) THEN
C
         DO I = 1, NODNUM
            AJMT(1,1) = AJMT(1,1)  + DXSI(I)*X(I)
            AJMT(1,2) = AJMT(1,2)  + DXSI(I)*Y(I)
            AJMT(2,1) = AJMT(2,1)  + DETA(I)*X(I)
            AJMT(2,2) = AJMT(2,2)  + DETA(I)*Y(I)
         END DO
C
         DETJ = AJMT(1,1)*AJMT(2,2)-AJMT(2,1)*AJMT(1,2)
C
C        COMPUTE INVERSE OF JACOBIAN
C
         AJINV(1,1) =  AJMT(2,2)/DETJ
         AJINV(2,1) = -AJMT(2,1)/DETJ
         AJINV(1,2) = -AJMT(1,2)/DETJ
         AJINV(2,2) =  AJMT(1,1)/DETJ
C
      ELSE IF ( NELDIM .EQ. 3 ) THEN
C
         DO I = 1, NODNUM
C
            AJMT(1,1) = AJMT(1,1)  + DXSI(I)*X(I)
            AJMT(1,2) = AJMT(1,2)  + DXSI(I)*Y(I)
            AJMT(1,3) = AJMT(1,3)  + DXSI(I)*Z(I)
            AJMT(2,1) = AJMT(2,1)  + DETA(I)*X(I)
            AJMT(2,2) = AJMT(2,2)  + DETA(I)*Y(I)
            AJMT(2,3) = AJMT(2,3)  + DETA(I)*Z(I)
            AJMT(3,1) = AJMT(3,1)  + DCEE(I)*X(I)
            AJMT(3,2) = AJMT(3,2)  + DCEE(I)*Y(I)
            AJMT(3,3) = AJMT(3,3)  + DCEE(I)*Z(I)
        END DO
C
        DETJ = AJMT(1,1)*(AJMT(2,2)*AJMT(3,3)-AJMT(2,3)*AJMT(3,2))-
     1             AJMT(1,2)*(AJMT(2,1)*AJMT(3,3)-AJMT(2,3)*AJMT(3,1))+
     2             AJMT(1,3)*(AJMT(2,1)*AJMT(3,2)-AJMT(2,2)*AJMT(3,1))
C
C        COMPUTE INVERSE OF JACOBIAN
C
         AJINV(1,1) =   (AJMT(2,2)*AJMT(3,3)-AJMT(2,3)*AJMT(3,2))/DETJ
         AJINV(2,1) = -(AJMT(2,1)*AJMT(3,3)-AJMT(2,3)*AJMT(3,1))/DETJ
         AJINV(3,1) =   (AJMT(2,1)*AJMT(3,2)-AJMT(2,2)*AJMT(3,1))/DETJ
         AJINV(1,2) = -(AJMT(1,2)*AJMT(3,3)-AJMT(1,3)*AJMT(3,2))/DETJ
         AJINV(2,2) =   (AJMT(1,1)*AJMT(3,3)-AJMT(1,3)*AJMT(3,1))/DETJ
```

```
            AJINV(3,2) = -(AJMT(1,1)*AJMT(3,2)-AJMT(1,2)*AJMT(3,1))/DETJ
            AJINV(1,3) =  (AJMT(1,2)*AJMT(2,3)-AJMT(1,3)*AJMT(2,2))/DETJ
            AJINV(2,3) = -(AJMT(1,1)*AJMT(2,3)-AJMT(1,3)*AJMT(2,1))/DETJ
            AJINV(3,3) =  (AJMT(1,1)*AJMT(2,2)-AJMT(1,2)*AJMT(2,1))/DETJ
C
      END IF
C
      RETURN
      END
C
C
C
      SUBROUTINE ASTRSS(XSI,ETA,CEE,JTYPE,LAYER,NELDIM,NODNUM,
     1                  PMAT,THK,NBVAL,XE,YE,ZE,NSIDE,NVER)
C
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
C
      DIMENSION PMAT(6,100),XE(20),YE(20),ZE(20),THK(3)
C
      IF ( NELDIM .EQ. 2 ) THEN
C
         IF ( NODNUM .EQ. 4 ) THEN
C
            AC = (-XE(1)+XE(2)-XE(3)+XE(4))/4.0
            BC = (-YE(1)-YE(2)+YE(3)+YE(4))/4.0
C
            X = AC*XSI
            Y = BC*ETA
            A = (XE(2)-XE(1))/2.0
C
         ELSE IF ( NODNUM .EQ. 6 ) THEN
C
            AC = (-XE(3)+XE(4))/2.0
            BC = (-YE(1)-YE(2)+YE(5)+YE(6))/4.0
C
            X = AC*XSI
            Y = BC*ETA
C
         ELSE IF ( NODNUM .EQ. 8 ) THEN
C
            AC =  (-XE(4)+XE(5))/2.0
            BC =  (-YE(2)+YE(7))/2.0
C
            X = AC*XSI
            Y = BC*ETA
            A = (XE(2)-XE(1))/2.0
C
         END IF
C
      ELSE IF ( NELDIM .EQ. 3 ) THEN
C
         IF ( NODNUM .EQ. 8 ) THEN
C
           AC = (-XE(1)+XE(2)+XE(3)-XE(4)-XE(5)+XE(6)+XE(7)-XE(8))/8.0
           BC = (-YE(1)-YE(2)+YE(3)+YE(4)-YE(5)-YE(6)+YE(7)+YE(8))/8.0
           CC = (-ZE(1)-ZE(2)-ZE(3)-ZE(4)+ZE(5)+ZE(6)+ZE(7)+ZE(8))/8.0
C
           X = AC*XSI
           Y = BC*ETA
           Z = CC*CEE
C
         END IF
C
      END IF
C
      CALL MXINT(PMAT, 6, 100, 0.0D0)
C
```

```
      IF ( JTYPE .EQ. 1 ) THEN
C
C        2-D 2-LAYERED 6-NODE HYBRID ELEMENT.
C
C        OPTIONAL ZERO TRACTION CONDITIONS MAY BE
C        SPECIFIED ON DESIGNATED ELEMENT SIDES.
C
C
C             Y
C             ^
C             |
C             |
C             5-----------------6
C             |                 |
C             |F1               |F4
C             |                 |
C             |                 |
C             3---------------- 4
C             |                 |
C             |F2               |F3
C             |                 |
C             |                 |
C             1-----------------2 -------->X
C
C
C
         T1 = THK(1)/2.
         T2 = THK(2)/2.
C
         IF ( NVER .EQ. 11 ) THEN
C
C           LINEAR STRESS FIELD
C
            NBVAL = 10
C
            IF ( LAYER .EQ. 1 ) THEN
C
               PMAT(1,1)  =  1.0
               PMAT(1,2)  =  X
               PMAT(1,3)  =  Y
               PMAT(2,4)  =  1.0
               PMAT(2,5)  =  X
               PMAT(2,7)  = -Y
               PMAT(3,6)  =  1.0
               PMAT(3,7)  =  X
               PMAT(3,2)  = -Y
C
            ELSE IF ( LAYER .EQ. 2 ) THEN
C
               PMAT(1,8)  =  1.0
               PMAT(1,9)  =  X
               PMAT(1,10) =  Y
               PMAT(2,4)  =  1.0
               PMAT(2,5)  =  X
               PMAT(2,7)  = -(T1+T2+Y)
               PMAT(3,6)  =  1.0
               PMAT(3,2)  = -T1
               PMAT(3,7)  =  X
               PMAT(3,9)  = -(T2+Y)
C
            END IF
C
         ELSE IF ( NVER .EQ. 12 ) THEN
C
C           QUADRATIC STRESS FIELD
C
            NBVAL = 18
C
```

```
          IF ( LAYER .EQ. 1 ) THEN
C
             PMAT(1,1)   =  1.0
             PMAT(1,2)   = -X
             PMAT(1,3)   =  Y
             PMAT(1,4)   = -2*X*Y
             PMAT(1,5)   = -0.5*X**2
             PMAT(1,6)   =  Y**2
             PMAT(2,7)   =  1.0
             PMAT(2,8)   =  2*(T1+T2)*X - 2*X*Y
             PMAT(2,9)   =  X
             PMAT(2,5)   =  T1*Y - 0.5*Y**2
             PMAT(2,10)  = -Y
             PMAT(2,11)  =  T2*Y
             PMAT(2,12)  =  X**2
             PMAT(3,13)  =  1.0
             PMAT(3,5)   = -T1*X + X*Y
             PMAT(3,10)  =  X
             PMAT(3,11)  = -T2*X
             PMAT(3,2)   =  Y
             PMAT(3,8)   =  X**2
             PMAT(3,4)   =  Y**2
C
          ELSE IF ( LAYER .EQ. 2 ) THEN
C
             PMAT(1,14)  =  1.0
             PMAT(1,15)  = -X
             PMAT(1,16)  =  Y
             PMAT(1,17)  = -2*X*Y
             PMAT(1,11)  = -0.5*X**2
             PMAT(1,18)  =  Y**2
             PMAT(2,7)   =  1.0
             PMAT(2,5)   =  0.5*T1**2
             PMAT(2,10)  = -(T1+T2) - Y
             PMAT(2,11)  =  (T1*T2+0.5*T2**2) - 0.5*Y**2
             PMAT(2,9)   =  X
             PMAT(2,8)   = -2*X*Y
             PMAT(2,12)  =  X**2
             PMAT(3,13)  =  1.0
             PMAT(3,2)   =  T1
             PMAT(3,4)   =  T1**2
             PMAT(3,15)  =  T2 + Y
             PMAT(3,17)  = -T2**2 + Y**2
             PMAT(3,10)  =  X
             PMAT(3,11)  =  X*Y
             PMAT(3,8)   =  X**2
C
          END IF
C
       ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 1 ) THEN
C
C         TRACTIONS SX & TXY SET TO ZERO ON FACE F1
C
          NBVAL = 15
C
          IF ( LAYER .EQ. 1 ) THEN
C
             PMAT(1,1)   =  1.0
             PMAT(1,2)   = -X
             PMAT(1,3)   =  Y
             PMAT(1,4)   = -2*X*Y
             PMAT(1,5)   = -0.5*X**2
             PMAT(1,6)   =  Y**2
             PMAT(2,5)   = -0.5*T1**2 + T1*Y - 0.5*Y**2
             PMAT(2,7)   = -(T1+T2) + Y
             PMAT(2,8)   =  1.0
             PMAT(2,9)   = -T1*T2 + T2*Y
             PMAT(2,10)  =  2*T1*X - 2*X*Y
```

```
            PMAT(2,11) =  X
            PMAT(2,12) = -T2*X
            PMAT(2,13) =  X**2
            PMAT(3,2)  = -T1 + Y
            PMAT(3,4)  = -T1**2 + Y**2
            PMAT(3,7)  = -A - X
            PMAT(3,10) = -A**2 + X**2
            PMAT(3,9)  = -A*T2 - T2*X
            PMAT(3,5)  = -T1*X + X*Y
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,9)  = -A*(X+A)
            PMAT(1,14) =  (X**2-A**2)
            PMAT(1,15) =  Y*(X+A)
            PMAT(2,8)  =  1.0
            PMAT(2,11) =  X
            PMAT(2,7)  =  Y
            PMAT(2,12) =  X*Y
            PMAT(2,13) =  X**2
            PMAT(3,7)  = -(X+A)
            PMAT(3,10) =  (X**2-A**2)
            PMAT(3,9)  =  Y*(X+A)
C
         END IF
C
      ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 2 ) THEN
C
C        TRACTIONS SX & TXY SET TO ZERO ON FACE F2
C
         NBVAL = 15
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,9)  = -A*(X+A)
            PMAT(1,14) =  (X**2-A**2)
            PMAT(1,15) =  Y*(X+A)
            PMAT(2,8)  =  1.0
            PMAT(2,11) =  X
            PMAT(2,7)  =  Y
            PMAT(2,12) =  X*Y
            PMAT(2,13) =  X**2
            PMAT(3,7)  = -(X+A)
            PMAT(3,10) =  (X**2-A**2)
            PMAT(3,9)  =  Y*(X+A)
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,1)  =  1.0
            PMAT(1,2)  = -X
            PMAT(1,3)  =  Y
            PMAT(1,4)  = -2*X*Y
            PMAT(1,5)  = -0.5*X**2
            PMAT(1,6)  =  Y**2
            PMAT(2,5)  = -0.5*T2**2 - T2*Y - 0.5*Y**2
            PMAT(2,7)  =  (T1+T2) + Y
            PMAT(2,8)  =  1.0
            PMAT(2,9)  = -T1*T2 - T1*Y
            PMAT(2,10) = -2*T2*X - 2*X*Y
            PMAT(2,11) =  X
            PMAT(2,12) =  T1*X
            PMAT(2,13) =  X**2
            PMAT(3,2)  =  T2 + Y
            PMAT(3,4)  = -T2**2 + Y**2
            PMAT(3,7)  = -A - X
            PMAT(3,10) = -A**2 + X**2
            PMAT(3,9)  =  A*T1 + T1*X
            PMAT(3,5)  =  T2*X + X*Y
```

```
C
         END IF
C
      ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 4 ) THEN
C
C        TRACTIONS SX & TXY SET TO ZERO ON FACE F4
C
         NBVAL = 15
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)   =  1.0
            PMAT(1,2)   = -X
            PMAT(1,3)   =  Y
            PMAT(1,4)   = -2*X*Y
            PMAT(1,5)   = -0.5*X**2
            PMAT(1,6)   =  Y**2
            PMAT(2,5)   = -0.5*T1**2 + T1*Y - 0.5*Y**2
            PMAT(2,7)   = -(T1+T2) + Y
            PMAT(2,8)   =  1.0
            PMAT(2,9)   = -T1*T2 + T2*Y
            PMAT(2,10)  =  2*T1*X - 2*X*Y
            PMAT(2,11)  =  X
            PMAT(2,12)  = -T2*X
            PMAT(2,13)  =  X**2
            PMAT(3,2)   = -T1 + Y
            PMAT(3,4)   = -T1**2 + Y**2
            PMAT(3,7)   =  A - X
            PMAT(3,10)  = -A**2 + X**2
            PMAT(3,9)   =  A*T2 - T2*X
            PMAT(3,5)   = -T1*X + X*Y
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,9)   =  A*(X-A)
            PMAT(1,14)  =  (X**2-A**2)
            PMAT(1,15)  =  Y*(X-A)
            PMAT(2,8)   =  1.0
            PMAT(2,11)  =  X
            PMAT(2,7)   =  Y
            PMAT(2,12)  =  X*Y
            PMAT(2,13)  =  X**2
            PMAT(3,7)   = -(X-A)
            PMAT(3,10)  =  (X**2-A**2)
            PMAT(3,9)   =  Y*(X-A)
C
         END IF
C
      ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 3 ) THEN
C
C        TRACTIONS SX & TXY SET TO ZERO ON FACE F3
C
         NBVAL = 15
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,9)   =  A*(X-A)
            PMAT(1,14)  =  (X**2-A**2)
            PMAT(1,15)  =  Y*(X-A)
            PMAT(2,8)   =  1.0
            PMAT(2,11)  =  X
            PMAT(2,7)   =  Y
            PMAT(2,12)  =  X*Y
            PMAT(2,13)  =  X**2
            PMAT(3,7)   = -(X-A)
            PMAT(3,10)  =  (X**2-A**2)
            PMAT(3,9)   =  Y*(X-A)
C
```

```
            ELSE IF ( LAYER .EQ. 2 ) THEN
C
               PMAT(1,1)   =  1.0
               PMAT(1,2)   = -X
               PMAT(1,3)   =  Y
               PMAT(1,4)   = -2*X*Y
               PMAT(1,5)   = -0.5*X**2
               PMAT(1,6)   =  Y**2
               PMAT(2,5)   = -0.5*T2**2 - T2*Y - 0.5*Y**2
               PMAT(2,7)   =  (T1+T2) + Y
               PMAT(2,8)   =  1.0
               PMAT(2,9)   = -T1*T2 - T1*Y
               PMAT(2,10)  = -2*T2*X - 2*X*Y
               PMAT(2,11)  =  X
               PMAT(2,12)  =  T1*X
               PMAT(2,13)  =  X**2
               PMAT(3,2)   =  T2 + Y
               PMAT(3,4)   = -T2**2 + Y**2
               PMAT(3,7)   =  A - X
               PMAT(3,10)  = -A**2 + X**2
               PMAT(3,9)   = -A*T1 + T1*X
               PMAT(3,5)   =  T2*X + X*Y
C
            END IF
C
         END IF
C
      ELSE IF ( JTYPE .EQ. 2 ) THEN
C
C        2-D 2-LAYERED 10-NODE HYBRID ELEMENT.
C
C
C              Y
C              ^
C              |
C              |
C              9-----------------10
C              |                  |
C              |                  |
C              7                  8
C              |                  |
C              |                  |
C              5----------------- 6
C              |                  |
C              |                  |
C              3                  4
C              |                  |
C              |                  |
C              1-----------------2 ------->X
C
C
         T1 = THK(1)/2.
         T2 = THK(2)/2.
C
         IF ( NVER .EQ. 11 ) THEN
C
C           QUADRATIC STRESS FIELD
C
            NBVAL = 18
C
            IF ( LAYER .EQ. 1 ) THEN
C
               PMAT(1,1)   =  1.0
               PMAT(1,2)   = -X
               PMAT(1,3)   =  Y
               PMAT(1,4)   = -2*X*Y
               PMAT(1,5)   = -0.5*X**2
               PMAT(1,6)   =  Y**2
```

```
            PMAT(2,7)   =  1.0
            PMAT(2,8)   =  2*(T1+T2)*X - 2*X*Y
            PMAT(2,9)   =  X
            PMAT(2,5)   =  T1*Y - 0.5*Y**2
            PMAT(2,10)  = -Y
            PMAT(2,11)  =  T2*Y
            PMAT(2,12)  =  X**2
            PMAT(3,13)  =  1.0
            PMAT(3,5)   = -T1*X + X*Y
            PMAT(3,10)  =  X
            PMAT(3,11)  = -T2*X
            PMAT(3,2)   =  Y
            PMAT(3,8)   =  X**2
            PMAT(3,4)   =  Y**2
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,14)  =  1.0
            PMAT(1,15)  = -X
            PMAT(1,16)  =  Y
            PMAT(1,17)  = -2*X*Y
            PMAT(1,11)  = -0.5*X**2
            PMAT(1,18)  =  Y**2
            PMAT(2,7)   =  1.0
            PMAT(2,5)   =  0.5*T1**2
            PMAT(2,10)  = -(T1+T2) - Y
            PMAT(2,11)  =  (T1*T2+0.5*T2**2) - 0.5*Y**2
            PMAT(2,9)   =  X
            PMAT(2,8)   = -2*X*Y
            PMAT(2,12)  =  X**2
            PMAT(3,13)  =  1.0
            PMAT(3,2)   =  T1
            PMAT(3,4)   =  T1**2
            PMAT(3,15)  =  T2 + Y
            PMAT(3,17)  = -T2**2 + Y**2
            PMAT(3,10)  =  X
            PMAT(3,11)  =  X*Y
            PMAT(3,8)   =  X**2
C
         END IF
C
C
      ELSE IF ( NVER .EQ. 12 ) THEN
C
C        CUBIC ORDER EXPANSION
C
         NBVAL = 28
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)   =  1.0
            PMAT(1,2)   = -X
            PMAT(1,3)   =  Y
            PMAT(1,4)   = -2*X*Y
            PMAT(1,5)   = -0.5*X**2
            PMAT(1,6)   =  Y**2
            PMAT(1,7)   = -3*X*Y**2
            PMAT(1,8)   = -Y*X**2
            PMAT(1,9)   = -X**3/3.
            PMAT(1,10)  =  Y**3
            PMAT(2,5)   = -T1**2/2 + T1*Y - 0.5*Y**2
            PMAT(2,8)   = -2*T1**3/3 + T1**2*Y - Y**3/3.
            PMAT(2,13)  =  T1+T2 - Y
            PMAT(2,12)  =  1.0
            PMAT(2,14)  = -(T1*T2+0.5*T2**2) + T2*Y
            PMAT(2,15)  =  (T1*T2**2+T2**3/3.) - T2**2*Y
            PMAT(2,9)   = -T1**2*X + 2*T1*X*Y - X*Y**2
            PMAT(2,16)  =  X
```

```
                 PMAT(2,17) =  2*(T1+T2)*X - 2*X*Y
                 PMAT(2,18) = -(2*T1*T2+T2**2)*X + 2*T2*X*Y
                 PMAT(2,19) =  3*(T1+T2)*X**2 - 3*Y*X**2
                 PMAT(2,11) =  X**2
                 PMAT(2,20) =  X**3
                 PMAT(3,2)  = -T1 + Y
                 PMAT(3,4)  = -T1**2 + Y**2
                 PMAT(3,7)  = -T1**3 + Y**3
                 PMAT(3,21) =  1.0
                 PMAT(3,22) = -T2
                 PMAT(3,23) =  T2**2
                 PMAT(3,24) = -T2**3
                 PMAT(3,5)  = -T1*X + X*Y
                 PMAT(3,8)  = -T1**2*X + X*Y**2
                 PMAT(3,13) =  X
                 PMAT(3,14) = -T2*X
                 PMAT(3,15) =  T2**2*X
                 PMAT(3,9)  = -T1*X**2 + Y*X**2
                 PMAT(3,17) =  X**2
                 PMAT(3,18) = -T2*X**2
                 PMAT(3,19) =  X**3
C
      ELSE IF ( LAYER .EQ. 2 ) THEN
C
                 PMAT(1,25) =  1.0
                 PMAT(1,22) = -X
                 PMAT(1,26) =  Y
                 PMAT(1,23) = -2*X*Y
                 PMAT(1,14) = -0.5*X**2
                 PMAT(1,27) =  Y**2
                 PMAT(1,24) = -3*X*Y**2
                 PMAT(1,15) = -Y*X**2
                 PMAT(1,18) = -X**3/3.
                 PMAT(1,28) =  Y**3
                 PMAT(2,12) =  1.0
                 PMAT(2,16) =  X
                 PMAT(2,13) = -Y
                 PMAT(2,17) = -2*X*Y
                 PMAT(2,11) =  X**2
                 PMAT(2,14) = -0.5*Y**2
                 PMAT(2,18) = -X*Y**2
                 PMAT(2,19) = -3*Y*X**2
                 PMAT(2,20) =  X**3
                 PMAT(2,15) = -Y**3/3.
                 PMAT(3,21) =  1.0
                 PMAT(3,13) =  X
                 PMAT(3,22) =  Y
                 PMAT(3,14) =  X*Y
                 PMAT(3,17) =  X**2
                 PMAT(3,23) =  Y**2
                 PMAT(3,15) =  X*Y**2
                 PMAT(3,18) =  Y*X**2
                 PMAT(3,19) =  X**3
                 PMAT(3,24) =  Y**3
C
            END IF
C
         END IF
C
      ELSE IF ( JTYPE .EQ. 3 ) THEN
C
C        2-D 2-LAYERED 13-NODE HYBRID ELEMENT.
C
C              Y
C              ^
C              |
C              |
C              11-------12-------13
```

```
C              |                  |
C              |                  |
C              9                  10
C              |                  |
C              |                  |
C              6--------7-------  8
C              |                  |
C              |                  |
C              4                  5
C              |                  |
C              |                  |
C              1--------2--------3 ------->X
C
C
      T1 = THK(2)/2.
      T2 = THK(3)/2.
C
      IF ( NVER .EQ. 11 ) THEN
C
C        COMPLETE CUBIC EXPANSION
C
C        ( CONTINUITY OF TXY IS VIOLATED BY THE BETA 26&27 TERMS )
C
         NBVAL = 27
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)  =  1.0
            PMAT(1,2)  =  X
            PMAT(1,3)  =  Y
            PMAT(1,4)  =  X**2
            PMAT(1,5)  =  X*Y
            PMAT(1,6)  =  Y**2
            PMAT(1,7)  =  X**3
            PMAT(1,8)  =  3*X**2*Y
            PMAT(1,9)  =  3*X*Y**2
            PMAT(2,4)  =  T1**2 - 2*T1*Y + Y**2
            PMAT(2,8)  =  2*T1**3 - 3*T1**2*Y + Y**3
            PMAT(2,11) =  1.0
            PMAT(2,16) = -(T1+T2) + Y
            PMAT(2,17) =  (T2**2+2*T1*T2) - 2*T2*Y
            PMAT(2,23) = -(T2**3+3*T1*T2**2) + 3*T2**2*Y
            PMAT(2,7)  =  3*T1**2*X - 6*T1*X*Y.+ 3*X*Y**2
            PMAT(2,20) = -(T1+T2)*X + X*Y
            PMAT(2,22) =  (6*T1*T2+3*T2**2)*X - 6*T2*X*Y
            PMAT(2,14) =  X
            PMAT(2,25) = -3*(T1+T2)*X**2 + 3*X**2*Y
            PMAT(2,18) =  X**2
            PMAT(3,2)  =  T1 - Y
            PMAT(3,5)  =  0.5*T1**2 - 0.5*Y**2
            PMAT(3,9)  =  T1**3 - Y**3
            PMAT(3,12) =  1.0
            PMAT(3,13) =  T2
            PMAT(3,19) = -0.5*T2**2
            PMAT(3,24) =  T2**3
            PMAT(3,4)  =  2*T1*X - 2*X*Y
            PMAT(3,8)  =  2*T1**2*X - 3*X*Y**2
            PMAT(3,16) = -X
            PMAT(3,17) =  2*T2*X
            PMAT(3,23) = -3*T2**2*X
            PMAT(3,7)  =  3*T1*X**2 - 3*X**2*Y
            PMAT(3,20) = -0.5*X**2
            PMAT(3,22) =  3*T2*X**2
            PMAT(3,25) = -X**3
            PMAT(3,26) =  X**4
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
```

```
            PMAT(1,10) =  1.0
            PMAT(1,13) =  X
            PMAT(1,15) =  Y
            PMAT(1,17) =  X**2
            PMAT(1,19) =  X*Y
            PMAT(1,21) =  Y**2
            PMAT(1,22) =  X**3
            PMAT(1,23) =  3*X**2*Y
            PMAT(1,24) =  3*X*Y**2
            PMAT(2,11) =  1.0
            PMAT(2,14) =  X
            PMAT(2,16) =  Y
            PMAT(2,17) =  Y**2
            PMAT(2,18) =  X**2
            PMAT(2,20) =  X*Y
            PMAT(2,22) =  3*X*Y**2
            PMAT(2,23) =  Y**3
            PMAT(2,25) =  3*X**2*Y
            PMAT(3,12) =  1.0
            PMAT(3,13) = -Y
            PMAT(3,16) = -X
            PMAT(3,17) = -2*X*Y
            PMAT(3,19) = -0.5*Y**2
            PMAT(3,20) = -0.5*X**2
            PMAT(3,22) = -3*X**2*Y
            PMAT(3,23) = -3*X*Y**2
            PMAT(3,24) = -Y**3
            PMAT(3,25) = -X**3
            PMAT(3,27) =  X**4
C
         END IF
C
      ELSE IF ( NVER .EQ. 12 ) THEN
C
C        QUADRATIC STRESS FIELD
C
C        (ONLY STRESS CONTINUITY CONDITIONS AT INTERFACE ENFORCED)
C
         NBVAL = 30
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)  =  Y**2
            PMAT(1,2)  =  X**2
            PMAT(1,3)  =  X*Y
            PMAT(1,4)  =  Y
            PMAT(1,5)  =  X
            PMAT(1,6)  =  1.0
            PMAT(2,7)  =  X*Y-X*T1
            PMAT(2,8)  =  Y
            PMAT(2,9)  =  1.0
            PMAT(2,10) =  X**2
            PMAT(2,11) = -X*T2
            PMAT(2,12) =  X
            PMAT(2,13) =  Y**2
            PMAT(3,14) =  Y**2
            PMAT(3,15) =  X*Y
            PMAT(3,16) =  X**2
            PMAT(3,17) =  Y
            PMAT(3,18) =  X
            PMAT(3,19) =  1.0
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,20) =  1.0
            PMAT(1,21) =  Y**2
            PMAT(1,22) =  X**2
            PMAT(1,23) =  X*Y
```

```
                  PMAT(1,24) =  Y
                  PMAT(1,25) =  X
                  PMAT(2,26) =  Y**2-T2**2
                  PMAT(2,27) =  T2+Y
                  PMAT(2,8)  =  T1
                  PMAT(2,9)  =  1.0
                  PMAT(2,10) =  X**2
                  PMAT(2,11) =  X*Y
                  PMAT(2,12) =  X
                  PMAT(2,13) =  T1**2
                  PMAT(3,28) =  Y**2-T2**2
                  PMAT(3,29) =  X*Y+T2*X
                  PMAT(3,30) =  T2+Y
                  PMAT(3,14) =  T1**2
                  PMAT(3,15) =  T1*X
                  PMAT(3,16) =  X**2
                  PMAT(3,17) =  T1
                  PMAT(3,18) =  X
                  PMAT(3,19) =  1.0
C
               END IF
C
            END IF
C
         ELSE IF ( JTYPE .EQ. 4 ) THEN
C
C           2-D 3-LAYERED 8-NODE HYBRID ELEMENT.
C
C                  Y
C                  ^
C                  |
C                  |
C                  7---------------- 8
C                  |                 |
C                  |                 |
C                  |                 |
C                  |                 |
C                  |                 |
C                  5-----------------6
C                  |                 |
C               F1 |                 | F2
C                  |                 |
C                  |                 |
C                  3---------------- 4
C                  |                 |
C                  |                 |
C                  |                 |
C                  |                 |
C                  1-----------------2 ------->X
C
C
            T1 = THK(1)/2.
            T2 = THK(2)/2.
            T3 = THK(3)/2.
C
            IF ( NVER .EQ. 11 ) THEN
C
C              QUADRATIC FIELD EXPANSION
C
               NBVAL = 24
C
               IF ( LAYER .EQ. 1 ) THEN
C
                  PMAT(1,1)  =  1.0
                  PMAT(1,2)  =  X
                  PMAT(1,3)  =  Y
                  PMAT(1,4)  =  X*Y
                  PMAT(1,5)  = -0.5*X**2
```

```
            PMAT(1,6)  =  Y**2
            PMAT(2,5)  = -0.5*T1**2 + T1*Y - 0.5*Y**2
            PMAT(2,7)  = -(T1+T2) + Y
            PMAT(2,8)  = -(T1*T2+0.5*T2**2) + T2*Y
            PMAT(2,9)  =  1.0
            PMAT(2,10) =  X
            PMAT(2,11) = -(T1+T2)*X + X*Y
            PMAT(2,12) =  X**2
            PMAT(3,2)  =  T1 - Y
            PMAT(3,4)  =  0.5*T1**2 - 0.5*Y**2
            PMAT(3,13) =  1.0
            PMAT(3,14) =  T2
            PMAT(3,15) = -0.5*T2**2
            PMAT(3,5)  = -T1*X + X*Y
            PMAT(3,7)  = -X
            PMAT(3,8)  = -T2*X
            PMAT(3,11) = -0.5*X**2
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,16) =  1.0
            PMAT(1,14) =  X
            PMAT(1,17) =  Y
            PMAT(1,15) =  X*Y
            PMAT(1,8)  = -0.5*X**2
            PMAT(1,18) =  Y**2
            PMAT(2,9)  =  1.0
            PMAT(2,10) =  X
            PMAT(2,7)  =  Y
            PMAT(2,11) =  X*Y
            PMAT(2,12) =  X**2
            PMAT(2,8)  = -0.5*Y**2
            PMAT(3,13) =  1.0
            PMAT(3,7)  = -X
            PMAT(3,14) = -Y
            PMAT(3,8)  =  X*Y
            PMAT(3,11) = -0.5*X**2
            PMAT(3,15) = -0.5*Y**2
C
         ELSE IF ( LAYER .EQ. 3 ) THEN
C
            PMAT(1,19) =  1.0
            PMAT(1,20) =  X
            PMAT(1,21) =  Y
            PMAT(1,22) =  X*Y
            PMAT(1,23) = -0.5*X**2
            PMAT(1,24) =  Y**2
            PMAT(2,9)  =  1.0
            PMAT(2,7)  = (T2+T3) + Y
            PMAT(2,8)  = -(T2*T3+0.5*T2**2) - T2*Y
            PMAT(2,23) = -0.5*T3**2 - T3*Y - 0.5*Y**2
            PMAT(2,10) =  X
            PMAT(2,11) =  (T2+T3)*X + X*Y
            PMAT(2,12) =  X**2
            PMAT(3,13) =  1.0
            PMAT(3,14) = -T2
            PMAT(3,15) = -0.5*T2**2
            PMAT(3,20) = -T3 - Y
            PMAT(3,22) =  0.5*T3**2 - 0.5*Y**2
            PMAT(3,7)  = -X
            PMAT(3,8)  =  T2*X
            PMAT(3,23) =  T3*X + X*Y
            PMAT(3,11) = -0.5*X**2
C
         END IF
C
      ELSE IF ( NVER .EQ. 12 ) THEN
C
```

```
C          CUBIC FIELD EXPANSION
C
           NBVAL = 38
C
           IF ( LAYER .EQ. 1 ) THEN
C
              PMAT(1,1)   =  1.0
              PMAT(1,2)   =  X
              PMAT(1,3)   =  Y
              PMAT(1,4)   =  X*Y
              PMAT(1,5)   = -X**2/2.
              PMAT(1,6)   =  Y**2
              PMAT(1,7)   = -3.*X*Y**2
              PMAT(1,8)   = -Y*X**2
              PMAT(1,9)   = -X**3/3.
              PMAT(1,10)  =  Y**3
              PMAT(2,5)   = -0.5*T1**2 + T1*Y - 0.5*Y**2
              PMAT(2,8)   = -2*T1**3/3 + T1**2*Y - Y**3/3.
              PMAT(2,21)  =  1.0
              PMAT(2,23)  =  T1+T2 - Y
              PMAT(2,15)  = -T1*T2-0.5*T2**2 + T2*Y
              PMAT(2,18)  =  T1*T2**2+T2**3/3. - T2**2*Y
              PMAT(2,9)   = -T1**2*X + 2*T1*X*Y - X*Y**2
              PMAT(2,22)  =  X
              PMAT(2,24)  =  2*(T1+T2)*X - 2*X*Y
              PMAT(2,19)  = -(2*T1*T2+T2**2)*X + 2*T2*X*Y
              PMAT(2,26)  =  3*(T1+T2)*X**2 - 3*Y*X**2
              PMAT(2,25)  =  X**2
              PMAT(2,27)  =  X**3
              PMAT(3,2)   =  T1 - Y
              PMAT(3,4)   =  0.5*T1**2 - 0.5*Y**2
              PMAT(3,7)   = -T1**3 + Y**3
              PMAT(3,28)  =  1.0
              PMAT(3,12)  =  T2
              PMAT(3,14)  = -0.5*T2**2
              PMAT(3,17)  = -T2**3
              PMAT(3,5)   = -T1*X + X*Y
              PMAT(3,8)   = -T1**2*X + X*Y**2
              PMAT(3,23)  =  X
              PMAT(3,15)  = -T2*X
              PMAT(3,18)  =  T2**2*X
              PMAT(3,9)   = -T1*X**2 + Y*X**2
              PMAT(3,24)  =  X**2
              PMAT(3,19)  = -T2*X**2
              PMAT(3,26)  =  X**3
C
           ELSE IF ( LAYER .EQ. 2 ) THEN
C
              PMAT(1,11)  =  1.0
              PMAT(1,12)  =  X
              PMAT(1,13)  =  Y
              PMAT(1,14)  =  X*Y
              PMAT(1,15)  = -0.5*X**2
              PMAT(1,16)  =  Y**2
              PMAT(1,17)  = -3*X*Y**2
              PMAT(1,18)  = -Y*X**2
              PMAT(1,19)  = -X**3/3.
              PMAT(1,20)  =  Y**3
              PMAT(2,21)  =  1.0
              PMAT(2,22)  =  X
              PMAT(2,23)  = -Y
              PMAT(2,24)  = -2*X*Y
              PMAT(2,25)  =  X**2
              PMAT(2,15)  = -0.5*Y**2
              PMAT(2,19)  = -X*Y**2
              PMAT(2,26)  = -3*Y*X**2
              PMAT(2,27)  =  X**3
              PMAT(2,18)  = -Y**3/3.
```

```
            PMAT(3,28) =  1.0
            PMAT(3,23) =  X
            PMAT(3,12) = -Y
            PMAT(3,15) =  X*Y
            PMAT(3,24) =  X**2
            PMAT(3,14) = -0.5*Y**2
            PMAT(3,18) =  X*Y**2
            PMAT(3,19) =  Y*X**2
            PMAT(3,26) =  X**3
            PMAT(3,17) =  Y**3
C
         ELSE IF ( LAYER .EQ. 3 ) THEN
C
            PMAT(1,29) =  1.0
            PMAT(1,30) =  X
            PMAT(1,31) =  Y
            PMAT(1,32) =  X*Y
            PMAT(1,33) = -0.5*X**2
            PMAT(1,34) =  Y**2
            PMAT(1,35) = -3*X*Y**2
            PMAT(1,36) = -Y*X**2
            PMAT(1,37) = -X**3/3.
            PMAT(1,38) =  Y**3
            PMAT(2,23) = -Y - (T2+T3)
            PMAT(2,15) = -(T2*T3+0.5*T2**2) - T2*Y
            PMAT(2,18) = -(T3*T2**2+T2**3/3.) - T2**2*Y
            PMAT(2,33) = -0.5*T3**2 - T3*Y - 0.5*Y**2
            PMAT(2,36) =  2*T3**3/3. + T3**2*Y - Y**3/3.
            PMAT(2,21) =  1.0
            PMAT(2,24) = -2*(T2+T3)*X - 2*X*Y
            PMAT(2,19) = -2*(T2*T3+0.5*T2**2)*X - 2*T2*X*Y
            PMAT(2,37) =  (T3**2-2*T2*T3)*X - 2*T2*X*Y - X*Y**2
            PMAT(2,22) =  X
            PMAT(2,25) =  X**2
            PMAT(2,26) = -3*(T2+T3)*X**2 - 3*Y*X**2
            PMAT(2,27) =  X**3
            PMAT(3,12) = -T2
            PMAT(3,14) = -0.5*T2**2
            PMAT(3,17) =  T2**3
            PMAT(3,28) =  1.0
            PMAT(3,30) = -T3 - Y
            PMAT(3,32) =  0.5*T3**2 - 0.5*Y**2
            PMAT(3,35) =  T3**3 + Y**3
            PMAT(3,23) =  X
            PMAT(3,15) =  T2*X
            PMAT(3,18) =  T2**2*X
            PMAT(3,33) =  T3*X + X*Y
            PMAT(3,36) = -T3**2*X + X*Y**2
            PMAT(3,24) =  X**2
            PMAT(3,19) =  T2*X**2
            PMAT(3,37) =  T3*X**2 + Y*X**2
            PMAT(3,26) =  X**3
C
         END IF
C
      ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 1 ) THEN
C
C        ZERO TRACTION CONDITION OF SXX AND TXY
C        IMPOSED ON ELEMENT SIDE F1
C
         NBVAL = 21
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)  =  1.0
            PMAT(1,2)  = -X
            PMAT(1,3)  =  Y
            PMAT(1,4)  = -2*X*Y
```

```
          PMAT(1,5)   = -X**2
          PMAT(1,6)   =  Y**2
          PMAT(2,5)   = -0.5*T1**2 + Y*T1 - 0.5*Y**2
          PMAT(2,7)   = -(T1+T2) +  Y
          PMAT(2,8)   =  1.0
          PMAT(2,9)   = -T1*T2 +  Y*T2
          PMAT(2,10)  =  2*X*T1 - 2*X*Y
          PMAT(2,11)  =  X
          PMAT(2,12)  = -X*T2
          PMAT(2,13)  =  X**2
          PMAT(3,2)   = -T1 + Y
          PMAT(3,4)   = -T1**2 +  Y**2
          PMAT(3,7)   = -A - X
          PMAT(3,10)  = -A**2 +  X**2
          PMAT(3,9)   = -T2*A  - X*T2
          PMAT(3,5)   = -X*T1 +  X*Y
C
       ELSE IF ( LAYER .EQ. 2 ) THEN
C
          PMAT(1,9)   = -A*(X+A)
          PMAT(1,14)  =  (X**2-A**2)
          PMAT(1,15)  =  Y*(X+A)
          PMAT(2,8)   =  1.0
          PMAT(2,11)  =  X
          PMAT(2,7)   =  Y
          PMAT(2,12)  =  X*Y
          PMAT(2,13)  =  X**2
          PMAT(3,7)   = -(X+A)
          PMAT(3,10)  =  (X**2-A**2)
          PMAT(3,9)   =  Y*(X+A)
C
       ELSE IF ( LAYER .EQ. 3 ) THEN
C
          PMAT(1,16)  =  1.0
          PMAT(1,17)  = -X
          PMAT(1,18)  =  Y
          PMAT(1,19)  = -X*Y
          PMAT(1,20)  = -0.5*X**2
          PMAT(1,21)  =  Y**2
          PMAT(2,20)  = -0.5*T3**2  - T3*Y  - 0.5*Y**2
          PMAT(2,7)   =  (T2+T3) + Y
          PMAT(2,8)   =  1.0
          PMAT(2,9)   = -T2*T3  - T2*Y
          PMAT(2,10)  = -2*T3*X - 2*X*Y
          PMAT(2,11)  =  X
          PMAT(2,12)  =  T2*X
          PMAT(2,13)  =  X**2
          PMAT(3,17)  =  T3 + Y
          PMAT(3,19)  = -T3**2 +  Y**2
          PMAT(3,7)   = -A - X
          PMAT(3,10)  = -A**2 + X**2
          PMAT(3,9)   =  T2*A + T2*X
          PMAT(3,20)  =  T3*X +  X*Y
C
       END IF
C
    ELSE IF ( NVER .EQ. 13 .AND. NSIDE .EQ. 2 ) THEN
C
C      ZERO TRACTION CONDITION OF SXX AND TXY
C      IMPOSED ON FACE F2
C
       NBVAL = 21
C
       IF ( LAYER .EQ. 1 ) THEN
C
          PMAT(1,1)   =  1.0
          PMAT(1,2)   = -X
          PMAT(1,3)   =  Y
```

```
              PMAT(1,4)   = -2*X*Y
              PMAT(1,5)   = -X**2
              PMAT(1,6)   =  Y**2
              PMAT(2,5)   = -0.5*T1**2 + Y*T1 - 0.5*Y**2
              PMAT(2,7)   = -(T1+T2) +  Y
              PMAT(2,8)   =  1.0
              PMAT(2,9)   = -T1*T2 +  Y*T2
              PMAT(2,10)  =  2*X*T1 - 2*X*Y
              PMAT(2,11)  =  X
              PMAT(2,12)  = -X*T2
              PMAT(2,13)  =  X**2
              PMAT(3,2)   = -T1 + Y
              PMAT(3,4)   = -T1**2 +  Y**2
              PMAT(3,7)   =  A - X
              PMAT(3,10)  = -A**2 +  X**2
              PMAT(3,9)   =  T2*A  - X*T2
              PMAT(3,5)   = -X*T1 +  X*Y
C
           ELSE IF ( LAYER .EQ. 2 ) THEN
C
              PMAT(1,9)   =  A*(X-A)
              PMAT(1,14)  =  (X**2-A**2)
              PMAT(1,15)  =  Y*(X-A)
              PMAT(2,8)   =  1.0
              PMAT(2,11)  =  X
              PMAT(2,7)   =  Y
              PMAT(2,12)  =  X*Y
              PMAT(2,13)  =  X**2
              PMAT(3,7)   = -(X-A)
              PMAT(3,10)  =  (X**2-A**2)
              PMAT(3,9)   =  Y*(X-A)
C
           ELSE IF ( LAYER .EQ. 3 ) THEN
C
              PMAT(1,16)  =  1.0
              PMAT(1,17)  = -X
              PMAT(1,18)  =  Y
              PMAT(1,19)  = -X*Y
              PMAT(1,20)  = -0.5*X**2
              PMAT(1,21)  =  Y**2
              PMAT(2,20)  = -0.5*T3**2  - T3*Y  - 0.5*Y**2
              PMAT(2,7)   =  (T2+T3) + Y
              PMAT(2,8)   =  1.0
              PMAT(2,9)   = -T2*T3  - T2*Y
              PMAT(2,10)  = -2*T3*X - 2*X*Y
              PMAT(2,11)  =  X
              PMAT(2,12)  =  T2*X
              PMAT(2,13)  =  X**2
              PMAT(3,17)  =  T3 + Y
              PMAT(3,19)  = -T3**2 +  Y**2
              PMAT(3,7)   =  A - X
              PMAT(3,10)  = -A**2 + X**2
              PMAT(3,9)   = -T2*A + T2*X
              PMAT(3,20)  =  T3*X +  X*Y
C
           END IF
C
        END IF
C
     ELSE IF ( JTYPE .EQ. 5 ) THEN
C
C       2-LAYER 3-D HYBRID ELEMENT.
C
C                                   Y,V
C                 Z,W              /
C                 |               /
C                 |  12-------11
C                 | /|        /|
```

```
C                 |/ |       / |
C                 9---------10  |
C                 |  |       |  |
C                 |  8------|--7
C                 | /|       | /|
C                 |/ |       |/ |
C                 5----------6  |
C                 |  |       |  |
C                 |  4------|--3
C                 | /        | /
C                 |/         |/
C                 1----------2 --------- X,U
C
C
         T1 = THK(1)/2.
         T2 = THK(2)/2.
C
         IF ( NVER .EQ. 11 ) THEN
C
C           TRILINEAR STRESS FIELD
C
            NBVAL = 48
C
            IF ( LAYER .EQ. 1 ) THEN
C
               PMAT(1,1)  =  1.0
               PMAT(1,2)  = -X
               PMAT(1,3)  = -X
               PMAT(1,4)  =  Y
               PMAT(1,5)  =  Z
               PMAT(1,6)  = -X*Y
               PMAT(1,7)  = -X*Z
               PMAT(1,8)  =  Z*Y
               PMAT(2,9)  =  1.0
               PMAT(2,10) =  X
               PMAT(2,11) =  Y
               PMAT(2,12) =  Z
               PMAT(2,13) =  X*Y
               PMAT(2,14) =  X*Z
               PMAT(2,15) = -Z*Y
               PMAT(3,16) =  T1+T2 - Z
               PMAT(3,17) =  T1+T2 - Z
               PMAT(3,18) =  1.0
               PMAT(3,19) =  (T1+T2)*X - X*Z
               PMAT(3,20) =  X
               PMAT(3,21) =  (T1+T2)*Y - Z*Y
               PMAT(3,22) =  Y
               PMAT(3,23) =  X*Y
               PMAT(4,25) = -T1 + Z
               PMAT(4,27) =  1.0
               PMAT(4,28) = -T2
               PMAT(4,13) =  T1*X - X*Z
               PMAT(4,29) =  X
               PMAT(4,30) =  T2*X
               PMAT(4,17) =  Y
               PMAT(4,19) =  X*Y
               PMAT(5,3)  = -T1 + Z
               PMAT(5,31) =  1.0
               PMAT(5,32) = -T2
               PMAT(5,16) =  X
               PMAT(5,6)  = -T1*Y + Z*Y
               PMAT(5,33) =  Y
               PMAT(5,34) = -T2*Y
               PMAT(5,21) =  X*Y
               PMAT(6,24) =  1.0
               PMAT(6,11) = -X
               PMAT(6,25) = -X
               PMAT(6,2)  =  Y
```

```
            PMAT(6,26) =  Z
            PMAT(6,15) =  X*Z
            PMAT(6,7)  =  Z*Y
C
         ELSE IF ( LAYER .EQ. 2 ) THEN
C
            PMAT(1,35) =  1.0
            PMAT(1,36) = -X
            PMAT(1,32) = -X
            PMAT(1,37) =  Y
            PMAT(1,38) =  Z
            PMAT(1,34) = -X*Y
            PMAT(1,39) = -X*Z
            PMAT(1,40) =  Y*Z
            PMAT(2,41) =  1.0
            PMAT(2,42) =  X
            PMAT(2,47) =  Y
            PMAT(2,43) =  Z
            PMAT(2,30) =  X*Y
            PMAT(2,44) =  X*Z
            PMAT(2,45) = -Z*Y
            PMAT(3,18) =  1.0
            PMAT(3,20) =  X
            PMAT(3,22) =  Y
            PMAT(3,16) = -Z
            PMAT(3,17) = -Z
            PMAT(3,23) =  X*Y
            PMAT(3,19) = -X*Z
            PMAT(3,21) = -Z*Y
            PMAT(4,27) =  1.0
            PMAT(4,29) =  X
            PMAT(4,17) =  Y
            PMAT(4,28) =  Z
            PMAT(4,19) =  X*Y
            PMAT(4,30) = -X*Z
            PMAT(5,31) =  1.0
            PMAT(5,16) =  X
            PMAT(5,33) =  Y
            PMAT(5,32) =  Z
            PMAT(5,21) =  X*Y
            PMAT(5,34) =  Y*Z
            PMAT(6,46) =  1.0
            PMAT(6,47) = -X
            PMAT(6,28) = -X
            PMAT(6,36) =  Y
            PMAT(6,48) =  Z
            PMAT(6,45) =  X*Z
            PMAT(6,39) =  Z*Y
C
         END IF
C
      ELSE IF ( NVER .EQ. 12 ) THEN
C
C        QUADRATIC STRESS FIELD
C
         NBVAL = 78
C
         IF ( LAYER .EQ. 1 ) THEN
C
            PMAT(1,1)  =  Y*Z
            PMAT(1,2)  =  X*Z
            PMAT(1,3)  =  Z
            PMAT(1,4)  =  Y**2
            PMAT(1,5)  =  X**2
            PMAT(1,6)  =  X*Y
            PMAT(1,7)  =  Y
            PMAT(1,8)  =  X
            PMAT(1,9)  =  Z**2
```

```
PMAT(1,10) =  1.0
PMAT(2,11) =  Y*Z
PMAT(2,12) =  X*Z
PMAT(2,13) =  Z
PMAT(2,14) =  Y**2
PMAT(2,15) =  X**2
PMAT(2,16) =  X*Y
PMAT(2,17) =  Y
PMAT(2,18) =  X
PMAT(2,19) =  1.0
PMAT(2,20) =  Z**2
PMAT(3,21) =  Z**2-2*Z*T1
PMAT(3,22) =  Y*Z
PMAT(3,23) =  X*Z
PMAT(3,24) =  Z
PMAT(3,25) =  Y**2
PMAT(3,26) =  X**2
PMAT(3,27) =  X*Y
PMAT(3,28) =  Y
PMAT(3,29) =  X
PMAT(3,30) =  1.0
PMAT(3,31) = -2*Z*T2
PMAT(4,21) =  2*Y*T1-Y*Z
PMAT(4,23) = -X*Y
PMAT(4,24) = -Y
PMAT(4,14) = -Y*Z
PMAT(4,34) = -2*X*Z
PMAT(4,16) = -X*Z
PMAT(4,17) = -Z
PMAT(4,41) = -Y
PMAT(4,42) =  X
PMAT(4,36) = -Z
PMAT(4,43) =  1.0
PMAT(4,31) =  2*Y*T2
PMAT(4,39) =  Z**2
PMAT(4,5)  =  Y*Z
PMAT(4,44) =  Y**2
PMAT(4,45) = -2*X*Y
PMAT(4,46) =  X**2
PMAT(5,22) = -X*Y
PMAT(5,33) = -2*Y*Z
PMAT(5,14) =  X*Z
PMAT(5,47) =  Y
PMAT(5,35) = -Z
PMAT(5,41) =  X
PMAT(5,48) =  1.0
PMAT(5,38) =  Z**2
PMAT(5,5)  = -X*Z
PMAT(5,6)  = -Y*Z
PMAT(5,21) = -X*Z
PMAT(5,8)  = -Z
PMAT(5,49) =  Y**2
PMAT(5,44) = -2*X*Y
PMAT(5,45) =  X**2
PMAT(6,2)  = -Y*Z
PMAT(6,11) = -X*Z
PMAT(6,32) =  Z
PMAT(6,33) =  Y**2
PMAT(6,14) = -X*Y
PMAT(6,34) =  X**2
PMAT(6,35) =  Y
PMAT(6,36) =  X
PMAT(6,37) =  1.0
PMAT(6,38) = -2*Y*Z
PMAT(6,39) = -2*X*Z
PMAT(6,5)  = -X*Y
PMAT(6,40) =  Z**2
PMAT(6,21) =  X*Y
```

```
C
      ELSE IF ( LAYER .EQ. 2 ) THEN
C
         PMAT(1,50) =  Y*Z
         PMAT(1,51) =  X*Z
         PMAT(1,52) =  Z
         PMAT(1,53) = -2*X*Y
         PMAT(1,54) =  Y**2
         PMAT(1,55) =  X**2
         PMAT(1,56) =  Y
         PMAT(1,57) =  X
         PMAT(1,58) =  1.0
         PMAT(1,59) =  Z**2
         PMAT(1,60) = -X*Y
         PMAT(2,61) =  Y*Z
         PMAT(2,62) =  X*Z
         PMAT(2,63) =  Z
         PMAT(2,64) =  Y**2
         PMAT(2,65) =  X**2
         PMAT(2,66) =  X*Y
         PMAT(2,67) =  Y
         PMAT(2,68) =  X
         PMAT(2,69) =  1.0
         PMAT(2,70) =  Z**2
         PMAT(3,31) =  (-T2**2+Z**2-2*T1*T2)
         PMAT(3,22) =  (Y*(T2+T1)+Y*Z)
         PMAT(3,23) =  (X*(T2+T1)+X*Z)
         PMAT(3,24) =  (T2+T1+Z)
         PMAT(3,25) =  Y**2
         PMAT(3,26) =  X**2
         PMAT(3,27) =  X*Y
         PMAT(3,28) =  Y
         PMAT(3,29) =  X
         PMAT(3,30) =  1.0
         PMAT(3,21) = -T1**2
         PMAT(4,77) =  (Z**2-T2**2)
         PMAT(4,55) =  (Y*Z+T2*Y)
         PMAT(4,67) =  (-T2-Z)
         PMAT(4,31) =  (T2*Y-Y*Z)
         PMAT(4,64) =  (-Y*Z-T2*Y)
         PMAT(4,66) =  (-X*Z-T2*X)
         PMAT(4,73) =  (-T2-Z)
         PMAT(4,72) =  (-2*X*Z-2*T2*X)
         PMAT(4,23) = -X*Y
         PMAT(4,24) = -Y
         PMAT(4,14) = -T1*Y
         PMAT(4,34) = -2*T1*X
         PMAT(4,16) = -T1*X
         PMAT(4,17) = -T1
         PMAT(4,41) = -Y
         PMAT(4,42) =  X
         PMAT(4,36) = -T1
         PMAT(4,43) =  1.0
         PMAT(4,39) =  T1**2
         PMAT(4,5)  =  T1*Y
         PMAT(4,21) =  T1*Y
         PMAT(4,44) =  Y**2
         PMAT(4,45) = -2*X*Y
         PMAT(4,46) =  X**2
         PMAT(5,76) =  (Z**2-T2**2)
         PMAT(5,60) =  (Y*Z+T2*Y)
         PMAT(5,64) =  (X*Z+T2*X)
         PMAT(5,55) =  (-X*Z-T2*X)
         PMAT(5,31) =  (-X*Z-T2*X)
         PMAT(5,75) =  (T2+Z)
         PMAT(5,22) = -X*Y
         PMAT(5,33) = -2*T1*Y
         PMAT(5,14) =  T1*X
```

```
                PMAT(5,47) =  Y
                PMAT(5,35) = -T1
                PMAT(5,41) =  X
                PMAT(5,48) =  1.0
                PMAT(5,38) =  T1**2
                PMAT(5,5)  = -T1*X
                PMAT(5,6)  = -T1*Y
                PMAT(5,21) = -T1*X
                PMAT(5,8)  = -T1
                PMAT(5,49) =  Y**2
                PMAT(5,44) = -2*X*Y
                PMAT(5,45) =  X**2
                PMAT(6,61) = -X*Z
                PMAT(6,51) = -Y*Z
                PMAT(6,71) =  Z
                PMAT(6,53) =  Y**2
                PMAT(6,64) = -X*Y
                PMAT(6,72) =  X**2
                PMAT(6,55) = -X*Y
                PMAT(6,73) =  X
                PMAT(6,57) = -Y
                PMAT(6,74) =  1.0
                PMAT(6,31) =  X*Y
                PMAT(6,75) = -Y
                PMAT(6,76) = -2*Y*Z
                PMAT(6,77) = -2*X*Z
                PMAT(6,78) =  Z**2
C
              END IF
C
           END IF
C
        END IF
C
        RETURN
        END
C
C
C
        SUBROUTINE IOPNTS(IET,NTPS,JTYPE,NELDIM,NORD,LAYER,
     1                    XSI,ETA,CEE                           )
C
        IMPLICIT REAL*8(A-H,O-Z)
C
C       IN FIRST PASS SET NUMBER OF OUTPUT POINTS
C
        IF ( IET .EQ. 0 ) THEN
C
           IF ( JTYPE .NE. 5 ) NTPS = 9
           IF ( JTYPE .EQ. 5 ) NTPS = 17
C
           RETURN
C
        END IF
C
C       SELECT SPECIFIC OUTPUT POINTS AT ELEMENT
C       CORNERS AND AT GAUSS (N=2) POINTS
C
        IF ( JTYPE .NE. 5 ) THEN
C
C          2-D ADHESIVE ELEMENTS
C
           IF ( IET .EQ. 1 ) THEN
C
              XSI = -1.0
              ETA = -1.0
C
           ELSE IF ( IET .EQ. 2 ) THEN
```

```
C
            XSI = -1.0
            ETA =  1.0
C
         ELSE IF ( IET .EQ. 3 ) THEN
C
            XSI =  1.0
            ETA = -1.0
C
         ELSE IF ( IET .EQ. 4 ) THEN
C
            XSI =  1.0
            ETA =  1.0
C
         ELSE IF ( IET .EQ. 5 ) THEN
C
            XSI =  0.0
            ETA =  0.0
C
         ELSE IF ( IET .EQ. 6 ) THEN
C
            XSI = -0.577350269189626
            ETA = -0.577350269189626
C
         ELSE IF ( IET .EQ. 7 ) THEN
C
            XSI =  0.577350269189626
            ETA = -0.577350269189626
C
         ELSE IF ( IET .EQ. 8 ) THEN
C
            XSI = -0.577350269189626
            ETA =  0.577350269189626
C
         ELSE IF ( IET .EQ. 9 ) THEN
C
            XSI =  0.577350269189626
            ETA =  0.577350269189626
C
         END IF
C
      ELSE IF ( JTYPE .EQ. 5 ) THEN
C
C        3-D ADHESIVE ELEMENT
C
         IF ( IET .EQ. 1 ) THEN
C
            XSI = -1.0
            ETA = -1.0
            CEE = -1.0
C
         ELSE IF ( IET .EQ. 2 ) THEN
C
            XSI = -1.0
            ETA = -1.0
            CEE =  1.0
C
         ELSE IF ( IET .EQ. 3 ) THEN
C
            XSI = -1.0
            ETA =  1.0
            CEE = -1.0
C
         ELSE IF ( IET .EQ. 4 ) THEN
C
            XSI = -1.0
            ETA =  1.0
            CEE =  1.0
```

```
C
         ELSE IF ( IET .EQ. 5 ) THEN
C
            XSI =  1.0
            ETA = -1.0
            CEE = -1.0
C
         ELSE IF ( IET .EQ. 6 ) THEN
C
            XSI =  1.0
            ETA = -1.0
            CEE =  1.0
C
         ELSE IF ( IET .EQ. 7 ) THEN
C
            XSI =  1.0
            ETA =  1.0
            CEE = -1.0
C
         ELSE IF ( IET .EQ. 8 ) THEN
C
            XSI =  1.0
            ETA =  1.0
            CEE =  1.0
C
         ELSE IF ( IET .EQ. 9 ) THEN
C
            XSI =  0.0
            ETA =  0.0
            CEE =  0.0
C
         ELSE IF ( IET .EQ. 10 ) THEN
C
            XSI = -0.577350269189626
            ETA = -0.577350269189626
            CEE = -0.577350269189626
C
         ELSE IF ( IET .EQ. 11 ) THEN
C
            XSI =  0.577350269189626
            ETA = -0.577350269189626
            CEE = -0.577350269189626
C
         ELSE IF ( IET .EQ. 12 ) THEN
C
            XSI = -0.577350269189626
            ETA =  0.577350269189626
            CEE = -0.577350269189626
C
         ELSE IF ( IET .EQ. 13 ) THEN
C
            XSI =  0.577350269189626
            ETA =  0.577350269189626
            CEE = -0.577350269189626
C
         ELSE IF ( IET .EQ. 14 ) THEN
C
            XSI = -0.577350269189626
            ETA = -0.577350269189626
            CEE =  0.577350269189626
C
         ELSE IF ( IET .EQ. 15 ) THEN
C
            XSI =  0.577350269189626
            ETA = -0.577350269189626
            CEE =  0.577350269189626
C
         ELSE IF ( IET .EQ. 16 ) THEN
```

```
C
              XSI = -0.577350269189626
              ETA =  0.577350269189626
              CEE =  0.577350269189626
C
           ELSE IF ( IET .EQ. 17 ) THEN
C
              XSI =  0.577350269189626
              ETA =  0.577350269189626
              CEE =  0.577350269189626
C
           END IF
C
        END IF
C
        RETURN
        END
C
C
C
        SUBROUTINE INVERS(A,B,INDEX,NDIM,NFT)
C
        I PLICIT DOUBLE PRECISION (A-H,O-Z)
C
        DIMENSION A(NDIM,NDIM),B(NDIM,NDIM),INDEX(NDIM)
C
        DO 12 I = 1, NFT
           DO 11 J = 1, NFT
              B(I,J) = 0.0
11         CONTINUE
           B(I,I) = 1.0
12      CONTINUE
        CALL LUDCMP(A,NFT,NDIM,INDEX,D)
        DO 13 J = 1, NFT
           CALL LUBKSB(A,NFT,NDIM,INDEX,B(1,J))
13      CONTINUE
C
        RETURN
        END
C
C
C
        SUBROUTINE LUDCMP(A,N,NP,INDX,D)
C
        IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
        PARAMETER (NMAX=100,TINY=1.0E-20)
        DIMENSION A(NP,NP),INDX(NP),VV(NMAX)
        D=1.
        DO 12 I=1,N
          AAMAX=0.
          DO 11 J=1,N
            IF (ABS(A(I,J)).GT.AAMAX) AAMAX=ABS(A(I,J))
11        CONTINUE
          IF (AAMAX.EQ.0.) PAUSE 'Singular matrix.'
          VV(I)=1./AAMAX
12      CONTINUE
        DO 19 J=1,N
          IF (J.GT.1) THEN
            DO 14 I=1,J-1
              SUM=A(I,J)
              IF (I.GT.1)THEN
                DO 13 K=1,I-1
                  SUM=SUM-A(I,K)*A(K,J)
13              CONTINUE
                A(I,J)=SUM
              ENDIF
14          CONTINUE
```

```
          ENDIF
          AAMAX=0.
          DO 16 I=J,N
            SUM=A(I,J)
            IF (J.GT.1)THEN
              DO 15 K=1,J-1
                SUM=SUM-A(I,K)*A(K,J)
15            CONTINUE
              A(I,J)=SUM
            ENDIF
            DUM=VV(I)*ABS(SUM)
            IF (DUM.GE.AAMAX) THEN
              IMAX=I
              AAMAX=DUM
            ENDIF
16        CONTINUE
          IF (J.NE.IMAX)THEN
            DO 17 K=1,N
              DUM=A(IMAX,K)
              A(IMAX,K)=A(J,K)
              A(J,K)=DUM
17          CONTINUE
            D=-D
            VV(IMAX)=VV(J)
          ENDIF
          INDX(J)=IMAX
          IF(J.NE.N)THEN
            IF(A(J,J).EQ.0.)A(J,J)=TINY
            DUM=1./A(J,J)
            DO 18 I=J+1,N
              A(I,J)=A(I,J)*DUM
18          CONTINUE
          ENDIF
19      CONTINUE
        IF(A(N,N).EQ.0.)A(N,N)=TINY
        RETURN
        END
C
C
C
        SUBROUTINE LUBKSB(A,N,NP,INDX,B)
C
        IMPLICIT DOUBLE PRECISION(A-H,O-Z)
C
        DIMENSION A(NP,NP),INDX(NP),B(N)
        II=0
        DO 12 I=1,N
          LL=INDX(I)
          SUM=B(LL)
          B(LL)=B(I)
          IF (II.NE.0)THEN
            DO 11 J=II,I-1
              SUM=SUM-A(I,J)*B(J)
11          CONTINUE
          ELSE IF (SUM.NE.0.) THEN
            II=I
          ENDIF
          B(I)=SUM
12      CONTINUE
        DO 14 I=N,1,-1
          SUM=B(I)
          IF(I.LT.N)THEN
            DO 13 J=I+1,N
              SUM=SUM-A(I,J)*B(J)
13          CONTINUE
          ENDIF
          B(I)=SUM/A(I,I)
14      CONTINUE
```

```
      RETURN
      END
C
C
C
      SUBROUTINE GAUSS(NORD,NELDIM,IXSI,JETA,KCEE,XSI,ETA,CEE,WEIGHT)
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C     RETURN GAUSS POINTS AND WEIGHTS FOR NUMERICAL QUADRATURE
C
      IF ( NELDIM .EQ. 2 ) THEN
C
         CEE = 1.0
         IF ( NORD .EQ. 1 ) THEN
C
            XSI = 0.0
            ETA = 0.0
            WEIGHT = 4.0
C
         ELSE IF ( NORD .EQ. 2 ) THEN
C
            WEIGHT = 1.000
            XSI = 0.577350269189626
            ETA = 0.577350269189626
            IF ( IXSI .EQ. 2 ) XSI = -.577350269189626
            IF ( JETA .EQ. 2 ) ETA = -.577350269189626
C
         ELSE IF ( NORD .EQ. 3 ) THEN
C
            IF ( IXSI .EQ. 1 ) THEN
               XSI = 0.774596669241483
               WX  = 0.555555555555556
            ELSE IF ( IXSI .EQ. 2 ) THEN
               XSI = 0.000000000000000
               WX  = 0.888888888888889
            ELSE IF ( IXSI .EQ. 3 ) THEN
               XSI = -.774596669241483
               WX  = 0.555555555555556
            END IF
            IF ( JETA .EQ. 1 ) THEN
               ETA = 0.774596669241483
               WE  = 0.555555555555556
            ELSE IF ( JETA .EQ. 2 ) THEN
               ETA = 0.000000000000000
               WE  = 0.888888888888889
            ELSE IF ( JETA .EQ. 3 ) THEN
               ETA = -.774596669241483
               WE  = 0.555555555555556
            END IF
            WEIGHT = WX*WE
C
         ELSE IF ( NORD .EQ. 4 ) THEN
C
            IF ( IXSI .EQ. 1 ) THEN
               XSI = 0.861136311594053
               WX  = 0.347854845137454
            ELSE IF ( IXSI .EQ. 2 ) THEN
               XSI = 0.339981043584856
               WX  = 0.652145154862546
            ELSE IF ( IXSI .EQ. 3 ) THEN
               XSI = -.339981043584856
               WX  = 0.652145154862546
            ELSE IF ( IXSI .EQ. 4 ) THEN
               XSI = -.861136311594053
               WX  = 0.347854845137454
            END IF
            IF ( JETA .EQ. 1 ) THEN
```

```
            ETA = 0.861136311594053
            WE  = 0.347854845137454
        ELSE IF ( JETA .EQ. 2 ) THEN
            ETA = 0.339981043584856
            WE  = 0.652145154862546
        ELSE IF ( JETA .EQ. 3 ) THEN
            ETA = -.339981043584856
            WE  = 0.652145154862546
        ELSE IF ( JETA .EQ. 4 ) THEN
            ETA = -.861136311594053
            WE  = 0.347854845137454
        END IF
        WEIGHT = WX*WE
C
      ELSE IF ( NORD .EQ. 5 ) THEN
C
        IF ( IXSI .EQ. 1 ) THEN
            XSI = 0.906179845938664
            WX  = 0.236926885056189
        ELSE IF ( IXSI .EQ. 2 ) THEN
            XSI = 0.538469310105683
            WX  = 0.478628670499366
        ELSE IF ( IXSI .EQ. 3 ) THEN
            XSI = 0.000000000000000
            WX  = 0.568888888888889
        ELSE IF ( IXSI .EQ. 4 ) THEN
            XSI = -.538469310105683
            WX  = 0.478628670499366
        ELSE IF ( IXSI .EQ. 5 ) THEN
            XSI = -.906179845938664
            WX  = 0.236926885056189
        END IF
        IF ( JETA .EQ. 1 ) THEN
            ETA = 0.906179845938664
            WE  = 0.236926885056189
        ELSE IF ( JETA .EQ. 2 ) THEN
            ETA = 0.538469310105683
            WE  = 0.478628670499366
        ELSE IF ( JETA .EQ. 3 ) THEN
            ETA = 0.000000000000000
            WE  = 0.568888888888889
        ELSE IF ( JETA .EQ. 4 ) THEN
            ETA = -.538469310105683
            WE  = 0.478628670499366
        ELSE IF ( JETA .EQ. 5 ) THEN
            ETA = -.906179845938664
            WE  = 0.236926885056189
        END IF
        WEIGHT = WX*WE
C
      END IF
C
    ELSE IF ( NELDIM .EQ. 3 ) THEN
C
      IF ( NORD .EQ. 1 ) THEN
C
        XSI = 0.0
        ETA = 0.0
        CEE = 0.0
        WEIGHT = 8.0
C
      ELSE IF ( NORD .EQ. 2 ) THEN
C
        WEIGHT = 1.000
        XSI = 0.577350269189626
        ETA = 0.577350269189626
        CEE = 0.577350269189626
        IF ( IXSI .EQ. 2 ) XSI = -.577350269189626
```

```
            IF ( JETA .EQ. 2 ) ETA = -.577350269189626
            IF ( KCEE .EQ. 2 ) CEE = -.577350269189626
C
         ELSE IF ( NORD .EQ. 3 ) THEN
C
            IF ( IXSI .EQ. 1 ) THEN
               XSI = 0.774596669241483
               WX  = 0.555555555555556
            ELSE IF ( IXSI .EQ. 2 ) THEN
               XSI = 0.000000000000000
               WX  = 0.888888888888889
            ELSE IF ( IXSI .EQ. 3 ) THEN
               XSI = -.774596669241483
               WX  = 0.555555555555556
            END IF
            IF ( JETA .EQ. 1 ) THEN
               ETA = 0.774596669241483
               WE  = 0.555555555555556
            ELSE IF ( JETA .EQ. 2 ) THEN
               ETA = 0.000000000000000
               WE  = 0.888888888888889
            ELSE IF ( JETA .EQ. 3 ) THEN
               ETA = -.774596669241483
               WE  = 0.555555555555556
            END IF
            IF ( KCEE .EQ. 1 ) THEN
               CEE = 0.774596669241483
               WC  = 0.555555555555556
            ELSE IF ( KCEE .EQ. 2 ) THEN
               CEE = 0.000000000000000
               WC  = 0.888888888888889
            ELSE IF ( KCEE .EQ. 3 ) THEN
               CEE = -.774596669241483
               WC  = 0.555555555555556
            END IF
            WEIGHT = WX*WE*WC
C
         ELSE IF ( NORD .EQ. 4 ) THEN
C
            IF ( IXSI .EQ. 1 ) THEN
               XSI = 0.861136311594053
               WX  = 0.347854845137454
            ELSE IF ( IXSI .EQ. 2 ) THEN
               XSI = 0.339981043584856
               WX  = 0.652145154862546
            ELSE IF ( IXSI .EQ. 3 ) THEN
               XSI = -.339981043584856
               WX  = 0.652145154862546
            ELSE IF ( IXSI .EQ. 4 ) THEN
               XSI = -.861136311594053
               WX  = 0.347854845137454
            END IF
            IF ( JETA .EQ. 1 ) THEN
               ETA = 0.861136311594053
               WE  = 0.347854845137454
            ELSE IF ( JETA .EQ. 2 ) THEN
               ETA = 0.339981043584856
               WE  = 0.652145154862546
            ELSE IF ( JETA .EQ. 3 ) THEN
               ETA = -.339981043584856
               WE  = 0.652145154862546
            ELSE IF ( JETA .EQ. 4 ) THEN
               ETA = -.861136311594053
               WE  = 0.347854845137454
            END IF
            IF ( KCEE .EQ. 1 ) THEN
               CEE = 0.861136311594053
               WC  = 0.347854845137454
```

```
            ELSE IF ( KCEE .EQ. 2 ) THEN
                CEE = 0.339981043584856
                WC  = 0.652145154862546
            ELSE IF ( KCEE .EQ. 3 ) THEN
                CEE = -.339981043584856
                WC  = 0.652145154862546
            ELSE IF ( KCEE .EQ. 4 ) THEN
                CEE = -.861136311594053
                WC  = 0.347854845137454
            END IF
            WEIGHT = WX*WE*WC
C
         END IF
C
      END IF
C
      RETURN
      END
C
C
C
      SUBROUTINE MXMUL (A,B,C,IDIM,JDIM,KDIM,IROW,JCOL,KCOL)
C
C     MATRIX (A) TIMES (B)
C
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
C
      DIMENSION A(IDIM,1),B(JDIM,1),C(KDIM,1)
C
      DO I = 1, IROW
        DO K = 1, KCOL
          SUM = 0.0
            DO J = 1, JCOL
              SUM = SUM + A(I,J)*B(J,K)
            END DO
            C(I,K) = SUM
        END DO
      END DO
C
      RETURN
      END
C
C
C
      SUBROUTINE MXATB (A,B,C,IDIM,JDIM,KDIM,IROW,JCOL,KCOL)
C
C     MATRIX (A) TRANSPOSE TIMES (B)
C
      IMPLICIT DOUBLE PRECISION  (A-H,O-Z)
C
      DIMENSION A(IDIM,1),B(JDIM,1),C(KDIM,1)
C
      DO I = 1, IROW
        DO K = 1, KCOL
           SUM = 0.0
           DO J = 1, JCOL
             SUM = SUM + A(J,I)*B(J,K)
           END DO
           C(I,K) = SUM
        END DO
      END DO
C
      RETURN
      END
C
C
C
      SUBROUTINE MXINT(A,IDIM,JDIM,VAL)
```

```
C
C     MATRIX INITIALIZATION
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION A(IDIM,JDIM)
C
      DO I = 1, IDIM
        DO J = 1, JDIM
           A(I,J) = VAL
        END DO
      END DO
C
      RETURN
      END
C
C
C
      SUBROUTINE MXADD(A,B,IDIM,JDIM,IROW,JCOL,COEFF)
C
C     MATRIX ADDITION; A = A + COEFF*B
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
      DIMENSION A(IDIM,JDIM),B(IDIM,JDIM)
C
      DO I = 1, IROW
        DO J = 1, JCOL
           A(I,J) = A(I,J) + COEFF * B(I,J)
        END DO
      END DO
C
      RETURN
      END
```

APPENDIX B

Demonstration problem I: 2-D analysis of a single-lap joint.

ABAQUS INPUT FILE

```
*HEADING
 2-D SINGLE-LAP JOINT. 100 H2L6N ELEMENTS ALONG BONDLINE.
**
*NODE
1,       0.0,  0.0
51,     63.5,  0.0
151,    76.2,  0.0
605,     0.0,  1.6
655,    63.5,  1.6
755,    76.2,  1.6
1001,   63.5,  1.75
1101,   76.2,  1.75
1151,  139.7,  1.75
1605,   63.5,  3.35
1705,   76.2,  3.35
1755,  139.7,  3.35
2001,   63.5,  1.675
2101,   76.2,  1.675
**
*NGEN, NSET=BL
1,605,151
*NGEN, NSET=BM
51,655,151
*NGEN, NSET=BR
151,755,151
*NGEN, NSET=TL
1001,1605,151
*NGEN, NSET=TM
1101,1705,151
*NGEN, NSET=TR
1151,1755,151
*NGEN, NSET=MIDDLE
2001,2101,1
**
*NFILL
BL, BM,  50, 1
BM, BR, 100, 1
TL, TM, 100, 1
TM, TR,  50, 1
*ELEMENT,TYPE=CPE4
1,       1,    2,  153,  152
451,   454,  455,  606,  605
1101, 1101, 1102, 1253, 1252
1151, 1152, 1153, 1304, 1303
**
**        DEFINE ADHESIVE ELEMENT H2L6N
**
*USER ELEMENT, NODES=6, TYPE=U1, PROPERTIES=56
1,2
*ELEMENT, TYPE=U1
2001,  504,  505,  655,  656, 2001, 2002
2101, 2001, 2002, 1001, 1002, 1152, 1153
*ELGEN, ELSET=TOP
1101, 50, 1, 1, 1
1151,150, 1, 1, 3, 151, 150
*ELGEN, ELSET=BOT
1, 150, 1,1,3,151,150
451,50, 1,1,1
*ELGEN, ELSET=MID4
2001, 100, 1, 1, 1
```

```
*ELGEN, ELSET=MID5
2101, 100, 1, 1, 1
*ELSET,ELSET=ONE
 1
**
**        USER DEFINED SUBROUTINE:
**
*USER SUBROUTINE, INPUT=uel_hybrid.f
**
**        ELEMENT PROPERTIES
**
*SOLID SECTION, ELSET=TOP, MATERIAL=MID1
*SOLID SECTION, ELSET=BOT, MATERIAL=MID3
*MATERIAL, NAME=MID1
*ELASTIC,  TYPE=ISO
 0.69000E+05, 0.32E+00, 0.000000000E+00
**
**
*MATERIAL, NAME=MID3
*ELASTIC,  TYPE=ISO
 0.69000E+05, 0.32E+00, 0.000000000E+00
**
**        USER DEFINED ELEMENT PROPERTY LIST:
**
** BOTTOM ROW
**
*UEL PROPERTY, ELSET=MID4
 11.0, 1.0, 1.0
 1.0,  1.0
 0.4, 0.0, 69000.0, 69000.0, 69000.0, 0.32, 0.32, 0.32
 26136.3636, 26136.3636, 26136.3636
 1.0,  1.0
 0.15, 0.0, 3000.0, 3000.0, 3000.0, 0.36, 0.36, 0.36
 1102.9412, 1102.9412, 1102.9412,
**
** TOP ROW
**
*UEL PROPERTY, ELSET=MID5
 11.0, 1.0, 1.0
 1.0,  1.0
 0.15, 0.0, 3000.0, 3000.0, 3000.0, 0.36, 0.36, 0.36
 1102.9412, 1102.9412, 1102.9412,
 1.0,  1.0
 0.4, 0.0, 69000.0, 69000.0, 69000.0, 0.32, 0.32, 0.32
 26136.3636, 26136.3636, 26136.3636
**
**
*NSET, NSET=HOLD
1,152,303,454,605
*ELSET, ELSET=PULL
1150,1300,1450,1600
*ELSET, ELSET=NAVE
 500
*NGEN, NSET=ROLLER
   2,    5, 1
 606,  609, 1
1147, 1151, 1
1751, 1755, 1
**
**
*BOUNDARY
HOLD, 1, 2
ROLLER,  2
**
**
*STEP,PERTURBATION
*STATIC
**
```

```
**        LOAD CASE SPECIFICATION:
**
*DLOAD, OP=NEW
PULL, P2, -93.75
**
**
*NODE PRINT
 U
 RF
*EL PRINT,ELSET=NAVE,POSITION=AVERAGED AT NODES
 S
*END STEP
```

ABAQUS OUTPUT FILE

```
  AAAAAA     BBBBBBBBB     AAAAAA     QQQQQQQQ    U        U    SSSSSSSS
 A      A    B        B   A      A   Q        Q   U        U   S
A        A   B        B  A        A  Q        Q   U        U   S
A        A   B        B  A        A  Q        Q   U        U   S
AAAAAAAAAA   BBBBBBBBB   AAAAAAAAAA  Q        Q   U        U    SSSSSSSS
A        A   B        B  A        A  Q    Q   Q   U        U            S
A        A   B        B  A        A  Q     Q  Q   U        U            S
A        A   B        B  A        A  Q      Q Q   U        U            S
A        A   BBBBBBBBB   A        A   QQQQQQQQ     UUUUUUUU     SSSSSSSS
                                              Q
```

```
<|> <|> <|> <|> <|> <|> <|> <|> <|> <|>
<|> <|> <|> <|> <|> <|> <|>  |   |   |
 |   |   |   |   |   |   |  <|> <|> <|>
---------------------------------------
---------------------------------------
 |  <|>  |  <|>  |   |  <|> <|> <|> <|>
 |  <|>  |   |   |   |   |  <|> <|> <|>
<|>  |  <|>  |  <|> <|>  |  <|>  |  <|>
<|>  |  <|> <|> <|> <|> <|> <|>  |   |
<|> <|> <|> <|> <|> <|> <|>  |  <|>  |
<|> <|> <|> <|> <|> <|> <|>  |  <|> <|>
<|> <|> <|> <|> <|> <|> <|> <|> <|> <|>
```

```
   THIS PROGRAM HAS BEEN DEVELOPED BY

  HIBBITT, KARLSSON AND SORENSEN, INC.
            1080 MAIN STREET
         PAWTUCKET, R.I. 02860

THIS IS A PROPRIETARY PROGRAM. IT MAY ONLY BE
USED UNDER THE TERMS OF THE LICENSE AGREEMENT
BETWEEN HIBBITT, KARLSSON & SORENSEN, INC.
AND ARMY RESEARCH LABORATORY.
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                             *
*                     *****************                       *
*                     *  N O T I C E  *                       *
*                     *****************                       *
*                                                             *
*                                                             *
*                 THIS IS ABAQUS VERSION 5.3.                 *
*                                                             *
*                                                             *
*  PLEASE MAKE SURE YOU ARE USING VERSION 5.3 MANUALS         *
*  PLUS THE NOTES ACCOMPANYING THIS RELEASE. THESE NOTES      *
*  CAN BE OBTAINED BY USING THE INFORMATION OPTION ON THE     *
*  ABAQUS COMMAND LINE.                                       *
*                                                             *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

A B A Q U S   I N P U T   E C H O

```
                 5    10    15    20    25    30    35    40    45    50    55    60    65    70    75
               ------------------------------------------------------------------------------------------
               *HEADING
               *NODE
               1 ,0.0, 0.0
               51, 63.5, 0.0
CARD     5    151, 76.2, 0.0
```

```
605, 0.0, 1.6
655, 63.5, 1.6
755, 76.2, 1.6
1001, 63.5, 1.75
1101, 76.2, 1.75
1151, 139.7, 1.75
1605, 63.5, 3.35
1705, 76.2, 3.35
1755, 139.7, 3.35
2001, 63.5, 1.675
2101, 76.2, 1.675
*NGEN, NSET=BL
1,605,151
*NGEN, NSET=BM
51,655,151
*NGEN, NSET=BR
151,755,151
*NGEN, NSET=TL
1001,1605,151
*NGEN, NSET=TM
1101,1705,151
*NGEN, NSET=TR
1151,1755,151
*NGEN, NSET=MIDDLE
2001,2101,1
*NFILL
BL, BM, 50, 1
BM, BR, 100, 1
TL, TM, 100, 1
TM, TR, 50, 1
*ELEMENT,TYPE=CPE4
1, 1, 2, 153, 152
451, 454, 455, 606, 605
1101, 1101, 1102, 1253, 1252
1151, 1152, 1153, 1304, 1303
*USER ELEMENT,NODES=6,TYPE=U1,PROPERTIES=24,COORDINATES=3,VARIABLES=1
1,2
*ELEMENT, TYPE=U1
2001, 504, 505, 655, 656, 2001, 2002
2101, 2001, 2002, 1001, 1002, 1152, 1153
*ELGEN, ELSET=TOP
1101, 50, 1,1,1
1151, 150, 1, 1, 3, 151, 150
*ELGEN, ELSET=BOTTOM
1,150,1,1,3,151,150
451,50, 1,1,1
*ELGEN, ELSET=MID4
2001, 100, 1, 1, 1
*ELGEN, ELSET=MID5
2101, 100, 1, 1, 1
*ELSET,ELSET=ONE
 1
**
**                    USER DEFINED SUBROUTINE:
**
*USER SUBROUTINE,INPUT=uel_hybrid.f
**
**
**                    ELEMENT PROPERTIES
**
*SOLID SECTION,ELSET=TOP ,MATERIAL=MID1
*SOLID SECTION,ELSET=BOTTOM ,MATERIAL=MID3
*MATERIAL, NAME=MID1
*ELASTIC, TYPE=ISO
 0.69000E+05,  0.32E+00,  0.000000000E+00
**
**
*MATERIAL, NAME=MID3
*ELASTIC, TYPE=ISO
 0.69000E+05,  0.32E+00,  0.000000000E+00
**
**                    USER DEFINED ELEMENT PROPERTY LIST:
**
** BOTTOM ROW
*UEL PROPERTY,ELSET=MID4
 0.69E5,0.32,1.0
 0.3E4,0.36,1.0
 6.0,1.0,3.0,0.0
** TOP ROW
*UEL PROPERTY,ELSET=MID5
 0.3E4,0.36,1.0
 0.69E5,0.32,1.0
 6.0,1.0,3.0,0.0
*NSET,NSET=HOLD
1,152,303,454,605
```

```
*ELSET,ELSET=PULL
1150,1300,1450,1600
*ELSET, ELSET=NAVE
 500
*NGEN,NSET=ROLLER
2,5,1
606,609,1
1147,1151,1
1751,1755,1
**
**
*BOUNDARY
HOLD,1,2
ROLLER,2
*STEP,PERTURBATION
*STATIC
**
**                   LOAD CASE SPECIFICATION:
**
*DLOAD, OP=NEW
PULL,P2,-93.75
*NODE PRINT
 U
 RF
*EL PRINT,ELSET=NAVE,POSITION=AVERAGED AT NODES
 S
*END STEP
------------------------------------------------------------------------------
    5    10    15    20    25    30    35    40    45    50    55    60    65    70    75
------------------------------------------------------------------------------
```

```
  OPTIONS BEING PROCESSED
***************************

*HEADING
*NODE
*NGEN, NSET=BL
*NGEN, NSET=BM
*NGEN, NSET=BR
*NGEN, NSET=TL
*NGEN, NSET=TM
*NGEN, NSET=TR
*NGEN, NSET=MIDDLE
*NFILL
   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1          1      152      303      454      605

        BOUND  2         51      202      353      504      655

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1         51      202      353      504      655

        BOUND  2        151      302      453      604      755

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1       1001     1152     1303     1454     1605

        BOUND  2       1101     1252     1403     1554     1705

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1       1101     1252     1403     1554     1705

        BOUND  2       1151     1302     1453     1604     1755

*ELEMENT,TYPE=CPE4
*USER ELEMENT,NODES=6,TYPE=U1,PROPERTIES=24,COORDINATES=3,VARIABLES=1
*ELEMENT, TYPE=U1
*ELGEN, ELSET=TOP
*ELGEN, ELSET=BOTTOM
*ELGEN, ELSET=MID4
*ELGEN, ELSET=MID5
*ELSET,ELSET=ONE
```

```
*NSET,NSET=HOLD
*ELSET,ELSET=PULL
*ELSET, ELSET=NAVE
*NGEN,NSET=ROLLER
*MATERIAL, NAME=MID1
*ELASTIC, TYPE=ISO
*MATERIAL, NAME=MID3
*ELASTIC, TYPE=ISO
*USER ELEMENT,NODES=6,TYPE=U1,PROPERTIES=24,COORDINATES=3,VARIABLES=1
*SOLID SECTION,ELSET=TOP ,MATERIAL=MID1
*SOLID SECTION,ELSET=BOTTOM ,MATERIAL=MID3
*UEL PROPERTY,ELSET=MID4
*UEL PROPERTY,ELSET=MID5
*STEP,PERTURBATION
*STATIC
*DLOAD, OP=NEW
*EL PRINT,ELSET=NAVE,POSITION=AVERAGED AT NODES
*END STEP
*BOUNDARY
*STEP,PERTURBATION
*STATIC
*NODE PRINT
*END STEP
```

E L E M E N T   D E F I N I T I O N S

NUMBER	TYPE	PROPERTY REFERENCE	NODES FORMING ELEMENT					
1	CPE4	2	1	2	153	152		
2	CPE4	2	2	3	154	153		
3	CPE4	2	3	4	155	154		
4	CPE4	2	4	5	156	155		
5	CPE4	2	5	6	157	156		
6	CPE4	2	6	7	158	157		
7	CPE4	2	7	8	159	158		
8	CPE4	2	8	9	160	159		
9	CPE4	2	9	10	161	160		
10	CPE4	2	10	11	162	161		
.	.	.	.	.	.	.		
.	.	.	.	.	.	.		
.	.	.	.	.	.	.		
1590	CPE4	1	1593	1594	1745	1744		
1591	CPE4	1	1594	1595	1746	1745		
1592	CPE4	1	1595	1596	1747	1746		
1593	CPE4	1	1596	1597	1748	1747		
1594	CPE4	1	1597	1598	1749	1748		
1595	CPE4	1	1598	1599	1750	1749		
1596	CPE4	1	1599	1600	1751	1750		
1597	CPE4	1	1600	1601	1752	1751		
1598	CPE4	1	1601	1602	1753	1752		
1599	CPE4	1	1602	1603	1754	1753		
1600	CPE4	1	1603	1604	1755	1754		
2001	U1	3	504	505	655	656	2001	2002
2002	U1	3	505	506	656	657	2002	2003
2003	U1	3	506	507	657	658	2003	2004
2004	U1	3	507	508	658	659	2004	2005
2005	U1	3	508	509	659	660	2005	2006
2006	U1	3	509	510	660	661	2006	2007
2007	U1	3	510	511	661	662	2007	2008
2008	U1	3	511	512	662	663	2008	2009
2009	U1	3	512	513	663	664	2009	2010
2010	U1	3	513	514	664	665	2010	2011
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
2190	U1	4	2090	2091	1090	1091	1241	1242
2191	U1	4	2091	2092	1091	1092	1242	1243
2192	U1	4	2092	2093	1092	1093	1243	1244
2193	U1	4	2093	2094	1093	1094	1244	1245
2194	U1	4	2094	2095	1094	1095	1245	1246
2195	U1	4	2095	2096	1095	1096	1246	1247
2196	U1	4	2096	2097	1096	1097	1247	1248
2197	U1	4	2097	2098	1097	1098	1248	1249
2198	U1	4	2098	2099	1098	1099	1249	1250
2199	U1	4	2099	2100	1099	1100	1250	1251
2200	U1	4	2100	2101	1100	1101	1251	1252

U S E R   E L E M E N T S

ELEMENT TYPE U1
NUMBER OF NODES 6

NUMBER OF COORDINATES 3
NUMBER OF PROPERTIES 24
NUMBER OF VARIABLES 1

DEGREES OF FREEDOM

NODE	D.O.F.	
1	1	2
2	1	2
3	1	2
4	1	2
5	1	2
6	1	2

S O L I D   S E C T I O N

PROPERTY NUMBER 1
MATERIAL NAME MID1
ATTRIBUTES 1.0000 .00000E+00 .00000E+00

HOURGLASS CONTROL STIFFNESS PARAMETER 130.68

(USED WITH LOWER ORDER REDUCED INTEGRATED SOLID ELEMENTS LIKE CPS4R,CPE4RH,C3D8R)

PROPERTY NUMBER 2
MATERIAL NAME MID3
ATTRIBUTES 1.0000 .00000E+00 .00000E+00

HOURGLASS CONTROL STIFFNESS PARAMETER 130.68

(USED WITH LOWER ORDER REDUCED INTEGRATED SOLID ELEMENTS LIKE CPS4R,CPE4RH,C3D8R)

U S E R   E L E M E N T   P R O P E R T Y

PROPERTY NUMBER 3
PROPERTIES

11.00	1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+0
1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+0
.4000	.0000E+00	6.9000E+04	6.9000E+04	6.9000E+04	.3200	.3200	.3200
2.6136E+04	2.6136E+04	2.6136E+04	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+0
1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+0
.1500	.0000E+00	3000.	3000.	3000.	.3600	.3600	.3600
1103.	1103.	1103.	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+0

PROPERTY NUMBER 4
PROPERTIES

11.00	1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
.1500	.0000E+00	3000.	3000.	3000.	.3600	.3600	.3600
1103.	1103.	1103.	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
1.000	1.000	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00
.4000	.0000E+00	6.9000E+04	6.9000E+04	6.9000E+04	.3200	.3200	.3200
2.6136E+04	2.6136E+04	2.6136E+04	.0000E+00	.0000E+00	.0000E+00	.0000E+00	.0000E+00

M A T E R I A L   D E S C R I P T I O N

MATERIAL NAME: MID1

ELASTIC	YOUNG'S MODULUS	POISSON'S RATIO
	69000.	.32000

MATERIAL NAME: MID3

ELASTIC	YOUNG'S MODULUS	POISSON'S RATIO
	69000.	.32000

E L E M E N T   S E T S

SET	TOP	MEMBERS								
			1101	1102	1103	1104	1105	1106	1107	1108	11
			1113	1114	1115	1116	1117	1118	1119	1120	11
			1125	1126	1127	1128	1129	1130	1131	1132	11
			1581	1582	1583	1584	1585	1586	1587	1588	15
			1593	1594	1595	1596	1597	1598	1599	1600	

SET	BOTTOM	MEMBERS	1	2	3	4	5	6	7	8	
			13	14	15	16	17	18	19	20	
			481	482	483	484	485	486	487	488	4
			493	494	495	496	497	498	499	500	
SET	MID4	MEMBERS	2001	2002	2003	2004	2005	2006	2007	2008	20
			2013	2014	2015	2016	2017	2018	2019	2020	20
			2097	2098	2099	2100					
SET	MID5	MEMBERS	2101	2102	2103	2104	2105	2106	2107	2108	21
			2113	2114	2115	2116	2117	2118	2119	2120	21
			2197	2198	2199	2200					
SET	ONE	MEMBERS	1								
SET	PULL	MEMBERS	1150	1300	1450	1600					
SET	NAVE	MEMBERS	500								

N O D E   S E T S

SET	BL	MEMBERS	1	152	303	454	605				
SET	BM	MEMBERS	51	202	353	504	655				
SET	BR	MEMBERS	151	302	453	604	755				
SET	TL	MEMBERS	1001	1152	1303	1454	1605				
SET	TM	MEMBERS	1101	1252	1403	1554	1705				
SET	TR	MEMBERS	1151	1302	1453	1604	1755				
SET	MIDDLE	MEMBERS	2001	2002	2003	2004	2005	2006	2007	2008	20
			2013	2014	2015	2016	2017	2018	2019	2020	20
			2025	2026	2027	2028	2029	2030	2031	2032	20
			2037	2038	2039	2040	2041	2042	2043	2044	20
			2049	2050	2051	2052	2053	2054	2055	2056	20
			2061	2062	2063	2064	2065	2066	2067	2068	20
			2073	2074	2075	2076	2077	2078	2079	2080	20
			2085	2086	2087	2088	2089	2090	2091	2092	20
			2097	2098	2099	2100	2101				
SET	HOLD	MEMBERS	1	152	303	454	605				
SET	ROLLER	MEMBERS	2	3	4	5	606	607	608	609	11
			1151	1751	1752	1753	1754	1755			

N O D E   D E F I N I T I O N S

NODE NUMBER	COORDINATES			SINGLE POINT CONSTRAINTS TYPE	PLUS	DOF
1	.00000E+00	.00000E+00	.00000E+00			1 2
2	1.2700	.00000E+00	.00000E+00			2
3	2.5400	.00000E+00	.00000E+00			2
4	3.8100	.00000E+00	.00000E+00			2
5	5.0800	.00000E+00	.00000E+00			2
6	6.3500	.00000E+00	.00000E+00			
7	7.6200	.00000E+00	.00000E+00			
8	8.8900	.00000E+00	.00000E+00			
9	10.160	.00000E+00	.00000E+00			
10	11.430	.00000E+00	.00000E+00			
.	.	.	.			
.	.	.	.			
.	.	.	.			
2091	74.930	1.6750	.00000E+00			
2092	75.057	1.6750	.00000E+00			
2093	75.184	1.6750	.00000E+00			
2094	75.311	1.6750	.00000E+00			
2095	75.438	1.6750	.00000E+00			
2096	75.565	1.6750	.00000E+00			
2097	75.692	1.6750	.00000E+00			
2098	75.819	1.6750	.00000E+00			
2099	75.946	1.6750	.00000E+00			
2100	76.073	1.6750	.00000E+00			
2101	76.200	1.6750	.00000E+00			

S T E P 1 S T A T I C A N A L Y S I S

FIXED TIME INCREMENTS
TIME INCREMENT IS 2.220E-16
TIME PERIOD IS 2.220E-16

THIS IS A LINEAR PERTURBATION STEP.
ALL LOADS ARE DEFINED AS CHANGE IN LOAD TO THE REFERENCE STATE

EXTRAPOLATION WILL NOT BE USED

CHARACTERISTIC ELEMENT LENGTH .492

PRINT OF INCREMENT NUMBER, TIME, ETC., EVERY 1 INCREMENTS

E L E M E N T P R I N T

SUMMARIES WILL BE PRINTED WHERE APPLICABLE

TABLE 1 S11 S22 S33 S12

N O D E P R I N T

THE FOLLOWING TABLE IS PRINTED FOR ALL NODES AT EVERY 1 INCREMENT

SUMMARIES WILL BE PRINTED

TABLE 1 U1 U2

THE FOLLOWING TABLE IS PRINTED FOR ALL NODES AT EVERY 1 INCREMENT

SUMMARIES WILL BE PRINTED

TABLE 2 RF1 RF2

D I S T R I B U T E D L O A D S

ELEMENT	LOAD TYPE	AMP. REF.	MAGNITUDE	ELEMENT	LOAD TYPE	AMP. REF.	MAGNITUDE
1150	P2		-93.750	1300	P2		-93.750
1600	P2		-93.750	1450	P2		-93.750

B O U N D A R Y C O N D I T I O N S

NODE	DOF	AMP. REF.	MAGNITUDE	NODE	DOF	AMP. REF.	MAGNITUDE
1	1	(RAMP)	.00000E+00	1	2	(RAMP)	.00000E+00
2	2	(RAMP)	.00000E+00	3	2	(RAMP)	.00000E+00
4	2	(RAMP)	.00000E+00	5	2	(RAMP)	.00000E+00
152	1	(RAMP)	.00000E+00	152	2	(RAMP)	.00000E+00
303	1	(RAMP)	.00000E+00	303	2	(RAMP)	.00000E+00
454	1	(RAMP)	.00000E+00	454	2	(RAMP)	.00000E+00
605	1	(RAMP)	.00000E+00	605	2	(RAMP)	.00000E+00
606	2	(RAMP)	.00000E+00	607	2	(RAMP)	.00000E+00
608	2	(RAMP)	.00000E+00	609	2	(RAMP)	.00000E+00
1147	2	(RAMP)	.00000E+00	1148	2	(RAMP)	.00000E+00
1149	2	(RAMP)	.00000E+00	1150	2	(RAMP)	.00000E+00
1151	2	(RAMP)	.00000E+00	1751	2	(RAMP)	.00000E+00
1752	2	(RAMP)	.00000E+00	1753	2	(RAMP)	.00000E+00
1754	2	(RAMP)	.00000E+00	1755	2	(RAMP)	.00000E+00

- (RAMP) OR (STEP) - INDICATE USE OF DEFAULT AMPLITUDES ASSOCIATED WITH THE STEP

W A V E F R O N T M I N I M I Z A T I O N

WAVEFRONT MINIMIZATION METHOD 1 WILL BE USED.
NUMBER OF NODES 1611
NUMBER OF ELEMENTS 1200
ORIGINAL MAXIMUM D.O.F WAVEFRONT ESTIMATED AS 714
ORIGINAL RMS D.O.F WAVEFRONT ESTIMATED AS 429
PERIPHERAL DIAMETER IS DEFINED BY NODES 1 1151

WAVEFRONT OPTIMIZED BY CHOOSING 1151 AS THE STARTING NODE

MINIMUM WAVEFRONT OBTAINED USING METHOD 1. USE
*WAVEFRONT MINIMIZATION, NODES, METHOD=1
1, 1151
TO REDUCE THE CPU TIME ON SUBSEQUENT JOBS USING THIS SAME MESH.

P R O B L E M S I Z E

NUMBER OF ELEMENTS IS	1200
NUMBER OF NODES IS	1611
NUMBER OF NODES DEFINED BY THE USER	1611
NUMBER OF INTERNAL NODES GENERATED BY THE PROGRAM	0
TOTAL NUMBER OF VARIABLES IN THE MODEL	3222
(DEGREES OF FREEDOM PLUS ANY LAGRANGE MULTIPLIER VARIABLES)	
MAXIMUM D.O.F. WAVEFRONT ESTIMATED AS	32
RMS WAVEFRONT ESTIMATED AS	24

FILE SIZES - THESE VALUES ARE IN WORDS AND ARE CONSERVATIVE UPPER BOUNDS

UNIT	LENGTH
21	167400
22	167400

IF THE RESTART FILE IS WRITTEN ITS LENGTH WILL BE APPROXIMATELY
107747 WORDS WRITTEN IN THE PRE PROGRAM
PLUS 60720 WORDS WRITTEN AT THE BEGINNING OF EACH STEP
PLUS 223141 WORDS FOR EACH INCREMENT WRITTEN TO THE RESTART FILE

ALLOCATED WORKSPACE 436165
*USER SUBROUTINE,INPUT=uel_hybrid.f

END OF USER INPUT PROCESSING

JOB TIME SUMMARY
CPU TIME (SEC) = 5.8000

S T E P 1 S T A T I C A N A L Y S I S

FIXED TIME INCREMENTS	
TIME INCREMENT IS	2.220E-16
TIME PERIOD IS	2.220E-16

THIS IS A LINEAR PERTURBATION STEP.
ALL LOADS ARE DEFINED AS CHANGE IN LOAD TO THE REFERENCE STATE

ELEMENT ID 2101

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	-.797E+00	.426E+02	.247E+02
-1.0000	1.0000	.498E+01	.317E+02	.161E+02
1.0000	-1.0000	.138E+02	.693E+02	.402E+02
1.0000	1.0000	.332E+02	.619E+02	.438E+02
.0000	.0000	.159E+02	.531E+02	.330E+02
-.5774	-.5774	.616E+01	.462E+02	.297E+02
.5774	-.5774	.962E+01	.633E+02	.364E+02
-.5774	.5774	.178E+02	.412E+02	.263E+02
.5774	.5774	.258E+02	.594E+02	.370E+02

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	-.265E+02	.317E+02	.161E+02
-1.0000	1.0000	-.111E+02	-.170E+01	.110E+02
1.0000	-1.0000	.528E+02	.619E+02	.438E+02
1.0000	1.0000	.203E+02	.242E+02	.772E+00
.0000	.0000	.349E+00	.158E+02	-.107E+01
-.5774	-.5774	.166E+00	.234E+02	-.907E+01
.5774	-.5774	.122E+02	.384E+02	.354E+01

-.5774	.5774	.212E+01	.275E+01	.133E+02
.5774	.5774	-.174E+01	.163E+02	.133E+02

ELEMENT STRAIN ENERGY = .801E-02

ELEMENT ID 2001

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.202E+03	.242E+02	-.459E+01
-1.0000	1.0000	.445E+03	.115E+03	.647E+02
1.0000	-1.0000	.169E+03	.177E+02	-.627E+01
1.0000	1.0000	.368E+03	.509E+02	.512E+02
.0000	.0000	.294E+03	.475E+02	.692E+01
-.5774	-.5774	.229E+03	.239E+02	.147E+02
.5774	-.5774	.227E+03	.320E+02	.563E+01
-.5774	.5774	.369E+03	.756E+02	.231E+02
.5774	.5774	.353E+03	.645E+02	.101E+02

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.847E+02	.115E+03	.647E+02
-1.0000	1.0000	.408E+02	.127E+03	.623E+02
1.0000	-1.0000	.432E+02	.509E+02	.512E+02
1.0000	1.0000	.735E+01	.592E+02	.417E+02
.0000	.0000	.422E+02	.866E+02	.547E+02
-.5774	-.5774	.607E+02	.106E+03	.584E+02
.5774	-.5774	.479E+02	.623E+02	.498E+02
-.5774	.5774	.364E+02	.113E+03	.610E+02
.5774	.5774	.262E+02	.674E+02	.500E+02

ELEMENT STRAIN ENERGY = .476E-01

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.
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ELEMENT ID 2100

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.203E+02	.242E+02	.772E+00
-1.0000	1.0000	.528E+02	.619E+02	.438E+02
1.0000	-1.0000	-.111E+02	-.170E+01	.110E+02
1.0000	1.0000	-.265E+02	.317E+02	.161E+02
.0000	.0000	.349E+00	.158E+02	-.1[illegible]7E+01
-.5774	-.5774	-.174E+01	.163E+02	.1[illegible]3E+02
.5774	-.5774	.212E+01	.275E+01	.133E+02
-.5774	.5774	.122E+02	.384E+02	.354E+01
.5774	.5774	.166E+00	.234E+02	-.907E+01

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.332E+02	.619E+02	.438E+02
-1.0000	1.0000	.138E+02	.693E+02	.402E+02
1.0000	-1.0000	.498E+01	.317E+02	.161E+02
1.0000	1.0000	-.797E+00	.426E+02	.247E+02
.0000	.0000	.159E+02	.531E+02	.330E+02
-.5774	-.5774	.258E+02	.594E+02	.370E+02
.5774	-.5774	.178E+02	.412E+02	.263E+02
-.5774	.5774	.962E+01	.633E+02	.364E+02
.5774	.5774	.616E+01	.462E+02	.297E+02

ELEMENT ID 2200

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.735E+01	.592E+02	.417E+02
-1.0000	1.0000	.432E+02	.509E+02	.512E+02
1.0000	-1.0000	.408E+02	.127E+03	.623E+02

1.0000	1.0000	.847E+02	.115E+03	.647E+02
.0000	.0000	.422E+02	.866E+02	.547E+02
-.5774	-.5774	.262E+02	.674E+02	.500E+02
.5774	-.5774	.364E+02	.113E+03	.610E+02
-.5774	.5774	.479E+02	.623E+02	.498E+02
.5774	.5774	.607E+02	.106E+03	.584E+02

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

STRESS POINTS		STRESS COMPONENTS		
CI	CJ	SXX	SYY	SXY
-1.0000	-1.0000	.368E+03	.509E+02	.512E+02
-1.0000	1.0000	.169E+03	.177E+02	-.627E+01
1.0000	-1.0000	.445E+03	.115E+03	.647E+02
1.0000	1.0000	.202E+03	.242E+02	-.459E+01
.0000	.0000	.294E+03	.475E+02	.692E+01
-.5774	-.5774	.353E+03	.645E+02	.101E+02
.5774	-.5774	.369E+03	.756E+02	.231E+02
-.5774	.5774	.227E+03	.320E+02	.563E+01
.5774	.5774	.229E+03	.239E+02	.147E+02

ELEMENT STRAIN ENERGY = .476E-01

INCREMENT 1 SUMMARY

TIME INCREMENT COMPLETED 2.220E-16, FRACTION OF STEP COMPLETED 1.00
STEP TIME COMPLETED 2.220E-16, TOTAL TIME COMPLETED .000E+00

E L E M E N T   O U T P U T

THE FOLLOWING TABLE IS PRINTED FOR ELSET NAVE AND ELEMENT TYPE CPE4 AVERAGED AT THE NODE

NODE	FOOT-NOTE	S11	S22	S33	S12
503		248.5	22.90	86.84	-57.95
504		235.6	35.79	86.84	66.43
654		287.7	-16.28	86.84	-53.89
655		274.8	-3.389	86.84	70.49
MAXIMUM		287.7	35.79	86.84	70.49
NODE		654	504	504	655
MINIMUM		235.6	-16.28	86.84	-57.95
NODE		504	654	655	503

N O D E   O U T P U T

THE FOLLOWING TABLE IS PRINTED FOR ALL NODES

NODE	FOOT-NOTE	U1	U2
2		1.2104E-03	.0000E+00
3		2.3850E-03	.0000E+00
4		3.8386E-03	.0000E+00
5		6.3518E-03	.0000E+00
6		9.7042E-03	4.8198E-03
7		1.3104E-02	1.1474E-02
8		1.6396E-02	2.1403E-02
9		1.9556E-02	3.3845E-02
10		2.2586E-02	4.8795E-02
.		.	.
.		.	.
.		.	.
2091		.1302	-.2619
2092		.1304	-.2684
2093		.1307	-.2748
2094		.1309	-.2812
2095		.1312	-.2875
2096		.1314	-.2939
2097		.1317	-.3003
2098		.1321	-.3066
2099		.1324	-.3129
2100		.1325	-.3189
2101		.1315	-.3263
MAXIMUM		.2527	.6578

AT NODE	1755	189
MINIMUM	.0000E+00	-.6578
AT NODE	1	1567

THE FOLLOWING TABLE IS PRINTED FOR ALL NODES

NODE	FOOT-NOTE	RF1	RF2
1		-18.66	-27.60
2		.0000E+00	-56.85
3		.0000E+00	-49.30
4		.0000E+00	-42.34
5		.0000E+00	-62.37
152		-37.51	-.7832
303		-37.62	.6980
454		-37.46	-.2781
605		-18.74	28.11
606		.0000E+00	55.35
607		.0000E+00	62.71
608		.0000E+00	68.27
609		.0000E+00	21.39
1147		.0000E+00	-21.38
1148		.0000E+00	-68.27
1149		.0000E+00	-62.72
1150		.0000E+00	-55.34
1151		.0000E+00	-28.06
1751		.0000E+00	62.36
1752		.0000E+00	42.35
1753		.0000E+00	49.26
1754		.0000E+00	56.86
1755		.0000E+00	27.92
MAXIMUM		.0000E+00	68.27
AT NODE		2	608
MINIMUM		-37.62	-68.27
AT NODE		303	1148

THE ANALYSIS HAS BEEN COMPLETED

APPENDIX C

Demonstration problem II: 3-D analysis of a single-lap joint.

ABAQUS INPUT FILE

```
*HEADING
3-D SINGLE-LAP JOINT.  100 H2L12N ELEMENTS ALONG BONDLINE.
*PREPRINT, ECHO = NO, HISTORY = NO, MODEL = NO
*NODE
1,        0.0,    0.0,    0.0
301,     63.5,    0.0,    0.0
401,     76.2,    0.0,    0.0
4001,     0.0,    0.0,    1.6
4301,    63.5,    0.0,    1.6
4401,    76.2,    0.0,    1.6
5001,    63.5,    0.0,    1.75
5101,    76.2,    0.0,    1.75
5401,   139.7,    0.0,    1.75
9001,    63.5,    0.0,    3.35
9101,    76.2,    0.0,    3.35
9401,   139.7,    0.0,    3.35
4701,    63.5,    0.0,    1.675
4801,    76.2,    0.0,    1.675
50001,    0.0,    1.0,    0.0
50301,   63.5,    1.0,    0.0
50401,   76.2,    1.0,    0.0
54001,    0.0,    1.0,    1.6
54301,   63.5,    1.0,    1.6
54401,   76.2,    1.0,    1.6
55001,   63.5,    1.0,    1.75
55101,   76.2,    1.0,    1.75
55401,  139.7,    1.0,    1.75
59001,   63.5,    1.0,    3.35
59101,   76.2,    1.0,    3.35
59401,  139.7,    1.0,    3.35
54701,   63.5,    1.0,    1.675
54801,   76.2,    1.0,    1.675
**
*NGEN, NSET=FBL
1,4001,1000
*NGEN, NSET=FBM
301,4301,1000
*NGEN, NSET=FBR
401,4401,1000
*NGEN, NSET=FTL
5001,9001,1000
*NGEN, NSET=FTM
5101,9101,1000
*NGEN, NSET=FTR
5401,9401,1000
*NGEN, NSET=FMIDDLE
4701, 4801, 1
*NGEN, NSET=BBL
50001,54001,1000
*NGEN, NSET=BBM
50301,54301,1000
*NGEN, NSET=BBR
50401,54401,1000
*NGEN, NSET=BTL
55001,59001,1000
*NGEN, NSET=BTM
55101,59101,1000
```

```
*NGEN, NSET=BTR
55401,59401,1000
*NGEN, NSET=BMIDDLE
54701,54801, 1
**
*NFILL,NSET=FRONT
FBL,FBM,300
FBM,FBR,100
FTL,FTM,100
FTM,FTR,300
*NFILL,NSET=BACK
BBL,BBM,300
BBM,BBR,100
BTL,BTM,100
BTM,BTR,300
*NFILL
FRONT,BACK,5,10000
FMIDDLE,BMIDDLE,5,10000
**
*ELEMENT, TYPE=C3D8
1,      1,   3,10003,10001,1001,1003,11003,11001
151,  301,  302,10302,10301,1301,1302,11302,11301
4001,3001,3003,13003,13001,4001,4003,14003,14001
5001,5101,5103,15103,15101,6101,6103,16103,16101
6001,6001,6002,16002,16001,7001,7002,17002,17001
6101,6101,6103,16103,16101,7101,7103,17103,17101
**
*ELGEN,ELSET=BOT
1,   150,2,1,3,1000,1000,5,10000,10000
151, 100,1,1,3,1000,1000,5,10000,10000
4001,150,2,1,1,,,5,10000,10000
**
*ELGEN,ELSET=TOP
5001,150,2,1,1,,,5,10000,10000
6001,100,1,1,3,1000,1000,5,10000,10000
6101,150,2,1,3,1000,1000,5,10000,10000
**
** DEFINE ADHESIVE ELEMENT H2L12N
**
*USER ELEMENT,NODES=12,TYPE=U5,PROPERTIES=100,COORDINATES=3,VARIABLES=1
1, 2, 3
*ELEMENT,TYPE=U5
4701,3301,3302,13302,13301,4301,4302,14302,14301,4701,4702,14702,14701
4801,4701,4702,14702,14701,5001,5002,15002,15001,6001,6002,16002,16001
*ELGEN,ELSET=ADHBOT
4701,100,1,1,1,,,5,10000,10000
*ELGEN,ELSET=ADHTOP
4801,100,1,1,1,,,5,10000,10000
**
** USER DEFINED SUBROUTINE:
**
*USER SUBROUTINE,INPUT=uel_report.f
**
** ELEMENT PROPERTIES
**
*SOLID SECTION,ELSET=TOP ,MATERIAL=MID1
*MATERIAL, NAME=MID1
*ELASTIC, TYPE=ISO
 69000.0,  0.32,  0.0
**
*SOLID SECTION,ELSET=BOT ,MATERIAL=MID3
*MATERIAL, NAME=MID3
*ELASTIC, TYPE=ISO
 69000.0,  0.32,  0.0
**
**  USER DEFINED ELEMENT PROPERTY LIST:
**
** TOP ROW
```

```
**
*UEL PROPERTY,ELSET=ADHTOP
11.0, 1.0, 1.0
1.0
0.15, 0.0, 3000.0, 3000.0, 3000.0, 0.36, 0.36, 0.36
1102.9412, 1102.9412, 1102.9412
1.0
0.4,  0.0, 69000.0, 69000.0, 69000.0, 0.32, 0.32, 0.32
26136.3636, 26136.3636, 26136.3636
**
** BOTTOM ROW
**
*UEL PROPERTY,ELSET=ADHBOT
11.0, 1.0, 1.0
1.0
0.4,  0.0, 69000.0, 69000.0, 69000.0, 0.32, 0.32, 0.32
26136.3636, 26136.3636, 26136.3636
1.0
0.15, 0.0, 3000.0, 3000.0, 3000.0, 0.36, 0.36, 0.36
1102.9412, 1102.9412, 1102.9412
*NSET,NSET=L,GENERATE
10001, 14001, 1000
20001, 24001, 1000
30001, 34001, 1000
40001, 44001, 1000
**
*NSET,NSET=LSIDE
L,FBL,BBL
*NSET,NSET=ROLLB,GENERATE
1,        24, 1
10001, 10024, 1
20001, 20024, 1
30001, 30024, 1
40001, 40024, 1
50001, 50024, 1
4001,   4024, 1
14001, 14024, 1
24001, 24024, 1
34001, 34024, 1
44001, 44024, 1
54001, 54024, 1
*NSET,NSET=ROLLE,GENERATE
 5378,  5401, 1
15378, 15401, 1
25378, 25401, 1
35378, 35401, 1
45378, 45401, 1
55378, 55401, 1
 9378,  9401, 1
19378, 19401, 1
29378, 29401, 1
39378, 39401, 1
49378, 49401, 1
59378, 59401, 1
*ELSET,ELSET=PULL
 5150,  6250,  7250,  8250
15150, 16250, 17250, 18250
25150, 26250, 27250, 28250
35150, 36250, 37250, 38250
45150, 46250, 47250, 48250
*ELSET,ELSET=ONE
1
**
** BOUNDARY CONDITIONS:
**
*BOUNDARY
LSIDE, 1, 3
ROLLE, 3
```

```
ROLLB, 3
*STEP,PERTURBATION
*STATIC
**
** LOAD CASE SPECIFICATION:
**
*DLOAD, OP=NEW
PULL, P4, -93.75
*NODE PRINT
 U
*EL PRINT,ELSET=ONE
 MISES,
*END STEP
```

ABAQUS OUTPUT FILE

```
*PREPRINT, ECHO = NO, HISTORY = NO, MODEL = NO

  AAAAAA      BBBBBBBBB      AAAAAA       QQQQQQQQ     U         U     SSSSSSSS
 A      A     B        B    A      A     Q        Q    U         U    S
A        A    B        B   A        A    Q        Q    U         U    S
A        A    B        B   A        A    Q        Q    U         U    S
AAAAAAAAAA    BBBBBBBBB    AAAAAAAAAA    Q        Q    U         U     SSSSSSSS
A        A    B        B   A        A    Q    Q   Q    U         U             S
A        A    B        B   A        A    Q     Q  Q    U         U             S
A        A    B        B   A        A    Q      Q Q    U         U             S
A        A    BBBBBBBBB    A        A     QQQQQQQQ      UUUUUUUUU     SSSSSSSS
                                                   Q

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                     |   |   |   |   |   |   |  <|> <|> <|>
                    ---------------------------------------
                    ---------------------------------------
                     |  <|>  |  <|>  |   |  <|> <|> <|> <|>
                     |  <|>  |   |   |   |   |  <|> <|> <|>
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                    <|>  |  <|> <|> <|> <|> <|> <|>  |   |
                    <|> <|> <|> <|> <|> <|> <|>  |  <|>  |
                    <|> <|> <|> <|> <|> <|> <|>  |  <|> <|>
                    <|> <|> <|> <|> <|> <|> <|> <|> <|> <|>

                       THIS PROGRAM HAS BEEN DEVELOPED BY

                      HIBBITT, KARLSSON AND SORENSEN, INC.
                                1080 MAIN STREET
                             PAWTUCKET, R.I. 02860

                    THIS IS A PROPRIETARY PROGRAM. IT MAY ONLY BE
                    USED UNDER THE TERMS OF THE LICENSE AGREEMENT
                    BETWEEN HIBBITT, KARLSSON & SORENSEN, INC.
                    AND ARMY RESEARCH LABORATORY.

                 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
                 *                                                         *
                 *                   *****************                     *
                 *                   *  N O T I C E  *                     *
                 *                   *****************                     *
                 *                                                         *
                 *                                                         *
                 *               THIS IS ABAQUS VERSION 5.3.               *
                 *                                                         *
                 *                                                         *
                 *  PLEASE MAKE SURE YOU ARE USING VERSION 5.3 MANUALS     *
                 *  PLUS THE NOTES ACCOMPANYING THIS RELEASE. THESE NOTES  *
                 *  CAN BE OBTAINED BY USING THE INFORMATION OPTION ON THE *
                 *  ABAQUS COMMAND LINE.                                   *
                 *                                                         *
                 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *


   OPTIONS BEING PROCESSED
 ***************************

*HEADING
        3-D SINGLE-LAP JOINT.  100 H2L12N ELEMENTS ALONG BONDLINE.
*NODE
*NGEN, NSET=FBL
*NGEN, NSET=FBM
*NGEN, NSET=FBR
*NGEN, NSET=FTL
*NGEN, NSET=FTM
*NGEN, NSET=FTR
*NGEN, NSET=FMIDDLE
*NGEN, NSET=BBL
*NGEN, NSET=BBM
*NGEN, NSET=BBR
*NGEN, NSET=BTL
*NGEN, NSET=BTM
*NGEN, NSET=BTR
```

```
*NGEN, NSET=BMIDDLE
*NFILL,NSET=FRONT

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

   3-D SINGLE-LAP JOINT.  100 H2L12N ELEMENTS ALONG BONDLINE.

        BOUND  1              1     1001     2001     3001     4001

        BOUND  2            301     1301     2301     3301     4301

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1            301     1301     2301     3301     4301

        BOUND  2            401     1401     2401     3401     4401

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1           5001     6001     7001     8001     9001

        BOUND  2           5101     6101     7101     8101     9101

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1           5101     6101     7101     8101     9101

        BOUND  2           5401     6401     7401     8401     9401
*NFILL,NSET=BACK
   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1          50001    51001    52001    53001    54001

        BOUND  2          50301    51301    52301    53301    54301

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1          50301    51301    52301    53301    54301

        BOUND  2          50401    51401    52401    53401    54401

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1          55001    56001    57001    58001    59001

        BOUND  2          55101    56101    57101    58101    59101

   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

   3-D SINGLE-LAP JOINT.  100 H2L12N ELEMENTS ALONG BONDLINE.

        BOUND  1          55101    56101    57101    58101    59101

        BOUND  2          55401    56401    57401    58401    59401
*NFILL
   THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

        BOUND  1              1        2        3        4        5        6        7        8        9
                             11       12       13       14       15       16       17       18       19
                             21       22       23       24       25       26       27       28       29
                              .        .        .        .        .        .        .        .        .
                              .        .        .        .        .        .        .        .        .
                              .        .        .        .        .        .        .        .        .
                           9372     9373     9374     9375     9376     9377     9378     9379     9380
                           9382     9383     9384     9385     9386     9387     9388     9389     9390
                           9392     9393     9394     9395     9396     9397     9398     9399     9400

        BOUND  2          50001    50002    50003    50004    50005    50006    50007    50008    50009
                          50011    50012    50013    50014    50015    50016    50017    50018    50019
                          50021    50022    50023    50024    50025    50026    50027    50028    50029
                              .        .        .        .        .        .        .        .        .
                              .        .        .        .        .        .        .        .        .
                              .        .        .        .        .        .        .        .        .
                          59372    59373    59374    59375    59376    59377    59378    59379    59380
                          59382    59383    59384    59385    59386    59387    59388    59389    59390
```

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                    59392   59393   59394   59395   59396   59397   59398   59399   59400

THE FOLLOWING NODES WILL BE USED IN THE NFILL GENERATION

     BOUND  1        4701    4702    4703    4704    4705    4706    4707    4708    4709
                     4711    4712    4713    4714    4715    4716    4717    4718    4719
                     4721    4722    4723    4724    4725    4726    4727    4728    4729
                     4731    4732    4733    4734    4735    4736    4737    4738    4739
                     4741    4742    4743    4744    4745    4746    4747    4748    4749
                     4751    4752    4753    4754    4755    4756    4757    4758    4759
                     4761    4762    4763    4764    4765    4766    4767    4768    4769
                     4771    4772    4773    4774    4775    4776    4777    4778    4779
                     4781    4782    4783    4784    4785    4786    4787    4788    4789
                     4791    4792    4793    4794    4795    4796    4797    4798    4799
                     4801

     BOUND  2       54701   54702   54703   54704   54705   54706   54707   54708   54709
                    54711   54712   54713   54714   54715   54716   54717   54718   54719
                    54721   54722   54723   54724   54725   54726   54727   54728   54729
                    54731   54732   54733   54734   54735   54736   54737   54738   54739
                    54741   54742   54743   54744   54745   54746   54747   54748   54749
                    54751   54752   54753   54754   54755   54756   54757   54758   54759
                    54761   54762   54763   54764   54765   54766   54767   54768   54769
                    54771   54772   54773   54774   54775   54776   54777   54778   54779
                    54781   54782   54783   54784   54785   54786   54787   54788   54789
                    54791   54792   54793   54794   54795   54796   54797   54798   54799
                    54801

          *ELEMENT, TYPE=C3D8
          *ELGEN,ELSFT=BOT
          *ELGEN,ELSET=TOP
          *USER ELEMENT,NODES=12,TYPE=U5,PROPERTIES=100,COORDINATES=3,VARIABLES=1
          *ELEMENT,TYPE=U5
          *ELGEN,ELSET=ADHBOT
          *ELGEN,ELSET=ADHTOP
          *NSET,NSET=L,GENERATE
          *NSET,NSET=LSIDE
          *NSET,NSET=ROLLB,GENERATE
          *NSET,NSET=ROLLE,GENERATE
          *ELSET,ELSET=PULL
          *ELSET,ELSET=ONE
          *MATERIAL, NAME=MID1
          *ELASTIC, TYPE=ISO
          *MATERIAL, NAME=MID3
          *ELASTIC, TYPE=ISO
          *USER ELEMENT,NODES=12,TYPE=U5,PROPERTIES=100,COORDINATES=3,VARIABLES=1
          *SOLID SECTION,ELSET=TOP ,MATERIAL=MID1
          *SOLID SECTION,ELSET=BOT ,MATERIAL=MID3
          *UEL PROPERTY,ELSET=ADHTOP
          *UEL PROPERTY,ELSET=ADHBOT
          *STEP,PERTURBATION
          *STATIC
          *DLOAD, OP=NEW
          *EL PRINT,ELSET=ONE
          *END STEP
          *BOUNDARY
          *STEP,PERTURBATION
          *STATIC
          *NODE PRINT
          *END STEP

                              W A V E F R O N T   M I N I M I Z A T I O N

           WAVEFRONT MINIMIZATION METHOD 1 WILL BE USED.
           NUMBER OF NODES          15666
           NUMBER OF ELEMENTS       10000
           ORIGINAL MAXIMUM D.O.F WAVEFRONT ESTIMATED AS     8592
           ORIGINAL RMS D.O.F WAVEFRONT ESTIMATED AS         6967

           PERIPHERAL DIAMETER IS DEFINED BY NODES               1     5401

           WAVEFRONT OPTIMIZED  BY CHOOSING          1 AS THE STARTING NODE

           MINIMUM WAVEFRONT OBTAINED USING METHOD 2.   USE
           *WAVEFRONT MINIMIZATION, NODES, METHOD=2
                  1,     5401

TO REDUCE THE CPU TIME ON SUBSEQUENT JOBS USING THIS SAME MESH.

                         P R O B L E M   S I Z E

     NUMBER OF ELEMENTS IS                            10000
```

```
NUMBER OF NODES IS                                   15666
NUMBER OF NODES DEFINED BY THE USER                  15666
NUMBER OF INTERNAL NODES GENERATED BY THE PROGRAM        0
TOTAL NUMBER OF VARIABLES IN THE MODEL               46998
(DEGREES OF FREEDOM PLUS ANY LAGRANGE MULTIPLIER VARIABLES)
MAXIMUM D.O.F. WAVEFRONT ESTIMATED AS                  273
RMS WAVEFRONT ESTIMATED AS                             172


FILE SIZES - THESE VALUES ARE IN WORDS AND ARE CONSERVATIVE UPPER BOUNDS

  UNIT           LENGTH

    2           8815647
   10           2282000
   19           3328000
   21           3320000
   22           3320000
   25           2220000


IF THE RESTART FILE IS WRITTEN ITS LENGTH WILL BE APPROXIMATELY
             3323232 WORDS WRITTEN IN THE PRE PROGRAM
     PLUS    2772000 WORDS WRITTEN AT THE BEGINNING OF EACH STEP
     PLUS    4134521 WORDS FOR EACH INCREMENT WRITTEN TO THE RESTART FILE


ALLOCATED WORKSPACE                                              2002539
*USER SUBROUTINE,INPUT=uel_report.f

                           END OF USER INPUT PROCESSING

                     S T E P     1    S T A T I C   A N A L Y S I S


FIXED TIME INCREMENTS
TIME INCREMENT IS                                     2.220E-16
TIME PERIOD IS                                        2.220E-16

THIS IS A LINEAR PERTURBATION STEP.
ALL LOADS ARE DEFINED AS CHANGE IN LOAD TO THE REFERENCE STATE


ELEMENT ID 44900
```

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS			STRESS COMPONENTS					
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.546E+01	.245E+01	.506E+02	.652E+01	.552E+02	.165E+01
-1.0000	-1.0000	1.0000	.485E+02	.269E+02	.463E+02	.594E+01	.411E+02	.119E+01
-1.0000	1.0000	-1.0000	.548E+01	.129E+01	.418E+02	-.193E+01	.551E+02	-.235E+01
-1.0000	1.0000	1.0000	.470E+02	.263E+02	.396E+02	-.251E+01	.439E+02	-.197E+01
1.0000	-1.0000	-1.0000	.318E+02	.438E+02	.135E+03	-.936E+01	.678E+02	.338E+01
1.0000	-1.0000	1.0000	.743E+02	.629E+02	.119E+03	-.926E+01	.538E+02	.254E+01
1.0000	1.0000	-1.0000	.269E+02	.408E+02	.125E+03	.139E+02	.641E+02	-.626E+00
1.0000	1.0000	1.0000	.679E+02	.605E+02	.111E+03	.140E+02	.530E+02	-.618E+00
.0000	.0000	.0000	.384E+02	.331E+02	.836E+02	.215E+01	.543E+02	.399E+00
-.5774	-.5774	-.5774	.198E+02	.158E+02	.652E+02	.270E+01	.548E+02	.109E+01
.5774	-.5774	-.5774	.344E+02	.388E+02	.113E+03	-.252E+01	.617E+02	.204E+01
-.5774	.5774	-.5774	.190E+02	.150E+02	.602E+02	.169E+01	.547E+02	-.112E+01
.5774	.5774	-.5774	.320E+02	.374E+02	.107E+03	.702E+01	.604E+02	-.164E+00
-.5774	-.5774	.5774	.444E+02	.294E+02	.616E+02	.245E+01	.471E+02	.884E+00
.5774	-.5774	.5774	.588E+02	.506E+02	.105E+03	-.255E+01	.539E+02	.171E+01
-.5774	.5774	.5774	.432E+02	.287E+02	.573E+02	.143E+01	.479E+02	-.104E+01
.5774	.5774	.5774	.559E+02	.493E+02	.100E+03	.699E+01	.536E+02	-.217E+00

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS			STRAIN COMPONENTS					
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	-.773E-02	-.558E-02	.989E-02	-.229E-02	.336E-01	-.126E-03
-1.0000	-1.0000	1.0000	.515E-02	-.202E-02	.989E-02	-.333E-02	.461E-01	.149E-03
-1.0000	1.0000	-1.0000	-.713E-02	-.558E-02	.710E-02	.721E-02	.333E-01	.673E-03
-1.0000	1.0000	1.0000	.491E-02	-.202E-02	.710E-02	.616E-02	.462E-01	.519E-03
1.0000	-1.0000	-1.0000	-.773E-02	-.507E-02	.310E-01	-.178E-02	.554E-01	.254E-03
1.0000	-1.0000	1.0000	.515E-02	-.178E-02	.310E-01	-.257E-02	.679E-01	-.228E-06
1.0000	1.0000	-1.0000	-.713E-02	-.507E-02	.289E-01	.698E-02	.537E-01	.105E-02
1.0000	1.0000	1.0000	.491E-02	-.178E-02	.289E-01	.620E-02	.666E-01	.370E-03
.0000	.0000	.0000	-.120E-02	-.361E-02	.192E-01	.207E-02	.504E-01	.362E-03
-.5774	-.5774	-.5774	-.492E-02	-.473E-02	.138E-01	-.416E-03	.407E-01	.138E-03
.5774	-.5774	-.5774	-.492E-02	-.447E-02	.261E-01	-.181E-03	.532E-01	.294E-03
-.5774	.5774	-.5774	-.467E-02	-.473E-02	.123E-01	.498E-02	.405E-01	.548E-03
.5774	.5774	-.5774	-.467E-02	-.447E-02	.248E-01	.497E-02	.524E-01	.703E-03

-.5774	-.5774	.5774	.241E-02	-.271E-02	.138E-01	-.988E-03	.480E-01	.180E-03
.5774	-.5774	.5774	.241E-02	-.254E-02	.261E-01	-.667E-03	.604E-01	.159E-03
-.5774	.5774	.5774	.238E-02	-.271E-02	.123E-01	.440E-02	.479E-01	.446E-03
.5774	.5774	.5774	.238E-02	-.254E-02	.248E-01	.448E-02	.598E-01	.425E-03

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.378E+03	-.663E+01	.441E+02	.564E+01	.341E+02	.443E+01
-1.0000	-1.0000	1.0000	.190E+03	.285E+01	.211E+02	.966E+01	-.150E+02	-.158E+01
-1.0000	1.0000	-1.0000	.360E+03	-.905E+01	.385E+02	-.281E+01	.384E+02	.885E+01
-1.0000	1.0000	1.0000	.186E+03	.247E+01	.270E+02	.121E+01	-.997E+01	-.369E+01
1.0000	-1.0000	-1.0000	.391E+03	.334E+02	.111E+03	-.921E+01	.468E+02	.469E+01
1.0000	-1.0000	1.0000	.207E+03	-.271E+01	.249E+02	-.108E+02	-.229E+01	-.261E+01
1.0000	1.0000	-1.0000	.372E+03	.338E+02	.104E+03	.140E+02	.474E+02	.912E+01
1.0000	1.0000	1.0000	.203E+03	-.284E+00	.292E+02	.124E+02	-.946E+00	-.472E+01
.0000	.0000	.0000	.286E+03	.674E+01	.500E+02	.251E+01	.173E+02	.181E+01
-.5774	-.5774	-.5774	.338E+03	.151E+01	.499E+02	.273E+01	.272E+02	.380E+01
.5774	-.5774	-.5774	.346E+03	.194E+02	.807E+02	-.266E+01	.341E+02	.379E+01
-.5774	.5774	-.5774	.329E+03	.701E+00	.479E+02	.172E+01	.293E+02	.556E+01
.5774	.5774	-.5774	.337E+03	.195E+02	.781E+02	.687E+01	.349E+02	.555E+01
-.5774	-.5774	.5774	.232E+03	.166E+01	.303E+02	.437E+01	-.105E+01	-.623E+00
.5774	-.5774	.5774	.241E+03	.436E+01	.400E+02	-.290E+01	.581E+01	-.106E+01
-.5774	.5774	.5774	.228E+03	.154E+01	.321E+02	.335E+01	.129E+01	-.104E+01
.5774	.5774	.5774	.237E+03	.517E+01	.412E+02	.664E+01	.695E+01	-.148E+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.515E-02	-.202E-02	-.600E-03	-.295E-03	.921E-03	.149E-03
-1.0000	-1.0000	1.0000	.277E-02	-.945E-03	-.600E-03	-.227E-04	.552E-03	.266E-04
-1.0000	1.0000	-1.0000	.491E-02	-.202E-02	-.463E-03	.240E-03	.125E-02	.519E-03
-1.0000	1.0000	1.0000	.268E-02	-.945E-03	-.463E-03	.513E-03	.519E-03	-.212E-03
1.0000	-1.0000	-1.0000	.515E-02	-.178E-02	-.716E-03	-.153E-03	.165E-03	-.228E-06
1.0000	-1.0000	1.0000	.277E-02	-.110E-02	-.716E-03	-.113E-03	-.203E-03	-.287E-04
1.0000	1.0000	-1.0000	.491E-02	-.178E-02	-.696E-03	.188E-03	.544E-03	.370E-03
1.0000	1.0000	1.0000	.268E-02	-.110E-02	-.696E-03	.229E-03	-.189E-03	-.268E-03
.0000	.0000	.0000	.388E-02	-.146E-02	-.619E-03	.732E-04	.445E-03	.693E-04
-.5774	-.5774	-.5774	.460E-02	-.176E-02	-.601E-03	-.114E-03	.739E-03	.146E-03
.5774	-.5774	-.5774	.460E-02	-.167E-02	-.682E-03	-.836E-04	.309E-03	.720E-04
-.5774	.5774	-.5774	.448E-02	-.176E-02	-.536E-03	.172E-03	.892E-03	.286E-03
.5774	.5774	-.5774	.448E-02	-.167E-02	-.656E-03	.137E-03	.477E-03	.211E-03
-.5774	-.5774	.5774	.325E-02	-.119E-02	-.601E-03	.155E-04	.482E-03	.132E-04
.5774	-.5774	.5774	.325E-02	-.123E-02	-.682E-03	-.319E-04	.515E-04	-.301E-04
-.5774	.5774	.5774	.318E-02	-.119E-02	-.536E-03	.301E-03	.513E-03	-.504E-04
.5774	.5774	.5774	.318E-02	-.123E-02	-.656E-03	.189E-03	.983E-04	-.938E-04

ELEMENT ID 34900

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.115E+02	.225E+02	.575E+02	.488E+01	.538E+02	.300E+01
-1.0000	-1.0000	1.0000	.538E+02	.337E+02	.530E+02	.641E+01	.411E+02	.203E+01
-1.0000	1.0000	-1.0000	.132E+02	.195E+02	.562E+02	-.991E+01	.526E+02	-.162E+01
-1.0000	1.0000	1.0000	.517E+02	.306E+02	.513E+02	-.838E+01	.387E+02	-.116E+01
1.0000	-1.0000	-1.0000	.360E+02	.604E+02	.141E+03	-.102E+02	.708E+02	.235E+01
1.0000	-1.0000	1.0000	.773E+02	.675E+02	.125E+03	-.958E+01	.581E+02	.140E+01
1.0000	1.0000	-1.0000	.398E+02	.597E+02	.141E+03	.639E+01	.703E+02	-.227E+01
1.0000	1.0000	1.0000	.774E+02	.668E+02	.124E+03	.703E+01	.563E+02	-.180E+01
.0000	.0000	.0000	.451E+02	.451E+02	.936E+02	-.167E+01	.552E+02	.241E+00
-.5774	-.5774	-.5774	.259E+02	.322E+02	.734E+02	.249E+00	.544E+02	.175E+01
.5774	-.5774	-.5774	.401E+02	.538E+02	.120E+03	-.474E+01	.643E+02	.137E+01
-.5774	.5774	-.5774	.267E+02	.307E+02	.727E+02	-.446E+01	.537E+02	-.745E+00
.5774	.5774	-.5774	.416E+02	.531E+02	.120E+03	.101E+01	.638E+02	-.112E+01
-.5774	-.5774	.5774	.497E+02	.381E+02	.693E+02	.102E+01	.469E+02	.136E+01
.5774	-.5774	.5774	.637E+02	.584E+02	.112E+03	-.427E+01	.568E+02	.994E+00
-.5774	.5774	.5774	.492E+02	.366E+02	.685E+02	-.368E+01	.458E+02	-.654E+00
.5774	.5774	.5774	.639E+02	.577E+02	.112E+03	.149E+01	.559E+02	-.102[illegible]+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	-.896E-02	-.131E-02	.979E-02	-.114E-02	.337E-01	.416E-04
-1.0000	-1.0000	1.0000	.513E-02	-.188E-02	.979E-02	-.111E-02	.463E-01	.625E-04
-1.0000	1.0000	-1.0000	-.773E-02	-.131E-02	.989E-02	-.266E-02	.336E-01	-.158E-03
-1.0000	1.0000	1.0000	.515E-02	-.188E-02	.989E-02	-.262E-02	.461E-01	.138E-03
1.0000	-1.0000	-1.0000	-.896E-02	-.144E-02	.312E-01	-.102E-02	.575E-01	.820E-03
1.0000	-1.0000	1.0000	.513E-02	-.183E-02	.312E-01	-.111E-02	.702E-01	.753E-04
1.0000	1.0000	-1.0000	-.773E-02	-.144E-02	.310E-01	-.207E-02	.554E-01	.621E-03

1.0000	1.0000	1.0000	.515E-02	-.183E-02	.310E-01	-.216E-02	.679E-01	.151E-03
.0000	.0000	.0000	-.160E-02	-.161E-02	.205E-01	-.174E-02	.513E-01	.219E-03
-.5774	-.5774	-.5774	-.577E-02	-.145E-02	.143E-01	-.142E-02	.413E-01	.146E-03
.5774	-.5774	-.5774	-.577E-02	-.150E-02	.267E-01	-.130E-02	.548E-01	.503E-03
-.5774	.5774	-.5774	-.521E-02	-.145E-02	.143E-01	-.223E-02	.410E-01	.647E-04
.5774	.5774	-.5774	-.521E-02	-.150E-02	.266E-01	-.197E-02	.538E-01	.421E-03
-.5774	-.5774	.5774	.221E-02	-.175E-02	.143E-01	-.141E-02	.486E-01	.987E-04
.5774	-.5774	.5774	.221E-02	-.175E-02	.267E-01	-.134E-02	.621E-01	.200E-03
-.5774	.5774	.5774	.237E-02	-.175E-02	.143E-01	-.223E-02	.482E-01	.109E-03
.5774	.5774	.5774	.237E-02	-.175E-02	.266E-01	-.200E-02	.610E-01	.209E-03

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.380E+03	.899E+01	.507E+02	.718E+01	.347E+02	.372E+01
-1.0000	-1.0000	1.0000	.194E+03	-.278E+01	.268E+02	.123E+02	-.152E+02	-.130E+01
-1.0000	1.0000	-1.0000	.380E+03	.709E+01	.488E+02	-.761E+01	.317E+02	.228E+01
-1.0000	1.0000	1.0000	.190E+03	-.500E+01	.228E+02	-.247E+01	-.175E+02	-.288E+00
1.0000	-1.0000	-1.0000	.397E+03	.385E+02	.117E+03	-.926E+01	.517E+02	.329E+01
1.0000	-1.0000	1.0000	.209E+03	-.768E+00	.299E+02	-.558E+01	.180E+01	-.153E+01
1.0000	1.0000	-1.0000	.397E+03	.373E+02	.116E+03	.735E+01	.494E+02	.186E+01
1.0000	1.0000	1.0000	.205E+03	-.225E+01	.270E+02	.110E+02	.202E+00	-.516E+00
.0000	.0000	.0000	.294E+03	.101E+02	.548E+02	.162E+01	.171E+02	.939E+00
-.5774	-.5774	-.5774	.344E+03	.111E+02	.563E+02	.300E+01	.272E+02	.238E+01
.5774	-.5774	-.5774	.353E+03	.249E+02	.868E+02	-.283E+01	.371E+02	.216E+01
-.5774	.5774	-.5774	.344E+03	.101E+02	.551E+02	-.171E+01	.256E+02	.185E+01
.5774	.5774	-.5774	.353E+03	.241E+02	.860E+02	.292E+01	.357E+02	.163E+01
-.5774	-.5774	.5774	.236E+03	.937E+00	.346E+02	.579E+01	-.153E+01	-.195E+00
.5774	-.5774	.5774	.245E+03	.555E+01	.442E+02	-.531E+00	.836E+01	-.350E+00
-.5774	.5774	.5774	.234E+03	-.214E+00	.327E+02	.109E+01	-.286E+01	.929E-01
.5774	.5774	.5774	.243E+03	.464E+01	.426E+02	.523E+01	.726E+01	-.630E-01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.513E-02	-.188E-02	-.534E-03	.727E-05	.111E-02	.625E-04
-1.0000	-1.0000	1.0000	.280E-02	-.106E-02	-.534E-03	-.124E-03	.572E-03	.167E-04
-1.0000	1.0000	-1.0000	.515E-02	-.188E-02	-.600E-03	.414E-03	.921E-03	.138E-03
-1.0000	1.0000	1.0000	.277E-02	-.106E-02	-.600E-03	.283E-03	.552E-03	-.655E-04
1.0000	-1.0000	-1.0000	.513E-02	-.183E-02	-.703E-03	-.103E-03	.367E-03	.753E-04
1.0000	-1.0000	1.0000	.280E-02	-.112E-02	-.703E-03	-.130E-03	-.166E-03	-.418E-05
1.0000	1.0000	-1.0000	.515E-02	-.183E-02	-.716E-03	.254E-03	.165E-03	.151E-03
1.0000	1.0000	1.0000	.277E-02	-.112E-02	-.716E-03	.227E-03	-.203E-03	-.864E-04
.0000	.0000	.0000	.396E-02	-.147E-02	-.638E-03	.104E-03	.414E-03	.359E-04
-.5774	-.5774	-.5774	.464E-02	-.170E-02	-.581E-03	.447E-04	.804E-03	.630E-04
.5774	-.5774	-.5774	.464E-02	-.168E-02	-.673E-03	-.126E-04	.376E-03	.662E-04
-.5774	.5774	-.5774	.464E-02	-.170E-02	-.613E-03	.274E-03	.716E-03	.873E-04
.5774	.5774	-.5774	.464E-02	-.168E-02	-.687E-03	.200E-03	.281E-03	.906E-04
-.5774	-.5774	.5774	.329E-02	-.124E-02	-.581E-03	-.181E-04	.517E-03	.132E-04
.5774	-.5774	.5774	.329E-02	-.126E-02	-.673E-03	-[illegible]05E-04	.881E-04	.521E-05
-.5774	.5774	.5774	.328E-02	-.124E-02	-.613E-03	.211E-03	.483E-03	-.151E-04
.5774	.5774	.5774	.328E-02	-.126E-02	-.687E-03	.172E-03	.487E-04	-.230E-04

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STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.205E+03	-.225E+01	.270E+02	.110E+02	.202E+00	-.516E+00
-1.0000	-1.0000	1.0000	.397E+03	.373E+02	.116E+03	.735E+01	.494E+02	[illegible]
-1.0000	1.0000	-1.0000	.209E+03	-.768E+00	.299E+02	-.558E+01	.180E+01	-.153E+01
-1.0000	1.0000	1.0000	.397E+03	.385E+02	.117E+03	-.926E+01	.517E+02	.329E+01
1.0000	-1.0000	-1.0000	.190E+03	-.500E+01	.228E+02	-.247E+01	-.175E+02	-.288E+00
1.0000	-1.0000	1.0000	.380E+03	.709E+01	.488E+02	-.761E+01	.317E+02	.228E+01
1.0000	1.0000	-1.0000	.194E+03	-.278E+01	.268E+02	.123E+02	-.152E+02	-.130E+01
1.0000	1.0000	1.0000	.380E+03	.899E+01	.507E+02	.718E+01	.347E+02	.372E+01
.0000	.0000	.0000	.294E+03	.101E+02	.548E+02	.162E+01	.171E+02	.939E+00
-.5774	-.5774	-.5774	.243E+03	.464E+01	.426E+02	.523E+01	.726E+01	-.630E-01
.5774	-.5774	-.5774	.234E+03	-.214E+00	.327E+02	.109E+01	-.286E+01	.929E-01
-.5774	.5774	-.5774	.245E+03	.555E+01	.442E+02	-.531E+00	.836E+01	-.350E+00
.5774	.5774	-.5774	.236E+03	.937E+00	.346E+02	.579E+01	-.153E+01	-.195E+00
-.5774	-.5774	.5774	.353E+03	.241E+02	.860E+02	.292E+01	.357E+02	.163E+01
.5774	-.5774	.5774	.344E+03	.101E+02	.551E+02	-.171E+01	.256E+02	.185E+01
-.5774	.5774	.5774	.353E+03	.249E+02	.868E+02	-.283E+01	.371E+02	.216E+01
.5774	.5774	.5774	.344E+03	.111E+02	.563E+02	.300E+01	.272E+02	.238E+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.277E-02	-.112E-02	-.716E-03	.227E-03	-.203E-03	-.864E-04
-1.0000	-1.0000	1.0000	.515E-02	-.183E-02	-.716E-03	.254E-03	.165E-03	.151E-03
-1.0000	1.0000	-1.0000	.280E-02	-.112E-02	-.703E-03	-.130E-03	-.166E-03	-.418E-05
-1.0000	1.0000	1.0000	.513E-02	-.183E-02	-.703E-03	-.103E-03	.367E-03	.753E-04
1.0000	-1.0000	-1.0000	.277E-02	-.106E-02	-.600E-03	.283E-03	.552E-03	-.655E-04
1.0000	-1.0000	1.0000	.515E-02	-.188E-02	-.600E-03	.414E-03	.921E-03	.138E-03
1.0000	1.0000	-1.0000	.280E-02	-.106E-02	-.534E-03	-.124E-03	.572E-03	.167E-04
1.0000	1.0000	1.0000	.513E-02	-.188E-02	-.534E-03	.727E-05	.111E-02	.625E-04
.0000	.0000	.0000	.396E-02	-.147E-02	-.638E-03	.104E-03	.414E-03	.359E-04
-.5774	-.5774	-.5774	.328E-02	-.126E-02	-.687E-03	.172E-03	.487E-04	-.230E-04
.5774	-.5774	-.5774	.328E-02	-.124E-02	-.613E-03	.211E-03	.483E-03	-.151E-04
-.5774	.5774	-.5774	.329E-02	-.126E-02	-.673E-03	-.405E-04	.881E-04	.521E-05
.5774	.5774	-.5774	.329E-02	-.124E-02	-.581E-03	-.181E-04	.517E-03	.132E-04
-.5774	-.5774	.5774	.464E-02	-.168E-02	-.687E-03	.200E-03	.281E-03	.906E-04
.5774	-.5774	.5774	.464E-02	-.170E-02	-.613E-03	.274E-03	.716E-03	.873E-04
-.5774	.5774	.5774	.464E-02	-.168E-02	-.673E-03	-.126E-04	.376E-03	.662E-04
.5774	.5774	.5774	.464E-02	-.170E-02	-.581E-03	.447E-04	.804E-03	.630E-04

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.774E+02	.668E+02	.124E+03	.703E+01	.563E+02	-.180E+01
-1.0000	-1.0000	1.0000	.398E+02	.597E+02	.141E+03	.639E+01	.703E+02	-.227E+01
-1.0000	1.0000	-1.0000	.773E+02	.675E+02	.125E+03	-.958E+01	.581E+02	.140E+01
-1.0000	1.0000	1.0000	.360E+02	.604E+02	.141E+03	-.102E+02	.708E+02	.235E+01
1.0000	-1.0000	-1.0000	.517E+02	.306E+02	.513E+02	-.838E+01	.387E+02	-.116E+01
1.0000	-1.0000	1.0000	.132E+02	.195E+02	.562E+02	-.991E+01	.526E+02	-.162E+01
1.0000	1.0000	-1.0000	.538E+02	.337E+02	.530E+02	.641E+01	.411E+02	.203E+01
1.0000	1.0000	1.0000	.115E+02	.225E+02	.575E+02	.488E+01	.538E+02	.300E+01
.0000	.0000	.0000	.451E+02	.451E+02	.936E+02	-.167E+01	.552E+02	.241E+00
-.5774	-.5774	-.5774	.639E+02	.577E+02	.112E+03	.149E+01	.559E+02	-.102E+01
.5774	-.5774	-.5774	.492E+02	.366E+02	.685E+02	-.368E+01	.458E+02	-.654E+00
-.5774	.5774	-.5774	.637E+02	.584E+02	.112E+03	-.427E+01	.568E+02	.994E+00
.5774	.5774	-.5774	.497E+02	.381E+02	.693E+02	.102E+01	.469E+02	.136E+01
-.5774	-.5774	.5774	.416E+02	.531E+02	.120E+03	.101E+01	.638E+02	-.112E+01
.5774	-.5774	.5774	.267E+02	.307E+02	.727E+02	-.446E+01	.537E+02	-.745E+00
-.5774	.5774	.5774	.401E+02	.538E+02	.120E+03	-.474E+01	.643E+02	.137E+01
.5774	.5774	.5774	.259E+02	.322E+02	.734E+02	.249E+00	.544E+02	.175E+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.515E-02	-.183E-02	.310E-01	-.216E-02	.679E-01	.151E-03
-1.0000	-1.0000	1.0000	-.773E-02	-.144E-02	.310E-01	-.207E-02	.554E-01	.621E-03
-1.0000	1.0000	-1.0000	.513E-02	-.183E-02	.312E-01	-.111E-02	.702E-01	.753E-04
-1.0000	1.0000	1.0000	-.896E-02	-.144E-02	.312E-01	-.102E-02	.575E-01	.820E-03
1.0000	-1.0000	-1.0000	.515E-02	-.188E-02	.989E-02	-.262E-02	.461E-01	.138E-03
1.0000	-1.0000	1.0000	-.773E-02	-.131E-02	.989E-02	-.266E-02	.336E-01	-.158E-03
1.0000	1.0000	-1.0000	.513E-02	-.188E-02	.979E-02	-.111E-02	.463E-01	.625E-04
1.0000	1.0000	1.0000	-.896E-02	-.131E-02	.979E-02	-.114E-02	.337E-01	.416E-04
.0000	.0000	.0000	-.160E-02	-.161E-02	.205E-01	-.174E-02	.513E-01	.219E-03
-.5774	-.5774	-.5774	.237E-02	-.175E-02	.266E-01	-.200E-02	.610E-01	.209E-03
.5774	-.5774	-.5774	.237E-02	-.175E-02	.143E-01	-.223E-02	.482E-01	.109E-03
-.5774	.5774	-.5774	.221E-02	-.175E-02	.267E-01	-.134E-02	.621E-01	.200E-03
.5774	.5774	-.5774	.221E-02	-.175E-02	.143E-01	-.141E-02	.486E-01	.987E-04
-.5774	-.5774	.5774	-.521E-02	-.150E-02	.266E-01	-.197E-02	.538E-01	.421E-03
.5774	-.5774	.5774	-.521E-02	-.145E-02	.143E-01	-.225E-02	.410E-01	.647E-04
-.5774	.5774	.5774	-.577E-02	-.150E-02	.267E-01	-.130E-02	.548E-01	.503E-03
.5774	.5774	.5774	-.577E-02	-.145E-02	.143E-01	-.142E-02	.413E-01	.146E-03

ELEMENT ID 4701

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.203E+03	-.284E+00	.292E+02	.124E+02	-.946E+00	-.472E+01
-1.0000	-1.0000	1.0000	.372E+03	.338E+02	.104E+03	.140E+02	.474E+02	.912E+01
-1.0000	1.0000	-1.0000	.207E+03	-.271E+01	.249E+02	-.108E+02	-.229E+01	-.261E+01
-1.0000	1.0000	1.0000	.391E+03	.334E+02	.111E+03	-.921E+01	.468E+02	.469E+01
1.0000	-1.0000	-1.0000	.186E+03	.247E+01	.270E+02	.121E+01	-.997E+01	-.369E+01
1.0000	-1.0000	1.0000	.360E+03	-.905E+01	.385E+02	-.281E+01	.384E+02	.885E+01
1.0000	1.0000	-1.0000	.190E+03	.285E+01	.211E+02	.966E+01	-.150E+02	-.158E+01
1.0000	1.0000	1.0000	.378E+03	-.663E+01	.441E+02	.564E+01	.341E+02	.443E+01
.0000	.0000	.0000	.286E+03	.674E+01	.500E+02	.251E+01	.173E+02	.181E+01
-.5774	-.5774	-.5774	.237E+03	.517E+01	.412E+02	.664E+01	.695E+01	-.148E+01
.5774	-.5774	-.5774	.228E+03	.154E+01	.321E+02	.335E+01	.129E+01	-.104E+01
-.5774	.5774	-.5774	.241E+03	.436E+01	.400E+02	-.290E+01	.581E+01	-.106E+01

.5774	.5774	-.5774	.232E+03	.166E+01	.303E+02	.437E+01	-.105E+01	-.623E+00
-.5774	-.5774	.5774	.337E+03	.195E+02	.781E+02	.687E+01	.349E+02	.555E+01
.5774	-.5774	.5774	.329E+03	.701E+00	.479E+02	.172E+01	.293E+02	.556E+01
-.5774	.5774	.5774	.346E+03	.194E+02	.807E+02	-.266E+01	.341E+02	.379E+01
.5774	.5774	.5774	.338E+03	.151E+01	.499E+02	.273E+01	.272E+02	.380E+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 1

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.268E-02	-.110E-02	-.696E-03	.229E-03	-.189E-03	-.268E-03
-1.0000	-1.0000	1.0000	.491E-02	-.178E-02	-.696E-03	.188E-03	.544E-03	.370E-03
-1.0000	1.0000	-1.0000	.277E-02	-.110E-02	-.716E-03	-.113E-03	-.203E-03	-.287E-04
-1.0000	1.0000	1.0000	.515E-02	-.178E-02	-.716E-03	-.153E-03	.165E-03	-.228E-06
1.0000	-1.0000	-1.0000	.268E-02	-.945E-03	-.463E-03	.513E-03	.519E-03	-.212E-03
1.0000	-1.0000	1.0000	.491E-02	-.202E-02	-.463E-03	.240E-03	.125E-02	.519E-03
1.0000	1.0000	-1.0000	.277E-02	-.945E-03	-.600E-03	-.227E-04	.552E-03	.266E-04
1.0000	1.0000	1.0000	.515E-02	-.202E-02	-.600E-03	-.295E-03	.921E-03	.149E-03
.0000	.0000	.0000	.388E-02	-.146E-02	-.619E-03	.732E-04	.445E-03	.693E-04
-.5774	-.5774	-.5774	.318E-02	-.123E-02	-.656E-03	.189E-03	.983E-04	-.938E-04
.5774	-.5774	-.5774	.318E-02	-.119E-02	-.536E-03	.301E-03	.513E-03	-.504E-04
-.5774	.5774	-.5774	.325E-02	-.123E-02	-.682E-03	-.319E-04	.515E-04	-.301E-04
.5774	.5774	-.5774	.325E-02	-.119E-02	-.601E-03	.155E-04	.482E-03	.132E-04
-.5774	-.5774	.5774	.448E-02	-.167E-02	-.656E-03	.137E-03	.477E-03	.211E-03
.5774	-.5774	.5774	.448E-02	-.176E-02	-.536E-03	.172E-03	.892E-03	.286E-03
-.5774	.5774	.5774	.460E-02	-.167E-02	-.682E-03	-.836E-04	.309E-03	.720E-04
.5774	.5774	.5774	.460E-02	-.176E-02	-.601E-03	-.114E-03	.739E-03	.146E-03

STRESS OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRESS COMPONENTS			
CI	CJ	CK	SXX	SYY	SZZ	SYZ	SZX	SXY
-1.0000	-1.0000	-1.0000	.679E+02	.605E+02	.111E+03	.140E+02	.530E+02	-.618E+00
-1.0000	-1.0000	1.0000	.269E+02	.408E+02	.125E+03	.139E+02	.641E+02	-.626E+00
-1.0000	1.0000	-1.0000	.743E+02	.629E+02	.119E+03	-.926E+01	.538E+02	.254E+01
-1.0000	1.0000	1.0000	.318E+02	.438E+02	.135E+03	-.936E+01	.678E+02	.338E+01
1.0000	-1.0000	-1.0000	.470E+02	.263E+02	.396E+02	-.251E+01	.439E+02	-.197E+01
1.0000	-1.0000	1.0000	.548E+01	.129E+01	.418E+02	-.193E+01	.551E+02	-.235E+01
1.0000	1.0000	-1.0000	.485E+02	.269E+02	.463E+02	.594E+01	.411E+02	.119E+01
1.0000	1.0000	1.0000	.546E+01	.245E+01	.506E+02	.652E+01	.552E+02	.165E+01
.0000	.0000	.0000	.384E+02	.331E+02	.836E+02	.215E+01	.543E+02	.399E+00
-.5774	-.5774	-.5774	.559E+02	.493E+02	.100E+03	.699E+01	.536E+02	-.217E+00
.5774	-.5774	-.5774	.432E+02	.287E+02	.573E+02	.143E+01	.479E+02	-.104E+01
-.5774	.5774	-.5774	.588E+02	.506E+02	.105E+03	-.255E+01	.539E+02	.171E+01
.5774	.5774	-.5774	.444E+02	.294E+02	.616E+02	.245E+01	.471E+02	.884E+00
-.5774	-.5774	.5774	.320E+02	.374E+02	.107E+03	.702E+01	.604E+02	-.164E+00
.5774	-.5774	.5774	.190E+02	.150E+02	.602E+02	.169E+01	.547E+02	-.112E+01
-.5774	.5774	.5774	.344E+02	.388E+02	.113E+03	-.252E+01	.617E+02	.204E+01
.5774	.5774	.5774	.198E+02	.158E+02	.652E+02	.270E+01	.548E+02	.109E+01

STRAIN OUTPUT IN LOCAL COORDINATES FOR LAYER 2

RECOVERY POINTS					STRAIN COMPONENTS			
CI	CJ	CK	EXX	EYY	EZZ	EYZ	EZX	EXY
-1.0000	-1.0000	-1.0000	.491E-02	-.178E-02	.289E-01	.620E-02	.666E-01	.370E-03
-1.0000	-1.0000	1.0000	-.713E-02	-.507E-02	.289E-01	.698E-02	.537E-01	.105E-02
-1.0000	1.0000	-1.0000	.515E-02	-.178E-02	.310E-01	-.257E-02	.679E-01	-.228E-06
-1.0000	1.0000	1.0000	-.773E-02	-.507E-02	.310E-01	-.178E-02	.554E-01	.254E-03
1.0000	-1.0000	-1.0000	.491E-02	-.202E-02	.710E-02	.616E-02	.462E-01	.519E-03
1.0000	-1.0000	1.0000	-.713E-02	-.558E-02	.710E-02	.721E-02	.333E-01	.673E-03
1.0000	1.0000	-1.0000	.515E-02	-.202E-02	.989E-02	-.333E-02	.461E-01	.149E-03
1.0000	1.0000	1.0000	-.773E-02	-.558E-02	.989E-02	-.229E-02	.336E-01	-.126E-03
.0000	.0000	.0000	-.120E-02	-.361E-02	.192E-01	.207E-02	.504E-01	.362E-03
-.5774	-.5774	-.5774	.238E-02	-.254E-02	.248E-01	.448E-02	.598E-01	.425E-03
.5774	-.5774	-.5774	.238E-02	-.271E-02	.123E-01	.440E-02	.479E-01	.446E-03
-.5774	.5774	-.5774	.241E-02	-.254E-02	.261E-01	-.667E-03	.604E-01	.159E-03
.5774	.5774	-.5774	.241E-02	-.271E-02	.138E-01	-.988E-03	.480E-01	.180E-03
-.5774	-.5774	.5774	-.467E-02	-.447E-02	.248E-01	.497E-02	.524E-01	.703E-03
.5774	-.5774	.5774	-.467E-02	-.473E-02	.123E-01	.498E-02	.405E-01	.548E-03
-.5774	.5774	.5774	-.492E-02	-.447E-02	.261E-01	-.181E-03	.532E-01	.294E-03
.5774	.5774	.5774	-.492E-02	-.473E-02	.138E-01	-.416E-03	.407E-01	.138E-03

INCREMENT 1 SUMMARY

TIME INCREMENT COMPLETED 2.220E-16, FRACTION OF STEP COMPLETED 1.00
STEP TIME COMPLETED 2.220E-16, TOTAL TIME COMPLETED .000E+00

E L E M E N T   O U T P U T

THE FOLLOWING TABLE IS PRINTED FOR ELSET ONE AND ELEMENT TYPE C3D8 AT THE INTEGRATION

ELEMENT PT FOOT-NOTE MISES

1	1	71.96
	2	83.45
	3	65.04
	4	77.85
1	5	71.94
1	6	83.43
1	7	65.02
1	8	77.83
MAXIMUM		83.45
ELEMENT		1
MINIMUM		65.02
ELEMENT		1

N O D E   O U T P U T

THE FOLLOWING TABLE IS PRINTED FOR ALL NODES

NODE	FOOT-NOTE	U1	U2	U3
3		5.1742E-04	3.1125E-04	.0000E+00
5		9.9136E-04	2.9044E-04	.0000E+00
7		1.5074E-03	2.9095E-04	.0000E+00
9		2.0354E-03	2.8574E-04	.0000E+00
11		2.5695E-03	2.8841E-04	.0000E+00
13		3.1237E-03	2.9103E-04	.0000E+00
15		3.7166E-03	2.9437E-04	.0000E+00
17		4.3891E-03	3.1594E-04	.0000E+00
19		5.1916E-03	3.4756E-04	.0000E+00
21		6.2068E-03	5.1528E-04	.0000E+00
.		.	.	.
.		.	.	.
.		.	.	.
59385		.2942	-3.1596E-04	.0000E+00
59387		.2949	-2.9427E-04	.0000E+00
59389		.2955	-2.9117E-04	.0000E+00
59391		.2960	-2.8800E-04	.0000E+00
59393		.2966	-2.8749E-04	.0000E+00
59395		.2971	-2.8704E-04	.0000E+00
59397		.2976	-2.8693E-04	.0000E+00
59399		.2981	-2.8668E-04	.0000E+00
59401		.2987	-2.8657E-04	.0000E+00
MAXIMUM		.2987	1.4847E-03	.8600
AT NODE		5401	4800	1225
MINIMUM		.0000E+00	-1.4846E-03	-.8600
AT NODE		1	54702	58177

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